

Author Comments to Referee Comments #2:

We thank the referee for thoughtful comments that will improve the clarity of the paper. We address each of the comments below, with more detailed responses when appropriate. Reviewer comments are in black text with our responses in blue text.

Review of Wein et al., An Economical Tunable-Diode Laser Spectrometer for Fast-Response Measurement of Water Vapor in the Atmospheric Boundary Layer, AMT-2024-34, June 2024

The manuscript by Wein, et al. describes the recent development of a lightweight, low-cost, open-path TDLAS instrument suitable for research quality, fast-response measurements of water vapor in the atmospheric boundary layer and is highly appropriate for publication in AMT. The manuscript is well structured and describes details of the development and performance of the instrument that could reasonably allow reproduction of the instrument for use by others and includes discussion of several possible applications. The manuscript could use several minor corrections and modifications and I recommend publication following minor revision and considering of the following specific comments and questions.

Thank you. We hope that this paper will allow other investigators to develop similar instruments for their studies, and we are eager to see what future applications may be enabled by our work. We will make the suggested corrections.

Specific comments:

L8: First sentence could be restructured to remove redundancy of “high spatiotemporal variability” and “abundances varying...”

The redundancy will be removed.

L8: ABL should be defined here rather than L11, and then L11 could just use “ABL”

This will be corrected.

L8: “possesses” should be “poses” (or “presents”)

We will make this change.

L11: “in situ” is a Latin term and not hyphenated. I would think that you would want to include “open-path” in the description here since that is a critical aspect enabling the fast response time.

Thank you. We will add “open-path” and correct hyphenations.

L11: “tunable diode” is generally not hyphenated (although I see it also was in Dorsi et al 2014).

We will search on, and correct hyphenations, throughout.

L11: You define ‘TDLS’ first in the abstract as “tunable diode laser spectroscopy”, but then use it and subsequently define it as “tunable diode laser spectrometer”. Perhaps use “tunable diode laser absorption spectroscopy” in the abstract since that is the technique utilized and then TDLS as the spectrometer.

This will be clarified.

L12: you only need to include the acronym definition here if you will use the acronym alone later in the abstract. Comment also applies to L16 and L21.

These will be clarified.

L16: “proportional – integral”, as appears in L104 of the text

Thank you for noting this inconsistency. We will change to the appropriate term.

L17: “comprised of” should technically be “composed of” or “comprises”

Thank you. We will correct this.

L18: perhaps “agreed”

Past tense will be used here and in other places where it refers to specific tests, as opposed to general performance characteristics.

L19: perhaps “will allow” and preface with something like “The instrument is robust and simple to operate”

Thank you. We will make these changes.

L29: “tropics”

We will change to lower case.

L32: “underlying mesoscale processes”—meteorologically, mesoscale is typically 10 to 100s of km, which doesn’t seem appropriate here

“Mesoscale” will be changed to “Microscale.”

L39: “DIALs and Raman lidars” or “differential absorption and Raman lidars”

“DIAL and Raman lidars” will be changed to “differential absorption and Raman lidars.”

L45: “such as infrared gas analyzers (IRGAs)”

This change will be made.

L46: “have come to” -> “are typically used to”

This change will be made.

L47: it is really the cost (~x10, and for some applications the size/weight), not the limited number of vendors or some “highly specialized” nature that is the limitation, right? And potentially differences in required maintenance/recalibration? You expect the new TDLS to not require recalibration (does require initial calibration per L177) or regular maintenance, correct?

Yes, thank you. There are several factors that limit the availability of relatively inexpensive instruments. We have decided to modify this point to make it clear that our instrument is not designed as a substitute for high-quality commercial instruments that have served the community well for many decades. Rather, we hope that our approach enables new applications that are limited by cost. In addition, it is our view that by providing the raw data necessary to calculate absorbances, the need for frequent calibrations is reduced. However, maintenance will depend upon the particular application (e.g., cleaning of optics to remove dust, etc.).

L57: “prediction”

This change will be made.

L57: “capable of”

This change will be made.

L60: “development and performance”?

This change will be made.

