The manuscript, titled “Martian column CO_2 and pressure measurement with differential absorption lidar at 1.96 μm”, presents a lidar instrument for measuring atmospheric carbon dioxide (CO_2) on Mars for surface pressure determination. The manuscript reports a similar lidar instrument, as previously presented by some of the authors referred to in (Lin and Liu, 2021), but with different transmitter using 1.9 μm laser instead of 2.05 μm. The advantages of changing the lidar operating wavelength are not clearly justified. In addition, the manuscript suffers some oversights and lacks detailed discussions in some parts, which may lead to incorrect conclusions and ambiguity to the reader. The authors are encouraged to reevaluate the work analysis and presentation for future resubmission, while addressing the following issues.

1. The presented active lidar instrument cannot fully perform the surface pressure measurement by itself. It requires additional supporting instruments, such as infrared temperature sounder (section 2.3) for temperature profile measurement and involves iterative analysis with predetermined initial measurements. Even molecular atmospheric pressure, other that CO_2, requires more dedicated measurements or modeling (lines 106-108). For example, the multispectral sounder passive instrument, cited by (Natraj et al., 2022) can perform temperature, CO_2, and other molecules profiling, which can be used to derive the pressure on Mars, without the risk of using active element. Therefore, a strong justification for using a high-risk lidar instrument for Mars is required.
2. The presented analysis focused on measurement errors without addressing the measurement itself. The analysis should address assessments for the CO_2 differential optical depth and surface pressure measurement using the technology proposed in Table 2, including surface return signals. For example, the table lists several parameters, such as telescope and detector specifications, which were not included in modeling. Other specifications, such as detector noise, digitizer specifications and signal averaging were not addressed. The error analysis is limited and does not include other significant factors, such as molecular interference, electronic noise, laser jitter, ranging uncertainty, etc. For example, see (Refaat et al., 2015).
3. The spectral modeling presented in figures 1 and 3a focuses on strong CO_2 absorption lines around the suggested operating online and offline wavelengths. Nevertheless, weaker lines, within the same spectral band, should be included in the analysis since they contribute to the cross section and optical depth profiles. For example, weak lines contribution is significant toward the offline and may require updating its position. Probably this will change the results, such as the error presented in figure 3b.
4. The lidar operating platform is not clearly specified from the beginning. Later, toward the end of the paper, specifically in Table 2, surface reflectivity and satellite altitude are given, which implies an orbiter platform while the lidar pointing nadir toward the surface. Assuming this is true, the integration limits presented in the analysis are incorrect. For an arbiter, the column integration should start from the orbiter altitude, z, to the surface (at z = 0) not to the top of the atmosphere (TOA). As a matter of fact, even the definition of TOA on Mars is unclear. This appears in equations (2), (3) and (6), while equations (8) and (12) presents the correct integration limits but flipped (e.g., integration from z to 0 not 0 to z). It is unclear how this error would change the analytical results presented in figures 5 to 7 and

conclusions. Also, the meaning of presenting the errors with altitude z, is unclear. Does that means changing the orbiter altitude?

In addition, the authors should consider the following specific details:

Section 1: Introduction

Line 27: Please avoid the use of the word "air" for referring to Martian atmosphere, as it is relevant to Earth. For example, living creatures on Earth breath air, and the use of this word may imply that Mars atmosphere supports life. Same applies to the rest of the document, whenever the word "air" is used to address Martian atmosphere.

Lines 27-28: It is unclear how atmospheric dynamics are specifically associated with "dry air movements" not "total air movement" on extraterrestrial planets. This implies that water vapor, the difference between total and dry air, has no role in atmospheric dynamics. Please elaborate or change.

Lines 33-35: Please check the composition of the Martian atmosphere. Martian atmosphere does not contain hydrogen. The composition ratios listed for carbon dioxide, nitrogen and argon are inconsistent to what are listed in (Franz et al., 2017 and Williams, 2020).

