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Atmospheric Measurement Techniques Discussions
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Interactive comment on "A Cloud-Ozone Data Product from Aura OMI and MLS Satellite Measurements" *by* Jerald R. Ziemke et al.

Anonymous Referee #1

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General comments:

This is a generally well written manuscript on the retrieval of tropospheric ozone within convective clouds retrieved from UV nadir observations with the OMI instrument – complemented by MLS observations of stratospheric ozone. I think the manuscript should eventually be published, but there are several aspects that should first be addressed in my opinion. The approach used to determine what is called "cloud ozone" is quite pragmatic. This is not necessarily a problem, but the limitations of the applied method are not discussed in sufficient detail in my opinion. It is stated several times that the derived cloud ozone corresponds to the average O3 VMR inside the cloud. However, the nadir measurements are probably very insensitive to O3 in the lower or middle part of a convective cloud, i.e. the retrieved O3 VMR reflects O3 in the upper part of

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Discussion paper

the cloud and does that in a non-trivial way, probably. In this respect it would be very valuable to determine and/or show a measure of the sensitivity of the retrieval to O3 at different levels below cloud top. Perhaps you have already done sensitivity studies like that for earlier papers? I'm also wondering how different the cloud penetration depths at the wavelengths used for the OCP and the O3 retrievals are. The wavelengths are quite close, so the difference is probably not too large, but it may affect the results in a non-trivial way. I'm also wondering, what the effect of light-path enhancements due to multiple scattering inside the clouds on the O3 retrievals is? The RT is quite complex in this case and I'm not sure, whether this complexity can simply be neglected.

It is mentioned several times that the OCP is deep within the cloud (several 100 hPa below the actual cloud top). This surprises me and I wonder, whether this is expected. Have you performed simulations of the RT inside the cloud? The fact that OCPs are well below the cloud top suggests that a large fraction of the UV photons can penetrate the cloud deeply. I'm not sure this is expected. Perhaps I'm missing a point here. Please add more information here and, if available, mention or cite studies that deal with this complex RT problem.

You often use the term "above-cloud column", which is misleading, because the column in the paper actually also includes the ozone in the top part of the clouds. I suggest using another term or at least emphasizing this point explicitly in the paper.

I would like to point out that my intention is not to ask you to do a lot of RT simulations (perhaps you have already done so, though) to address the issues raised above, but rather to discuss these aspects openly (you've probably thought about all of them, and perhaps they are not that important), and to discuss the limitations of the method and the results.

Specific comments:

Line 56: "Huntreiser" -> "Huntrieser"

Line 123: “As shown by Vasilkov et al. (2008), the OCP at UV wavelengths lies deep inside the clouds, often by several hundred hPa and therefore is not a measure of true cloud top;”

I’m surprised that the OCP is so much below the cloud top at UV. Is this expected based on the approach to estimate cloud top pressure using the OMI UV radiances?

Line 137: “for bright clouds“

What about clouds that are not “bright”? I’m wondering how one would distinguish between bright clouds and the other ones. Do you only use bright clouds in this study?

Line 140: I find the term “cloud ozone” somewhat misleading, because it certainly does not correspond to the entire ozone column inside the cloud. The OCP will generally be well above the cloud bottom and the “cloud ozone” will then correspond only to a fraction of the column ozone actually inside the cloud.

Line 147: “OMI above-cloud column ozone”

This also includes the “cloud ozone”, right? I think this should be mentioned explicitly, because for the inexperienced reader this is not obvious, and it may suggest that there are different OMI ozone column data products.

Line 162: “With SCO representing column ozone from the top of the atmosphere down to the tropopause, all tropospheric ozone measurements in our analyses are independent of any stratospheric ozone barring possible unresolved stratospheric intrusions and unknown errors.”

I don’t agree with this statement. An important aspect is the (limited) vertical resolution of the MLS ozone profiles. MLS will not be able to retrieve the true vertical variation of ozone, but the measurement process corresponds to (roughly speaking) the convolution of the true vertical ozone profile with the MLS O3 averaging kernels, which will have a width of several km. This means, that some of the stratospheric O3 may (or rather will) be smeared into the troposphere. This effect will probably be on the order

of at least several DU, potentially significantly more. Perhaps this aspect has been addressed in previous studies already?

Figure 1, line 592: “For deep convective cumulonimbus clouds the cloud tops are near the tropopause and so the mean volume mixing ratio is primarily a measurement of average “in-cloud” ozone concentration.“

I don’t think this statement is correct. I agree that for well-developed Cb clouds one can assume that their tops are close to the tropopause, but the fraction of the measured column below cloud top will certainly not correspond to the average ozone amount inside the cloud, right? You measurement will be rather insensitive to the amount of ozone in the lower part of the cloud. It would be interesting to know what the mean penetration depth of UV radiation at around 350 nm inside optically thick clouds is.

Figure 1: y-axis label of the inset: “above cloud column ozone”

I think this is misleading (or I’m missing the point), because this ozone columns includes your “cloud ozone”, right?

Line 182: “above cloud column ozone“

See last comment.

Line 192: Effective scene pressure. I’m wondering, whether it would be better to determine an effective scene altitude, rather than pressure. But if you use only cases with f > 0.8 this probably does not make a big difference. Perhaps there was a specific reason to use pressure here?

Line 197: “In our case for deep convective cumulonimbus clouds the cloud tops are near tropopause level and so the derived mixing ratio is primarily an average measurement of ozone inside the clouds.“

As mentioned above, I don’t think this is true. I think the derived mixing ratio is some sort of average over a part of the cloud, and it’s probably non-trivial to determine what

part of the cloud this actually is. Again, if you know what the estimated penetration depth is, this would be a useful piece of information. Also, as mentioned above, the light-path enhancement due to multiple scattering will affect the sensitivity of the measurements to ozone inside the cloud.

Line 253: “theses” -> “these”

Line 628: “OCP’s” ->”OCPs”

Figures 8 and 9: I’m not sure, how robust the differences between background and cloud ozone really are. I accept that the clear sky values are probably very realistic average tropospheric O3 VMRs, but I’m not sure the cloud ozone is really a good measurement for the O3 VMR inside the cloud. There must be differences – perhaps small – in the penetration depths at the wavelengths used for the O3 retrieval and the OCP retrieval. This may lead to systematic errors. And I’m not sure, whether the light-path enhancements inside the cloud are compensated entirely by using the OCP retrievals for reference. These aspects should be commented upon, I think. The paper is still interesting, but I think the limitations of the technique should be stated. And if all of these potential problems are well understood – i.e. no limitations – this should also be mentioned.

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