Atmos. Meas. Tech. Discuss.,
doi:10.5194/amt-2016-103-AC3, 2016

Atmospheric Measurement Techniques Discussions

Interactive comment on "Altitude Registration of Limb-Scattered Radiation" *by* Leslie Moy et al.

Leslie Moy et al.

leslie.moy@ssaihq.com

Received and published: 6 September 2016

Replies are indicated with '»>' : Anonymous Referee #1 This paper provides an important analysis of the altitude registration of the OMPS Limb Profiler data set. This is a critical and difficult aspect of limb sounding data sets and is motivated by the steep accuracy and precision requirements on ozone monitoring that make it especially relevant to OMPS. Several different methods are discussed and a few are applied to the OMPS data set. The results are important and it seems that the authors have made good progress with understanding the corrections that need to be applied to the OMPS data; however, the paper is very short on detail and makes substantial claims that are not justified by the analysis. The overall logical flow of the paper is hard to follow even though the methods and analysis are quite simple.

For example, it is not clear which corrections are applied and in what order. Is the slit correction applied or just analysed? Then it seems that the RSAS analysis is applied

Printer-friendly version

Discussion paper

as a single value across the entire data set and then ARRM is investigated but not applied as the uncertainties are not understood. Yet, the conclusions state that the ARRM-corrected OMPS record has an altitude registration error of less than 50 m, which is substantially better than any previous studies would suggest is possible with methods such as these. In my opinion, the paper has potential to be published in AMT, but revision is required, most importantly a re-working of the logical flow of the paper and the accompanying explanations. New information including results and discussion is provided in the figure captions that is not provided or discussed in the text. This may be part of the problem that makes the logic hard to follow. This is should be revised and all statements comprehensively discussed in the main body of the paper (Fig 2 Fig 4 Fig 11 Fig 12-updated are extreme examples of this.) Additionally, the section on the uncertainties is especially hard to follow and needs reworking.

Abstract: The Knee method should also be mentioned as it has been used extensively in the past and the current abstract makes it sound like there are only two methods (RSAS and ARRM). »>Our paper focuses on describing on the two techniques that we use to determine altitude registration for OMPS (RSAS and ARRM), and results from these techniques. Although we describe the Knee method in the body of the paper for historical reasons, we do not use it and we therefore believe it does not warrant a mention in the Abstract.

Abstract, line 36: This statement seems to insinuate that the authors developed the RSAS method and that it is specific to ozone monitoring. »> New text: Two methods, the Rayleigh Scattering Attitude Sensing (RSAS) and Absolute Radiance Residual Method (ARRM), are able to determine altitude registration to... Also line 122: Though several variations of the RSAS technique have been developed for ozone sensors (McPeters et al., 2000; Rault et al., 2005; Taha et al., 2008), we find ... Introduction, line 65: many other species beyond ozone and aerosol can also be mea- sured by limb scattering, even though OMPS produces only these two products due to spectral resolution limitations, other instruments have produced many other products. »>New text: Instruments that measure the solar radiation scattered by the earth's atmosphere in the limb direction provide a low cost way of measuring trace gases, aerosol profiles and clouds from satellites.

Introduction, line 68: the 100 m accuracy requirement needs a reference »>Reference included

Introduction, line 78: statement regarding insensitivity of RSAS to radiometric errors and drift needs justification or at least a reference. »> New text: One of these techniques, known as Rayleigh Scattering Attitude Sensing (RSAS), is relatively insensitive to instrument radiometric errors because it utilizes measurements at two altitudes (20 and 40 km) where many of the errors are correlated.

Theoretical Basis, line 90: The claim is that "most scene-based altitude registration methods" use the gradient in the Rayleigh scattering profile. Are there some that don't? Are there only the three mentioned later (RSAS, ARRM, Knee)? »>We used the word 'most' because even though we did a literature search and only found references to variations of the RSAS and Knee methods, we leave open the possibility there are others.

Theoretical Basis, line 95: Clouds outside the "circular cone" from the tangent point to the horizon can impact the contribution of the upwelling radiance to the limb signal. »>New Text: For wavelengths longer than 310 nm, the limb-scattered radiance has a significant contribution from diffuse upwelling radiance (DUR), which is affected by tropospheric clouds, aerosols and surface albedos within a circular cone whose base extends hundreds of km to the horizon. The further these reflectors are from the apex of the cone, the less is their contribution to DUR. At non-ozone absorbing wavelengths DUR can be as much as half of the measured radiance. Since DUR is challenging to model accurately, all successful altitude registration methods must be relatively insensitive to reflectivity variations within the cone.

Theoretical Basis, line 142: At several points in the paper, the same statement is made that “RSAS method work best where aerosol extinction is small”. This needs to be quantified. How small? How does this error relate to the errors that arise from the uncertainty in the pressure profiles? Or from the signal to noise levels in the measured radiances? »>We use RSAS when/where the aerosol effect is minimal (ideally none but that’s hard to determine). On average (using an aerosol climatology the effect is ∼1% (100 m) in the southern hemisphere and sharply increasing to ∼2% (200 m) in the north pole), but averages can be deceiving. Our strategy was to find the cleanest time/place according to OSIRIS measurements (Fig. 8). There is new text in Section 3.2. Aerosol errors are independent of pressure errors so the two will sum in quadrature.