L61: “high accuracy and precision matching that of” and “lower cost and greater flexibility that would allow widespread deployment for routine observations”

This change will be made.

L67: “laser diode”? and what is meant by a “generic” package since it does require built-in TEC and tight coupling of the fiber?

“Generic” will be removed and we will replace with “butterfly.”

L69: “components”? and “components and exhibits”

This change will be made.

L71: I'm a little skeptical of the emphasis on the use of the instrument by fully inexperienced operators.

This is a fair statement. We will clarify this to mean operators without extensive experience with laser spectroscopy.

L76: “2023), the reported instruments have had a slow response, resulting in limited vertical resolution”

This change will be made.

L78: an example of a location?

We will provide examples of such locations.

L81: what is meant by “terrain and variable inhomogeneity”?

this will be changed to “heterogenous scalar and vector fields resulting from complex terrain.”

L89: “based on” would be more appropriate

This change will be made.

L90: the clause “a schematic of which is shown in Fig. 1.” currently references the previously reported (Dorsi et al 2014) instrument. The clause could be inserted immediately after “described here” in L89 to be clear.

This change will be made.

L92: “is rapidly scanned”; “variations, a short”

Noted; however this change conflicts with the intended meaning of the sentence.

L100: Figure 1 shows the trigger pulse passing from the receiver microcontroller to the laser drive, but the text states that the trigger pulse for data collection originates from the laser driver board.

This inconsistency will be corrected.

L104: “TEC controller”

This change will be made.

L105: “temperature of 0.002K” should be “temperature of $XX.XXX \pm 0.002$ K” or say “A temperature stability of ± 0.002 K, consistent...”

Wording will be changed to “Temperature is maintained to ± 0.002 K of the setpoint,”.

L107: “DFB” should be “laser” (or “DFB laser diode”)

“DFB” will be changed to “Laser.”

L108: “a digital-to-analog (DAC) output” since the 3.6 has two, although the 4.1 does not have a DAC, so only from the 3.6 (although, as noted, now discontinued).

Wording will be changed to “the digital-to-analog (DAC) output from the Teensy 3.6.”

L110: “Arduino-compatible” hyphenated? But not “laser driving” or “data acquisition”

This change will be made.

L111: “based on”

This change will be made.

L112: “previous instruments” developed in your lab? Or universally?

This will be clarified.

L117: “scans to ~ 10 kHz and faster, resulting in high precision of the measurements”—precision from averaging over multiple scans? Current operation is only 10 Hz (100 msec) scans?

L320 says “tests showing that full scans over the water [line] at ~ 1000 Hz are possible” and that higher scan (measurement) rates result in reduced precision (for individual scans)

Thank you. We meant “high resolution,” albeit with reduced point-to-point precision. We will clarify this in the text.

L120: Reference to Figure 2 is missing from the text (\sim L129?). Fig 3 is already mentioned on L126. Reorder sentences to put “Prior to...” after the circuit discussion? Would it make sense to include Figure 2 in supplemental material? That would allow additional inclusion of the custom TIA circuit and supporting circuit board.

Reference to Figure 2 will be added. Because we do not have more substantial material for a supplement, we will come up with a way to provide adequate information to laser driving and detector amplifying circuits. In fact, both were quite simple and adapted from information that is readily available on the World Wide Web. We decided not to provide the actual circuit diagrams or fabrication files because they are fairly limited to the specific components we used, one of which is no longer available. We will add a note that we can provide details of our electronics and circuit board fabrication upon request.

L129: “A Teensy model 4.1 with a built-in Micro-SD card feature was used...”; “a trigger pulse”

This change will be made.

L131: ADC not defined at first use; “data acquisition analog-to-digital conversion (ADC) is started.”?

This change will be made.

L132: There is some discrepancy regarding the discussion of Fig 3. It says here that the plot contains 445 points, but the figure shows 4 complete scans. Figure 4 shows 445 points without showing a complete scan (~10+425+~10?). It would be best to clearly describe the sequence of one scan (475 points? 30 + 425 + 20?) and show the complete scan in Figure 4.

