Solar Background Radiation Temperature Calibration of a Pure Rotational Raman Lidar, Jayaweera et al. Revised – a Review

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General Comments

The simplicity of this technique is very compelling and should become a standard part of calibration for rotational Raman lidar temperature measurements. The authors have shown that the technique provides results consistent with and sometimes better than the traditional calibration technique and permits tracking changes in system configuration that would likely be missed if only episodic external calibrations are performed. I believe the paper should be published after some fairly minor revisions.

I do have some significant concerns with the manuscript as it currently stands which I detail in the major comments. Perhaps the most important of the major comments is the one concerning the determination of r_{solar}. The authors really should take advantage of the demonstrated insensitivity of the r_{solar} ratio to changes in SZA. Two closely spaced wavelength intervals illuminated by broadband light in the absence of significant absorbers should be essentially constant as shown in a limited way by the authors. This suggests that the ratio r_{solar} could be determined under a broader range of conditions than studied by the authors. This is a great strength of the technique and should be emphasized as such.

In the minor comments provided, I have taken the liberty to offer rather detailed changes with the hope that this paper becomes a standard reference in the literature.

Major Comments

1. Line 138/Eq 3:
    1. I believe that the equation as written is incorrect. The number density n(z) as used is the volume mixing ratio of both nitrogen and oxygen. But the scattering cross section of these molecules is different and the current equation does not capture this. I suggest following a notation similar to what is used in either the numerator or denominator of eq 4 in Adam et al., "Notes on Temperature-Dependent Lidar Equations" JTECH, 2009 Vol 26, 1021-1039, (or the notation you use in your eq 8 below) where the number density of either N_2 or O_2 is now inside of the larger summation over the two different molecules

$$F_L(T) = \frac{\sum_{n=N_2,O_2} \eta_n \sum_i \left[\frac{d\sigma(\lambda_{X,i}, T, \pi)}{d\Omega}\right]_n \xi(\lambda_{X,i})}{\sum_{n=N_2,O_2} \eta_n \left[\frac{d\sigma_t(\lambda_X, \pi)}{d\Omega}\right]_n \xi(\lambda_X)}, \quad (4)$$

    2. Also, I had some trouble reconciling the notation in equations 3 and 4. I think my trouble came from what appears to be mixed usage of the notation "RR". In equation 3,

the notation RR usually stands for either the entire signal of J_H or J_L (as in the cases of N_{RR}, C_{RR}, B_{RR}). However, the use of RR in tau_{RR} refers to just a single line and this is confusing. I suggest 1) dropping the RR subscript from tau and, in general, changing RR to Jx with the explanation that x can be either H or L referring to either the high or low RR channel. With this change in notation, equation 4 follows more naturally.

2. Line 187, sentence starting "We tested …"
    1. A variation of 0.2% is surely within the uncertainty of the technique. If so, this result implies that the solar background value is independent of SZA and the authors should so state. Such a result would make the technique more robust and easier to implement. Please add a sentence following the one written something like "This result suggests that r_{solar} is independent of solar zenith angle as would be expected for the two closely spaced wavelength intervals.
3. Lines 284-293: Please be careful with this discussion. Four of the six comparisons presented do not differ beyond the uncertainty bars indicated (1-sigma?). Thus it would seem justified to state that the background and external methods yield similar results for those 4 metrics whereas for the other 2 metrics (mean bias 4-8 and mean IQR 1-8) the background method shows better agreement at the 1-sigma level of significance.

Minor Comments

1. Lines 5, 45: Suggest "rotational Raman temperature lidar"
2. Line 53: "reduced accuracy" → "reduced precision"
    1. the term accuracy refers to a deviation from truth whereas precision refers to the spread of a set of measurements. Use of a larger ensemble of radiosondes should reduce the uncertainty in the mean value but, unfortunately, does not necessarily guarantee that we are closer to the truth.
3. Line 64: Suggest "using Licel GmbH transient recorders, which enable …"
4. Line 112: "rotational temperature" → "rotational Raman temperature"
5. Line 127: please italicize "*a priori*"
6. Line 136: Why use PRR here? Why not NRR? Then line 139 becomes simply "where NRR is the true backscattered signal ..."
7. Line 142: Suggest "Following the methodology of MG (2019) we can define …"
8. Line 158: "random error" → "random uncertainty"
    1. same comment as in 2 above
9. Lines 139-140: "geometrical overlap" → "overlap"
    1. O(z) is the entire overlap function which consists of geometrical and optical components.
10. Line 141: I believe that "attenuated" should be dropped. The attenuation is being accounted for in the equation elsewhere.
11. Line 158: "random error" → "random uncertainty"
12. Lines 162-163: Suggest "Depending on the external instrument's operating schedule..."
13. Line 169: I was not clear on what "This approach" referred to. Suggest "The approach that we present here mirrors ..."
14. Line 170: "mixing calibration" → "mixing ratio calibration"
15. Line 171: "this approach" → "the approach here"
16. Line 171: "only one reference radiosonde measurement" → "a single calibration based on an ensemble of radiosondes"

17. Line 173: Suggest “drifts”→”calibration changes” to distinguish from the recently used different context of drift.
18. Line 173: Instead of “The relative calibration …” as written, I suggest starting a new paragraph with something like: "We now define the relative calibration time series as follows". I believe that such a sentence will better prepare the reader for equation 6
19. Line 177: C* was earlier called just the calibration constant. I also think "derive" is the wrong word to use here. Instead I suggest: " We can now use r_{solar} to calculate the time series of the calibration constant C*, the function ..."
20. Line 210: “has been launching” → “had been launching”
21. Line 218: sentence starting “We employed …”. This has already been stated, right? I suggest deleting this sentence.
22. Line 222: “measurement”→”measurements”
23. Line 224: “details”→”detail”
24. Line 225: suggest “low J’s photomultiplier with” → “the low-J channel photomultiplier to”
25. Line 231: suggest “within a mean difference of less” → “better”
26. Line 297: “which decreases” → “which can decrease”