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Atmospheric Measurement Techniques
Discussions
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Interactive comment on "Proposed standardized definitions for vertical resolution and uncertainty in the NDACC lidar ozone and temperature algorithms – Part 3: Temperature uncertainty budget" *by* Thierry Leblanc et al.

Anonymous Referee #2

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1 Overall

The paper summarizes procedure and results for obtaining the uncertainty budget of atmospheric temperature profiles measured by laser radars using the weak light scattered back from molecules in the atmosphere. It is part of a series of similar papers summarizing results of an extensive report generated under support from the International Space Science Institute in Bern, Switzerland. It is good to have peer reviewed summaries of these findings in the scientific literature. The content of this paper is very well suited for Atmospheric Measurement Techniques. Although the paper does

not lead to a substantial revision of the main sources of uncertainty, which have been known for decades, it does provide a comprehensive framework. It explicitly addresses also the minor sources of error. Overall this is an important reference document. I recommend publication, after the following questions have been addressed.

2 Major points

- The **abstract** should give numbers (in K) for the typical uncertainty attributable to the different uncertainty sources at representative altitudes. A short summary of Fig. 10 would do. E.g. for a typical stratospheric / mesospheric NDACC lidar
  - overall uncertainty: from 15 to 50 km 0.1 to 1 K, from 60 to 80 km 1 to 10 K
  - signal detection uncertainty: from 15 to 50 km 0.1 to 1 K, from 60 to 80 km 1 to 10 K
  - far range tie-on temperature : 0.1 K at 60 km (30 km below tie-on altitude), 1 K at 75 km (15 km below tie-on, 10 K at 90 km (tie-on altitude)
  - background estimation uncertainty: < 0.01 to 0.1 K at most altitudes below 60 km, 0.1 to 1 K above 60 km
  - counter saturation correction uncertainty: < 0.01 to 0.1 K at all altitudes, if excessive count rates are avoided
  - uncertainty in correction for Rayleigh extinction: 1 K to < 0.1 K at altitudes from 10 to 20 km, negligible above 20 km
  - uncertainty due to other sources: < 0.1 K
- Outside of the abstract, it would be good to also have a table summarizing these various uncertainty values, for typical altitudes (say 30, 60, 80 km).

- I realize that the authors put a lot of work into estimating also the minor / almost negligible uncertainties. This is good, and needs to be done to show what is major and what is minor. However, from a user perspective, when reading the paper, especially, abstract, conclusions and looking at the final Figure 10, it would really help to bring out the major uncertainties much clearer, e.g. be marking them in bold, thicker lines, . . . Also please add some text that differentiates between major and minor uncertainties. Some of these uncertainties are really small and almost irrelevant. More guidance would really help users!!

- Certain other uncertainties are ignored completely: There is no mention of multiple scattering, which can invalidate Eq. 3. Yet, multiple scattering may be a root cause why so many intercomparisons between lidar measured temperatures and other sources (e.g. radiosondes) show a low bias up to 1 or 2 K for the lidar data (e.g. Reichardt and Reichardt, 2006). The authors should come back to this in conclusions and abstract, and should at least give some numbers/ ideas.

- Not dealing with additional aerosol scattering and extinction from the stratospheric aerosol layer is also a weak point for a paper with the scope of this manuscript. The authors should come back to this in conclusions and abstract, and should at least give some numbers/ ideas.

- Another weak point, in my opinion, is the omission of the effect of filter bandwidth on receiver efficiency altitude dependence, due to including / excluding rotational Raman wings for scattering from cold / warm regions of the atmosphere. (See e.g. She, 2001; Whiteman, 2003). This can also introduce temperature uncertainties up to 0.2 or 0.4 K, more relevant than some of the smaller uncertainties discussed here. Given the intended comprehensive scope of the manuscript, uncertainty / error sources of this magnitude should be at least mentioned in introduction, conclusions and abstract.

- Throughout the manuscript I find the term “background noise” confusing / misleading. Nearly always the authors mean “background” i.e. an underlying smooth curve, but not “noise” i.e. random deviations from a smooth curve. I suggest to replace “background noise” by “background” throughout this paper (and the two companion papers!!).