Fig. 3 shows the continuous signal output from the TIA circuit as recorded by an oscilloscope. Fig. 4 shows a complete scan read from the TIA circuit by the Teensy 4.1. There is dead time between scans not shown in Figure 4 for when data are written to the microSD card. We will clarify this in the text.

L132: How does the math for 7.2 kHz “raw” ADC work with 475 pts / 100 msec at 32x oversampling? Does 7.2 kHz already include the 32x and so is faster than the 4750 samples / sec?

The Teensy 4.1 samples at 300,000 samples per second. Therefore, the full bandwidth is 9375 samples per second with 32x oversampling. At 100 ms we use 50% of this available bandwidth in order to slow down the “write-to-SD” process and provide overhead for performing calculations, as desired. We will clarify this in the text.

L144: omit “on the opposite side of optical path both operated in photovoltaic mode”? A following sentence begins “The photodiode is operated in photovoltaic mode”

This change will be made.

L148: It seems like the “AD1101, Analog Devices” is actually “HMCAD1101”? I could not find a part at Analog Devices that was just “AD1101”.

Correct part number is LT1013 CN8. This will be changed in the text.

L165: description here is “1st-order polynomial” while the caption in Fig 4 uses “linear fit”—these are indeed the same thing, but it might be clearer to be consistent.

“1st-order polynomial” will be replaced with “linear fit” where applicable.

L166: It would be useful to have a little more clarity on the process of converting the temperature – wavelength determination to the current ramp scan to account “for the

possible drift of the tune temperature by removing the nonlinear output laser wavelength response to a linear current ramp” and determination of the scan wavelength range.

We agree. Although it is a straightforward process, with a result that is fairly unremarkable (e.g., a linear conversion from bit number to wavelength), it requires a fairly lengthy discussion. However, we have decided to add a short explanation of how we measured the conversion, and we will provide the specific equation for our specific scan parameters. In addition, we will note that the conversion depends on specific conditions of the ramp.

L182: Accuracy metrics of the BMP280?

The details of the BMP280 will be added.

L187: Does “These calculations” refer to the real time processing that is planned for future implementation and not the present version that is the focus of the manuscript?

Yes. We are in the process of developing embedded codes for processing spectra in real time for future versions of the instrument. This clarification will be made.

L190: The units of the x axis in Figure 4(b) are wavenumber, not wavelength as stated. Since wavelength is otherwise used consistently in the manuscript; I would suggest using wavelength here as well.

Units will be adjusted.

L190: In Figure 4(A), it might be helpful to use color on the trace to highlight the region of the scan used for the baseline fit. As noted in L132 comment, it would be clearer to plot a full scan including the 30 and 20 detector zero (laser off) points at the beginning and end of the scan.

These highlights will be added.

L198: no hyphen needed between number and unit “25 L” even when used as an adjective.

This change will be made.

L200: “saturated to a mixing ratio of ~27,000 ppm”—was the air in the chamber saturated (potential condensation)? Or was the saturation temperature of the generator lower than the ambient temperature? What is/are the values (uncertainty) of the mixing ratio reported by the reference CRDS measurement rather than “~”?

The sentence starting on L200 will be changed to “A beaker of warm water was placed inside the chamber to humidify the air to 29,000 ppm, just below the saturation point. Over the course of the next two hours water vapor mixing ratios in the chamber were reduced to ~13,000 ppm by stepwise-addition of relative dry ambient air from the laboratory.”

L201: “admitted to the chamber”—also flow out of the chamber as well to maintain P?

This will be clarified.

L207: It would be good to include information about the linear regression as text in Figure 5

The fit parameters will be included in the Figure 5 caption.

L209: remove period following “points)”; omit reference

This change will be made.

L213: “Allan variance”

This change will be made.

L222: sensitivity is not affected by averaging— “detection limit”?

Thank you for noting this ambiguity. We will clarify when we mean precision and/or limits of detection.

L256: Omit “A long electrical line”? This was replaced with the “10 m twisted pair cable”? No comma needed after “cell” or hyphens between numbers and units; the word “long” could be omitted.

This change will be made.

L307: “Teensys”

This change will be made.

L320: “tested powered”

This change will be made.

L336: “include”

This change will be made.

L342: ABL already defined in introduction

This change will be made.