Also, what about uncertainty in the upwelling radiance? Is it truly effectively zero in the 40/20 ratio? Sections 3.2 and 4.2 make conflicting statements about the importance of accurate modelling of the DUR. »>New Text Section 2.1 (line 170): However, since the noise varies randomly from orbit to orbit, DUR modeling errors are reduced by averaging data from multiple orbits (this is confirmed in daily averages of the sun-normalized radiances where short scale features are not seen). Also our estimate of our RSAS uncertainty is based on both the southern polar region and the equator which span the range of surface heterogeneity (the source of DUR variation). New text in Section 3.2

Theoretical Bases, line 157: What is the reason that the sensitivity of the 295 nm radiance to ozone drops substantially above 65 km? Is this ozone in the line of sight, or total column? »>Text added (Section 2.2): Though 295 nm radiances can be very ozone sensitive, this sensitivity drops to less than 0.2% for a 10% change in ozone above 65 km because the ozone density at high altitudes is exceedingly low. (see Figure 5).

Theoretical Basis, line 159: Did the authors develop ARRM, or is there a reference that should be cited? They begin this discussion about the problems with the method before stating how it works, or even any reference to the technique. »>Sentence added to Abstract: “ARRM, a new technique introduced in this paper, can be applied across all seasons and altitudes." And Section 2.2: We developed ARRM to be applicable over many latitudes and times.

Theoretical Basis, line 165: It is unclear what this statement about the goal of "correcting" radiance residuals means in the context of deriving the tangent altitude information. »>Paragraph reworded to distinguish between McGee's findings and our method.

Theoretical Basis, line 186: Again, quantification of these statements is necessary. "ARRM may not be as good as RSAS" – in what conditions and how by how much? At what value of aerosol extinction, or conversely at what uncertainty in absolute radiance, would you prefer to use ARRM over RSAS or vice versa? »> It is a question of absolute TH error versus relative error. Because RSAS uses ratios it cancels out much of the instrument errors. The sentence has been rewritten to reflect this.

Theoretical Basis, line 201: It is not clear that shifting the ozone profile as is done in Fig. 5 translates to exactly the same error in altitude registration in the UV limb radiance. Also, the discussion/analysis surrounding Fig. 5 neglects the non-linearity of the inversion, which is especially important below 20 km, i.e. shifting the registered tangent altitude and performing the retrieval does not produce identical results to simply shifting the ozone profile by that same amount. »>True. We now say it is an estimate and explicitly name the qualifiers you point out.

Validation: The logical tracing of the errors coming from the different terms is very difficult to follow and this entire section is in need of some systematic thought and re-organization. »>Rewritten section with our reasoning better described.

Validation, line 358: It does not appear that the cross referenced Section 3.3 results support the claim that ARRM can "track drifts or sudden changes of 50 m" »>We addedd a figure (new Figure 10) and changed the value.

Conclusion, line 400: What is the OMPS ARRM record? The statement was made that the ARRM results are not applied to the OMPS data. »> We were referring to the

ARRM timeseries in Figure 9. The ARRM results showed errors within our uncertainty so were not applied.

Conclusion, line 401: Is the uncertainty in assumed pressure profiles the biggest source of uncertainty in both methods? Previously it was explained that it is aerosol for RSAS. In the southern hemisphere, the GPH is the larger error source. It is difficult to determine which error source is larger in the northern hemisphere, but we believe we have been conservative in our error estimations to include the full range of variations.

Conclusion, line 409: It is not convincingly shown that these methods provide altitude registration tracking to better than 50 m. »>The conclusion section has been rewritten.

Figure 1: The statement in the caption: "Since the ratio of 40 to 20 km radiances at 350 nm varies by 8-10%/km" is confusing. How can the ratio of radiances at two set tangent altitudes vary with tangent altitude? »> Attenuation causes the slope of 350 nm radiances to change sharply between 40 and 20 km (Fig. 1b), a ∼10% /km difference between 20 and 40 km.

Figure 2: Why 353 nm instead of 350 as in Fig. 1? fixed

Figure 3: This should be shown together with the solar scattering angle at the tangent point so it is clear what is happening here (for readers not familiar with OMPS this will not be obvious). Also the authors should consider showing some of the complexity involved with the aerosol parameters by repeating this same curve for different altitudes, extinction profiles, and particle size distributions, all of which are stated as important factors. »> Scattering angle included in figure.

Figure 9: Are these results for individual radiance profiles, or daily averages? The low amount of noise is surprising based on previous studies using such methods as these. »>Yes, these are daily averages – text updated

Interactive comment on Atmos. Meas. Tech. Discuss., doi:10.5194/amt-2016-103, 2016.