Dear Editor, September 9, 2025

I have reviewed the manuscript below, which was submitted to the journal *Atmospheric Measurement Techniques:*

"Delta ^{13}C carbon isotopic composition of CO_2 in the atmosphere by Lidar. A preliminary study with a CDIAL system at 2-µm," by authors Fabien Gibert, Dimitri Edouart, Didier Mondelain, Claire Cénac, and Camille Yver.

Overview:

The manuscript describes initial measurements of atmospheric 12CO2 and 13CO2 with a lidar and discusses the results in context of carbon source analysis. The measurements were made from the ground in a nearly horizontal path by using 3 wavelength coherent DIAL lidar that operates in the spectral region between 2050 and 2053 nm. The lidar uses an off-line wavelength, one at the absorption peak of a 12CO2 line, and the other on the absorption peak of a 13CO2 line. The lidar used was a previous coherent DIAL lidar that had been updated with a higher power laser and the new capability to tune to the targeted 13CO2 line. The theory of the CDIAL lidar measurements are reviewed and measurements of 12CO2 and 13CO2 made over a several km long atmospheric path are shown and compared to those from an in-situ sensor. The measurement precisions and accuracies are discussed in the context of those needed for determination of atmospheric CO2 fluxes. The primary measurement challenge is the limited capability to measure 13CO2. This is mainly caused by its weak line absorption due to its small atmospheric concentration of ~ 4 ppm, which is roughly 1% of 12CO2. The manuscript also discusses possible approaches to improve the 13CO2 measurement precision and accuracy.

Findings and Recommendation:

The manuscript addresses work to address an important area to better remotely sense and understand fluxes of carbon between the Earth's surface and atmosphere by measuring the isotopic ratio of atmospheric CO2. It gives a detailed review of the theory of the coherent DIAL lidar measurements. It reports important lidar measurements including those extended in time, comparisons to the in-situ sensors and evaluation of its measurement stability via Allan variance. The manuscript is well written and cites a large number of relevant references.

Although found that some updates needed, I recommend accepting an updated version of this manuscript after the mandatory changes are incorporated.

Mandatory changes:

1. The lidar's wind speed measurements are mentioned a few times, but there is little discussion of them in the manuscript and the wind measurement results aren't shown. If the focus is on CO2 measurements, then I recommend just mentioning the lidar is also capable of wind measurements and give a reference.
2. The lidar's demonstration measurements are made over a few km long nearly horizontal path. They are compared to in situ measurements, which are much more accurate, especially for 13CO2. Given the in-situ sensor's higher accuracy and the lidar's relatively short range, the potential benefits of using a lidar for these type of atmospheric measurements (ie in the atmosphere near the in-situ sensor) is unclear. This needs to be clarified in the introduction and conclusion.

3. The manuscript's introduction needs to be clearer about what accuracies and resolutions are needed for this type of lidar to be useful in determining flux signatures, especially given the small change their fluxes make in Delta CO2.
4. Line 29 the phrase: "devasting consequences for …" please reword using phrasing from a relevant review paper.
5. In Figure 2 the components used to measure the transmitted pulse energies or powers (ie P_0) need to be shown. Also it needs to show the key blocks for the signal processing after the detector
6. In Figure 1 the lines for the 3 wavelengths appear faint and need to be darker or clearer
7. For the lidar measurement comparisons to in situ, please give the azimuthal angle of the wind vector (if measured) relative to the lidar's azimuthal pointing angle.
8. In Table 2 the signal processing is described as spectral accumulation, while on Line 177 it references 2000 shot averaging for each wavelength. Please clarify what is meant by spectral accumulation, how it is performed and what is being averaged (the signal or its spectrum)?
9. In Figure 3, (a)-(d) are plotted to 10 km, but the later measurements primarily go to 3 km, while Fig. 3e only to 2 km. Since the most useful range is limited to 3-4 km please replot (a)-(d) accordingly.
10. In Figure 5, the data points are very hard to see. They need to be replotted with symbols that are larger or have more contrast.
11. Both plots in Figure 5 show that both tau values increase linearly with range, Please comment on what that implies for the spatial variability of 12CO2 & 13CO2 in the path. If there is high spatial uniformity of 12CO2 and 13CO2 in the path, then what does that imply about benefits of lidar vs in-situ measurements?
12. In Table 4, it is unclear whether the values are for before or after bias correction. Please clarify.
13. It seems other possible sources of systematic measurement error could be caused by the lidar hardware. Possibilities might include a wavelength dependent response of the optics or detector that measures the Po values for each wavelength or slight changes in the beam pattern from the transmitter for the 3 wavelengths. Please briefly address the possibilities of the lidar hardware being a source of systematic error.
14. In Figure 7 the better known (in situ) measurements are plotted on the y-axis with the lidar values on the x-axis. Since here the primary question here is about the lidar measurements it seems their values should be plotted on the y-axis. Also, if possible, please plot the measurements made on the different days with different colors or symbols.
15. In Figure 9 the dots for the lidar measurements are difficult to see. Please replot in a darker color or larger symbol size.

<u>Recommended changes</u>

1. The manuscript doesn't clearly address the targeted application scenario of this type of lidar. For example, it solely intended for research, or for deployment for single units or a network? Is the targeted use primarily intended for horizontal, slant or vertical path measurements?

2. Line 46, specify what type of gas emissions
3. Line 49 “interesting ways”. Do the authors mean simpler or more affordable?
4. Line 53 “outstanding information.” Do the authors mean new information?
5. Line 62 “confronted” Do the authors mean compared to?
6. Line 78, 1st two equations, the equal signs did not get type set correctly
7. Line 113. “the ACS are larger by one order of magnitude” Do the authors mean compared to those in the 1.6 um band?
8. On page 5 please comment on why the wavelengths are switched at 60 Hz.
9. On page 5 the diameter of the lens used for the common transmit receive path is given as 50 mm. Diffraction limited lens are commercially available with much larger diameters and it seems that using one would improve the lidar’s CNRs and the measurement precisions. Please comment on why this lens diameter was chosen.