Responses to Anonymous Referee # 2

The authors thank the referee for providing the constructive comments on our paper.

General Comments:

This manuscript deals with the effects of polar mesospheric clouds (PMCs) on stratospheric ozone profile retrievals from OMI nadir observations. This PMC effect is generally neglected in ozone profiles retrievals using similar measurements with other instruments. It is demonstrated that neglecting PMCs in the retrieval can lead to substantial ozone retrieval errors in the upper stratosphere/lower mesosphere. The study also introduces a simultaneous PMC retrieval that clearly improves the ozone profile retrieval performance. The paper is overall well written, is suitable for publication in AMT and provides new and important information to the satellite retrieval community. I ask the authors to consider the specific comments listed below.

Specific comments:

Comments #1-3:

- Lines 73/74: I suggest citing the following (correct) references for GOME and SCIAMACHY:
  Bovensmann, H., Burrows, J. P., Buchwitz, M., Frerick, J., Noel, S., Rozanov, V. V., Chance, K. V., & Goede, A. P. H., SCIAMACHY: Mission objectives and Measurement modes. J. Atmos. Sci., 56, 127 – 150, 1999.
  Burrows et al., The Global Ozone Monitoring Experiment (GOME): Mission Concept and First Scientific Results, J. Atmos. Sci., 56, 151 – 175, 1999.
- Line 132: Period missing at end of sentence
- Line 140: ’few%’ -> ’few %’

Response #1-3: We have corrected the indicated sentences according to the reviewer’s comments.

Comments #4: Section 2.3: It would be good to briefly discuss how independent the PMC and the ozone retrieval are. I assume both quantities are well separated by the retrieval and this should be stated clearly.

Response #4: As we answered to the review #1’s comment #4, the positive signals due to PMC scattering increase at shorter wavelengths, while the positive signals due to negative ozone increase at longer wavelengths up to ~ 307 nm whose ozone weighting function peaks at the ozone density peak. Therefore, PMC signals could be separated from negative ozone signals using different dependence of positive signals on wavelengths. This is detailed in Deland et al (2003). We have included more statement for this discussion in section 2.2 of the revised manuscript, as following: “The false PMC signals due to a negative ozone deviation are screened out using the wavelength-dependence of PMC signals that become stronger at shorter wavelengths, whereas the residuals due to a negative ozone deviation increase at longer wavelengths for PMC detection wavelengths, as shown in Figure 1. The criteria for identifying PMC signals using residual albedo values are described in DeLand et al. (2003) and DeLand et al. (2007).”

Comments #5: Line 189: 'based on the particle shape plays a minor role in the UV scattering' Grammar incorrect, I think.

Response #5: This sentence have been revised to "We assumed PMCs to be spherical ice particles with a log-normal size distribution ($r_o = 55$ nm, $\sigma_g = 1.4$) because the particle shape plays a minor role in the UV scattering"

Comments #6: Line 197: 'climatological data above' Please mention what climatological data was used here.

Response #6: We have revised the associated sentences to "The temperature profile is taken from daily National Centers for Environmental Prediction (NCEP) final (FNL) Operational Global analysis data (http://rda.ucar.edu/datasets/ds083.2/) below 10 hPa, European Center for Medium Range Weather Forecasts (ECMWF) temperature profile climatology between 7 and 1 hPa (http://ecmwf.int/), and TOMS V8 temperature climatology (Bhartia and Wellemeyer, 2002) above"

- Bhartia, P. K. and Wellemeyer, C.: TOMS-V8 total O3 algorithm, in OMI Algorithm Theoretical Basis Document, Vol. II, OMI Ozone Products, ATBD-OMI-02, edited by P. K. Bhartia, 15-41, NASA Space Flight Cent., Greenbelt, Md., 2002.

Comments #7: Line 210: 'the retrieval could be adequately resolved below 0.5 hPa in the stratosphere' I don't fully understand this statement. What do you mean by 'the retrieval could be adequately resolved'? What is the threshold for the vertical resolution that you use to distinguish adequate from inadequate vertical resolution?

