

Atmos. Meas. Tech. Discuss., referee comment RC1
<https://doi.org/10.5194/amt-2021-116-RC1>, 2021
© Author(s) 2021. This work is distributed under
the Creative Commons Attribution 4.0 License.

Comment on amt-2021-116

Anonymous Referee #1

Referee comment on "Differential absorption lidar for water vapor isotopologues in the 1.98 μm spectral region: sensitivity analysis with respect to regional atmospheric variability" by Jonas Hamperl et al., Atmos. Meas. Tech. Discuss.,
<https://doi.org/10.5194/amt-2021-116-RC1>, 2021

This is an interesting paper on the predicted performance of a theoretical DIAL system to remotely measure water vapor isotopes. The authors have identified a region in the infrared around 1983 nm that shows potential for measurement of both H(16)OH and HD(16)O. Overall this is a very thorough analysis and is well done.

General comments

- To have a scientific impact, is the desired/required goal to achieve a <1% relative error? Is a specific water vapor isotope abundance precision in permil required?
- The laser development needed to bring the proposed instrument to reality will be far from trivial. The modeling effort assumes that the transmitter will have perfect qualities required for DIAL (such as spectral purity) which is a significant assumption. To be fair, the conclusions could be more clear to say that the predicted performance is a best-case scenario because of this assumption.
- While reading through, the biggest question I had was if the temperature sensitivity of the line strength was included in the model. I think the answer is yes, but it wasn't very clear in the text.
 - Line selection criteria for water vapor DIAL requires choosing lines that (1) avoid interferences, (2) have the appropriate line strength (will provide the optimal optical depth), and (3) are insensitive to temperature as highlighted in Browell et al. 1991 (Browell, E. V., S. Ismail, and B. E. Grossman, 1991: Temperature sensitivity of differential absorption lidar measurements of water vapor in the 720 nm region. Appl. Opt., 30, 1517–1524). Could this line selection consideration be more clearly articulated in section 2.1?
 - In the sections around Equation 5 would it help to include, or at least mention the temperature dependence in the absorption cross-sections?
 - The HD(16)O line at 1982.47 nm has a reasonably temperature-insensitive ground state energy of 91 cm^{-1} (something closer to 250 cm^{-1} would be ideal), but the interference H(16)OH line, directly underneath it, has a ground state energy of 2756

cm^{-1} . Is not some discussion warranted about how this creates a high sensitivity to temperature? Using the equations in Browell et al. (1991) it appears that the uncertainty in the number density would be up to 5% per K on line center. Unfortunately, the optical depth when tuned to the line center of that HD(16)O line is already less than optimal for DIAL. But should there be an online second option evaluated, moving to the weaker line at 1983.93nm to avoid this even if constraining the measurements to regions with high water vapor concentrations?

- The online for H(16)OH at 1982.93 nm has a ground state of 920 cm^{-1} which is still rather large compared to a typical water vapor DIAL system. Would it be helpful if the ground state energies were listed somewhere to help the reader understand that the model is taking these fundamental factors into account?
- The larger than typical DIAL errors/sensitivity to atmospheric temperature seems to be sidestepped somewhat by simply constraining the model temperature uncertainty to $\pm 0.5^\circ\text{K}$. Although there is a sentence in the conclusions about this, it is a significant issue and warrants more discussion. Could the authors suggest how this will be done in practice? For example, if reanalysis data will be needed to reach these levels of certainty, the DIAL measurement would not be useful in real time. Are they expecting another instrument like a Raman lidar to provide this information?
- Was the model using a **yearly** or **seasonal** mid-latitude average (high and low)? It was unclear if the proposed instrument is expected to perform well in mid-latitude winter conditions.
- Was the performance model limited to nighttime only? Was there any solar background modeled?
- What is the expected lowest useful range of the proposed instrument? The plots in Figure 6 indicate measurement would be limited to approximately $>150\text{m}$ above ground level (if 1% error is the goal). However, based on the curve shapes, the full overlap is not achieved until above 500m which could push the minimum range upward. As I'm sure the authors know, very slight differences in online and offline overlap or pointing can result in large systematic errors when pushing too far into the incomplete overlap region. Could these limitations be discussed a bit more clearly so the science community has realistic expectations of the proposed DIAL instrument?

specific comments

- line 46. Does it have to be a high-power laser transmitter?
- line 101. "... with and out of a gas absorption feature.." is unclear
- line 155 "two wavelength in (λ_{on}) and out of (λ_{off}) coincidence" is a bit awkward in English
- line 157, the lasers also need to be sufficiently close in wavelength (not just time)
- line 166, Why use a mixing ratio? A DIAL measures the number density of the absorbing molecule. When converting to a mixing ratio one has to assume a pressure and thereby increase the uncertainty.
- In section 3.4 the precision estimate is referring to figure 9, yet the text says figure 8

(in multiple locations)

- The x-axis labels in figure 9 seem to be incorrect? The text at line 397 says “The expected absolute precision for this configuration is well below 5‰ within the first 1.5 km and reaches 10‰ at a range height of 2.3 km” but the labels don’t match so it makes it hard to evaluate what is going on.
- line 415 “Indeed, HDO displays sufficiently high absorption [sic] lines in this range” Suggest adding a qualifier here such as “for measuring the lower 1km of the atmosphere with better than 1% relative error in the mid-latitudes and regions with higher water vapor concentrations.”