- While the paper extensively mentions uncertainties in Rayleigh-, ozone-, and nitrous oxide cross-sections, it never gives any values for the cross-sections themselves. Since this is intended as a reference publication, it would be very helpful for readers and for standardization, if the paper did include tables with recommended values for all of these cross-sections.

3 Minor points

pg.2, lines 10, 12: I suggest to replace "review" by "summarize" I don’t think the authors are giving a proper independent review of their work here. Rather, they summarize what they found in their own report.

pg. 3, line 3: Should that not be "proposing" instead of "propose"?

pg. 4, line 27: I think the authors mean "transmission", not "thickness". Isn’t optical thickness the quantity in the exponential function in Eq. 4, i.e. the τ in $T = \exp(-\tau)$, whereas T is the (one-way) transmission? Please check and correct.

pg. 7, lines 4, 5: Replace "noise" by "background"? See my major comment above. Also: Maybe (residual) fluorescence should be mentioned here too.

pg. 7, line 15: Please mention that dead-time correction in Eq. 10 is only a first order approximation. Generally, an exponential equation like Eq. 5 of Donovan et al. (1993) is needed.

pg. 8, line 15: Since this intends to be a reference publication: Please add a table giving (latitude dependent) recommended values for the constant g_0, g_1, g_2.

pg. 9, line 31: add "uncertainty in" before "the acceleration". Instead of "providing ... altitude dependent" maybe say "provided an altitude dependent formulation of gravity as in Eq. 15 is used".

pg. 11, line 3: Remove "a" before "Poisson". Maybe mention that Eq. 19 is only valid when $R(k)$ is the total number of counted photons in channel k.

pg. 14, line 21: Year / reference McGee is missing.

pg. 19, line 11: reference is missing.

pg. 21, last paragraph: I think it would be very helpful if the various uncertainty components introduced here were linked to the uncertainties used in NDACC lidar hdf files following the GEOMS hdf conventions of the Aura Validation Data Center. I think one or two paragraphs here, as well as some text in conclusions and abstract would be really warranted.

pg. 22, line 8: reference (to Table 2?) is missing.

pg. 22, last paragraph, also pg. 23, lines 30, 31: This may be right, but to me it is confusing. Are you not simply saying that averaging over many profiles will average out "random" uncertainties, but not "systematic uncertainties". Can this be reworded? Maybe show an equation that explains this? $\sqrt{a^2 + a^2} = \sqrt{2}a$ for uncorrelated uncertainties a, but $\sqrt{b^2 + 2bc + c^2} = b + c$ for correlated uncertainties b, c.

Figure 1: Too many lines. I think just showing one vertical sampling is enough. Lines have to be shifted for different signal strengths and vertical samplings anyways.

Figure 10: I think this is a very important Figure, because it shows the magnitudes of the different uncertainties. Unfortunately, in my copy I was not able to read the small print and figure out which line belongs to which uncertainty. Also, not all colored lines

appear in all plots. Please make the labels u_{xxx} much larger, maybe omit the u and just give the more important xxx. Please make sure to only show those xxx that actually have lines in each panel. Many colors are very similar, and it is very hard to tell which line is which color. Please use different colors, or draw arrows from the labels to the lines.

4 References

Donovan, D.P., J.A. Whiteway, and A.I. Carswell, Correction for nonlinear photon-counting effects in lidar systems, Applied Optics, 32, 6742–6753, 1993.

Reichardt J., and S. Reichardt, Determination of cloud effective particle size from the multiple-scattering effect on lidar integration-method temperature measurements, Applied Optics, 45, 2796–2804, 2006.

She C.-Y., Spectral structure of laser light scattering revisited: Bandwidths of nonresonant scattering lidars, Applied Optics, 40, 4875–4884, 2001.

Whiteman, D.N., Examination of the traditional Raman lidar technique. I. Evaluating the temperature-dependent lidar equations, Applied Optics, 42, 2571–2592, 2003.

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