Response #7: The indicated statement means that the vertical information of ozone could be adequately retrieved from OMI measurements up to 0.5 hPa in the stratosphere in other words. Our optimal estimation based retrieval is dependent on a priori information where the instrument's vertical sensitivity is weak for quantifying ozone variability, corresponding to the altitude range where the peak of averaging kernels is at a very different altitude (altitudes below ~ 5 km and above ~ 45 km in Fig.1 of this document). The Full Width at Half maximum (FWHM) of the averaging kernel could be quantitatively used to characterize the vertical resolution of the retrieval (Table 2 of Liu et al. 2010a presents the FWHM (km) for OMI). The validation efforts demonstrated that the OMI ozone retrieval could be adequately resolved below 0.5 hPa based on Figure 5 of Liu et al. 2010b. Therefore, we limited the comparison between OMI and MLS up to 0.1 hPa.

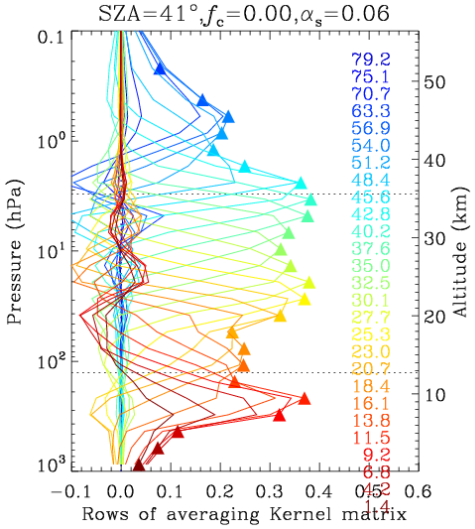

Figure 1. OMI averaging kernels

Comments #8: Fig. 1: I suggest splitting the first sentence in two sentences; one for the description of the upper panels and one for the lower panels.
Response #8: We have decided to remove the figure 1.c and 1.d because it adds nothing to the text. This caption have been revised to "Difference in OMI (black)/MLS(red)/MLS convolved with OMI averaging kernels (green) mean ozone profiles between PMC and non-PMC pixels as functions of MLS vertical layers, for (a) NH 2007 (July 2007, 75˚N-85˚N) and (b) SH 2008 (January 2008, 75˚S-85˚S) summer seasons, respectively"

Comments #9: Figure 1: please comment briefly on the origin of the 'discontinuity' of the OMI O3 C2 profiles around 1 hPa.
Response #9. This "discontinuity" is caused by an interpolation artifact. OMI partial columns are interpolated into the MLS grids for comparison; this point was not indicated in the text, but now in the first paragraph of the section 3.1. The following figure 2 compares OMI mean ozone profiles with OMI and MLS grids. The 'discontinuity' at ~ 1.1 hPa is not shown in OMI partial columns at OMI retrieval grids, but shown at MLS grids due to the smaller vertical spacing of 0.21 hPa compared to the vertical spacing of the upper layer (0.32 hPa) and that of the lower layer (0.26 hPa). We have not changed the manuscript due to this comment because we have removed this figure as mentioned in the response to comment #8.

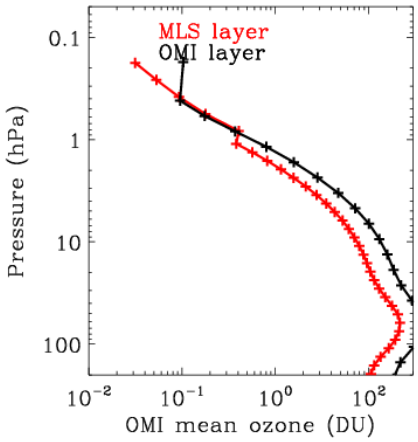

Figure 2. Comparison of OMI mean ozone profiles at MLS (red) and OMI (black) retrievals grids.

Comments #10:Figure 2: I'm not sure if Figure 1 and Figure 2 are consistent. In the lower panel of Fig. 1 the 'discontinuity' in the OMI profiles appears as a positive enhancement near 1hPa. However, this positive anomaly does not show up in the comparisons with MLS presented in Figure 2. Why not?
Response #10: As noted in the response to reviewer #1's comment #5, in figure 2, the comparison between OMI and original MLS profiles is miss-plotted instead of comparison between OMI and MLS convolved with OMI averaging kernels, so we have changed them to the revised figure. Figures 1c and d show the mean ozone profiles averaged over PMC and NPMC pixels, with the difference in mean ozone profiles between PMC and NPMC (figures 1 a and b). Therefore, the difference between red and black solid lines in Figure 1.c should be consistent with the black line In Figure 1.a. We can see the consistency between them: negative biases due to the presence of PMC. Figure 2 shows the mean biases of relative differences between OMI and MLS for PMC and non-PMC, respectively.