Lines 35-26: Please explain the difference between "global atmospheric dynamics" and "global atmospheric thermodynamics". Please elaborate on "the carbon cycle on Mars" and include a reference. Is the sentence refereeing to a current active carbon cycle or historical carbon cycle?

Line 39: Please elaborate on atmospheric temperature measurements using infrared remote sensing techniques and include reference. For example, introduce the infrared temperature sounder, referred to later in Line 66.

Lines 39-42: This paragraph addresses pressure measurement limitations on Earth. It is unclear how that is relevant to pressure measurement on Mars. Please explain.

Line 46: Please consider rephrasing "Passive instrument" to "Passive remote sensing instruments" to distinguish from in-situ barometers presented in the previous paragraph.

Line 67-69: For complete argument, it is beneficial to address some of the risks using a DIAL system on Mars, such as cost, complexity, lifetime, power consumption, weight, and size, etc., as compared to passive remote sensing.

Line 70-76: In this paragraph, please consider introducing the operating platform and target for this proposed lidar on Mars. For example, is it for a lander mission or orbiter. The last two sentences can move to section 2.4 "Wavelength Selection".

Section 2.1: DIAL Measurement

Line 84: Please specify that the CO_2 differential absorption optical depth is for a single path, as presented in equation (1). It is more common to use double-path optical depth analysis, since the transmitted radiation must travel forth and back, from and to, the lidar instrument.

Line 86: In equation (1), the measured differential optical depth, represented by the right term, includes the CO_2 differential optical depth and other differential optical depths from interfering molecules, as specified in (Lin and Liu, 2021 equation 5). Please specify and comment on why it is not included in this analysis.

Line 87: The sentence "$\Delta\tau_{CO2}$ represents the CO_2 DAOD at the online and offline wavelengths" is redundant.

Line 88-90: It is unclear why the transmitted laser energy, or power, was replaced by the calibration coefficients, and if these coefficients are assumed constants or variables in equation (1). An equation for the calibration coefficients, including units, would be helpful to show how they can be obtained through the zero-range measurement. For example, lidar equation is not defined at zero range due to the backscattered signal dependance on the reciprocal of the range squared (i.e., Lidar Signal $\rightarrow \infty$ at Range = 0).

Line 90-91: The cited references (Lin et al., 2015; Dobler et al., 2013; Campbell et al., 2020) are irrelevant since they present an intensity-modulated continuous-wave lidar systems, whereas the described system is pulsed (as pointed out in Line 71). Please check and update.

Line 92: Equation (2) is unclear since the lidar operating platform is not specified. Please see comment #4 and define the symbol z'.

Line 96: Equation (3) is redundant to equation (2) just by arranging terms. Probably it is better to solve (2) and (3), and present

$$N_{CO2}(z) = \int_{z}^{TOA} n_{CO2}(z')dz'$$

which is referred to as "the column CO_2 molecular number integrated from z to the top of atmosphere (TOA)". If we assume z' is altitude in meter and n_{CO2} is the number density in $1/m^3$, then N_{CO2} must be in $1/m^2$. Therefore, the physical interpretation of N_{CO2} is unclear. Please explain.

Line 98: Equation (4) is redundant to equation (2).

Line 99: By "the air pressure caused by CO_2" does it means "CO_2 partial atmospheric pressure at the surface"?

Line 100-103: Please include references for equations (5) and (6) or derivation. Why "the weighted mean Martian gravitation acceleration" is required not Martian gravitation acceleration? Please define $n_{CO2,model}$ in equation (6).

Line 102: The weighted mean Martian gravitational acceleration between z and TOA, represented by equation (6) is different than the representation in (Lin and Liu, 2021 equation 10). Why extra denominator was included?

Line 106-107: Please quantify P_{others}, relative to P_{CO2} here (Line 209) and validate the assumption of stability. What other "dedicated measurements" are required to measure P_{other}? If the plan to send an additional instrument to measure P_{other}, can it measure the total pressure as well? Then what is the benefit to send a lidar? Please compare lidar to (Natraj et al., 2022) for justification.

<u>Section 2.2: Surface Column CO_2 and Pressure Measurement</u>

Line 109: For the title of this section, is it meant to be "Column CO_2 and Surface Pressure Measurement"?

Section 2.2 is too short compared to other sections. Consider combining with previous section.

<u>Section 2.3: Atmospheric Pressure Measurement with IR Sounder Temperature Measurement</u>

Line 126-128: Please include a reference for equation (8) and the [average] molar Mass of Martian atmosphere. Define zero altitude on Mars used for the integration limits. Can the barometric formula be applied on Mars?

Line 131-132: This is confusing. Please state the difference between equations (8) and (5). Is one equation for surface pressure and the other for pressure profile? This indicates that an initial pressure profile is required to measure the pressure profile.

Line 139-140: Generally, iterative processes may converge or diverge. It is not clear if surface pressure determination through iterative process would converge. Please comment.

<u>Section 2.4: Wavelength Selection</u>

Line 158: Is it the Absorption Optical Depth (AOD) required to be 1.1 or the Differential Absorption Optical Depth (DAOD), as claimed in Line 145?

Line 164-165: How many HITRAN lines were used for AOD calculations and the criteria for selecting these lines? The results of Figure 3a indicates that weaker lines were neglected, which significantly contribute to the spectral profile. Please investigate since this may change your conclusions, such as the required online and offline positions and laser line stability.

Line 172-173: Please mark P(12) line on figure 1. What about other lines presented in figure, how do they compare to the selected P(10) line? Otherwise, limit the figure to the discussed lines.

<u>Section 2.5: Laser and Wavelength Locking</u>

Line 183-184: How the DAOD error, of less than 10^{-4}, was evaluated?

<u>Section 3.1: Error Analysis</u>

Line 193-198: Please define all symbols and discuss these equations.

Line 199: Which results are referred to? Do you mean "analysis"?

Line 206-207: Please include the error due to the initial pressure estimate used for the iterative process.

Line 209: Please include reference for <5% other pressure.

<u>Section 3.2: Simulation Results</u>

Line 238: Please define the figure of merit (FOM).

Line 240-241: Please state how the photon number per pulse was evaluated? Why was the photon number addressed here not signal as equation (1)?

Line 245: Typically, signal-induced shot noise is the dominant noise source for lidar systems, whereas daytime background can limit the dynamic range. Moreover, background blocking filters can resolve this issue as pointed out in (Line 294). Please investigate.

Line 277: Please elaborate on solar background noise calculation and why it wasn't included in the error analysis presented in equations (9) to (12).

Line 289-291: Need a figure for simulating the lidar return signals and CO_2 DAOD and surface pressure retrievals to support these claims.

<u>Figures and Tables</u>

Line 400: Figure 1: Please indicate the spectral resolution of the calculated cross section. It is unclear why wide spectral range is shown, rather than focusing on 1.9640146 μm line. This calculation focuses on the dominant spectral lines while ignoring weaker lines. Please include weaker line and plot in log scale to be comparable to the optical depth calculations presented in Figure 3.

Line 406: Figure 2: In addition, please include typical Martial vertical CO_2 profile as applied to equation (6).

Line 408: Figure 3: How the absorption optical depth, presented in figure 3a, was calculated? Is it based on a model similar to equation (2)? Please state the altitude limits.

Line 416: Figure 6: Please replace "system" with systematic". Check if these profiles calculated using HAPI or equations (11).

Line 425: Table 2: Some of the parameters listed in this table were not discussed within the manuscript. Please include a discussion for how these parameters are relevant to the measurements. For example, the beam expander throughput, telescope diameter and clear area ratio, detector quantum efficiency and dark current. What is the meaning of the "fill factor"? is the DRS APD a single detector or array? What is the detector noise-equivalent-power and how it influences the errors? Please define abbreviations.