Comments #11: Line 233: 'We can see that the PMC effect on OMI retrievals starts at 6 hPa (35 km)'This is only a minor point, but looking at Figure 2, the PMC effect on OMI ozone profile retrievals only starts at 40-45 km, not at 35 km.
Response #11: Considering results shown in Figure 2, the impact of PMCs on OMI retrievals starts at 3 km below 40 km. However, this impact is shown at altitudes down to 30 km in Figure 1 and Figure 9. So, we think that it would be good to say approximately "35 km".

Comments #12: Figure 4: Do the top panels of this Fig. really show Jacobians? I think this is not the case. They just show the percent change in radiances for different tau values, right? This is also what's described in the text. So it's Delta I, not d lnI / d lntau. This should be clarified. Does Fig. 4c show the quantity listed in the ordinate label?
Response #12: In VLIDORT radiative transfer code, the jacobian is defined as dI/dx, and normalized jacobian as $x \cdot dI/dx$. As noted in Section 2.1, the measurement radiance vector is defined as the logarithm of normalized radiance in our algorithm. Therefore, defining the jacobian as $\frac{dlnI}{dX} = \frac{1}{I} \cdot \frac{dI}{dX}$ is practically useful. We multiply them by the POD values ranging from10^{-5} to 10^{-3} to see how the radiance is relatively changed due to the actual POD values. We did not use the term of Jacobians in the manuscript, except for caption and thereby the y-axis title of this figure have been changed to "PMC sensitivity" for more clarification. Moreover we have revised the caption as following "(a) The sensitivity of normalized radiance to five POD values ranging from 10^{-5} to 10^{-3}, as functions of wavelength at SZA =70°, VZA= 45°, and AZA=135°. (b) Same as (a), but for AZA=45°. (c) The sensitivity of normalized radiance to the unit of POD as a function of AZA with various SZAs and VZAs at 267 nm. (d) PMC phase function as a function of scattering angle (Φ) for wavelengths ranging from 260 to 340 nm, normalized to unity at $\Phi = 90°$."

Comments #13: Line 321: 'This result are'
Response#13: We have revised them to "these result are"

Comments #14: Line 434: 'induced by not PMC scatterings' -> 'not induced by PMC scattering' ?
Response#14: We have revised them to "not induced by PMC scattering"

Comments #15: Line 348: 'above 6 hPa'
This is misleading. You mean altitudes above the 6 hPa level, but pressure levels below 6 hPa, right?
Response#15: "above 6 hPa" means below pressures of 6 hPa. We have revised them to "at pressure < 6 hPa" for clarification.

Comment #16: Line 350: '.. impact .. are' -> '.. impact .. is'
Response #16: We have corrected them to "impact is"

Comment #17: Line 394: 'by our algorithm using continuous wavelengths of 270-330 nm' This appears to contradict the statement in line 153, where you write that 5 discrete wavelengths between 267 and 293 nm are used for the OMI PMC retrievals. Or does the statement refer to the O3 retrieval? If yes, this should be stated explicitly.
Response #17: Yes, this statement refers to the O3 retrieval. The previous sentence ("The presence of PMCs ~ Bhartia et al. 2013) indicates that OMI ozone retrievals has more impact due to the presence of PMCS compared to SBUV ozone retrievals. The indicated sentence (by our algorithm~) explains

why OMI has more impact. For more clarification we have changed “our algorithm” to “our ozone fitting algorithm” The five discrete wavelengths are for the PMC detection algorithm (Deland et al., 2010).

Comments #18-19

Line 405: ’We compare’ -> ’We compared’ Line 410: ’stray lights’ -> ’stray light’

Line 411: ’The impact .. are’ -> ’The impact .. is

Response #19. We have corrected the indicated sentences according to review’s comments.

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Comment #20 Line 560: ’Transactions on’ ?

Response #20 The associated reference has been corrected to “Waters et al., .: The Earth Observing System Microwave Limb Sounder (EOS MLS) on the Aura satellite, IEEE T. Geosci. Remote Sens., 44, 1075–1092, 2006.

Comment #21 The reference list contains several types (which I’m not listing explicitly). Please go through the reference list again carefully. Thanks.

Response #21: We have united types of reference list in the revised manuscript.