General comments

This is an interesting manuscript that addresses a novel approach to retrieve the column-integrated mixing ratio of greenhouse gases (XCO2 or XCH4) by measurements with a multi-wavelength pulsed Lidar sounder. XCO2, its variance and other parameters are derived from comparison of the measured transmission line shape function to a modelled one by means of a least squares fit. The presented retrieval method appears to be quite similar to passive sensors that but it is adjusted to serve for the pulsed Lidar measurements with its specific averaging kernels. For evaluation purposes, real multi-wavelength Lidar measurements by a specific airborne CO2 Sounder Lidar are used to test the proposed algorithm. The retrieved XCO2 values agree pretty well (< 1 ppm) to independent measurements of the mixing ratio column using aircraft in-situ data which is a remarkable result of this study. In a wider context the results of this study demonstrate that active remote sensing in combination to advanced retrieval methods fulfils the stringent measurement requirement on XCO2 for flux inversion experiments as demanded by the top down approach. The overall quality of the manuscript is good and the material presented is very well suited for publication in AMT subject to a few minor questions and comments for improvement of the manuscript as detailed below.

Specific comments

Chapter 1 lines 37-46: a brief chapter on the background and motivation for the selected measurement approach and retrieval algorithm is missing here. Different to passive sensors, conventional DAOD-based retrieval techniques don`t need a first guess CO2 profile for the calculation of XCO2. What is the reason to give-up this advantage or what is the benefit of the selected approach.

Further to this, the measurement precision of active sensors always lacks on sufficient “good” photons, particularly, if applied from space. The highest measurement sensitivity can be achieved at wavelength positions where the DAOD is close to unity (dependent on the background noise). This would imply to spend most of the laser pulses at wavelength positions that are more favorably in terms of measurement sensitivity rather than to emit in the far wing where the DAOD is very small as shown in Fig 2. Could the authors comment or justify the choice of the wavelengths. This question is also related to the discussion chapter 7.2

Chapter 2: Although the instrument description is not the focus of this issue a table of the most important instrument parameters which largely dominate the measurement performance from instrument point of view would be very beneficial for the manuscript. The missing parameters comprise: the laser pulse energy, the spectral width and spectral purity of the laser pulses, the wavelength domain of the pulse train, the optical filter band width, the laser footprint on ground, the off-nadir sounding angle, and maybe others. This table should also give information on the wavelength stability during a typical averaging period. In particular, the accuracy (stability) of the emitted laser pulses within each pulse train and its reproducibility over the various pulse trains during the measurement. The wavelength stability is a key parameter that impacts on the systematic error.

Chapter 3

Line 115: The transition from Eq: 1 to Eq: 2 is somewhat puzzling. More information on the calibration parameter C2 should be given. It is assumed that the calibration requirement comes from the energy monitor device which is different to the signal detection system in Fig.2. What is calibration procedure of this parameter on ground and what is the stability during airborne measurements.

Line 130: The simple Eq. 4 assumes monochromatic laser pulses and almost zero emissions elsewhere (high spectral purity), otherwise it would fail. These important instrumental constraints should be added in this paragraph.

Lines 143-144: The introduction of the layered OD versus column OD is a bit confusing. What is measured and what is modelled? An equation for the measured column OD should be given here.

Line 150: the line shift is also influenced by atmospheric parameters … should be added.

Lines 161-163: It is agreed that the information content from measurement in the line wing appears to be rather small because of the small column OD in case of the selected CO_2 absorption line. However, passive sensors that are capable to resolve the absorption line profile would face similar problems since a higher spectral resolution results in a lower SNR. This is a confusing side discussion here, therefore it is recommended to drop these lines.

Lines 165-169: Selection of only one scale factor might be a bit too optimistic. It would imply that the selected line parameters and the absorption cross section model are accurate enough to serve for all wavelengths and all atmospheric layers. Could the authors comment on this issue.

Line 210, Eq. 9: further to above, the weighting factors introduced in the loss function are chosen to be similar at all wavelengths, just differing in their SNR. Maybe this is also a too simple approach and need to be justified in the manuscript. It takes not into account the various unfavorable column optical depths of the measurements in the line wing. The more optimal soundings with more optimal column ODs should be given more weight in the retrieval.

Chapter 5
Line 257: What is the reason present Eq. 19. It is not used in the manuscript

Chapter 6
Line 291: What are other possible noise contributions such laser speckles in the Lidar echoes or from pulse energy detection unit which are not considered in Eq. 24.

Page 13 Fig. 5: Several parameters have been fitted in Fig. 5 but only the rms variation of XCO_2 is discussed. What are the rms variations of the other fitted parameters and is there any interference to the retrieved XCO_2. Further to this, is the quality of the fit robust enough against changes of the first guess profiles CO_2 and H_2O or against errors of the spectroscopic or meteorological data.

Chapter 7.1
As known from many previous studies, systematic measurement errors play a key role in flux inversion experiments, and the requirements are very stringent there. The discussion on this topic is a bit thin. The authors are requested to discuss possible sources of systematic errors which may be related to the processing algorithms (linearization step, weighting factors, scale factor, first guess profiles, and spectroscopy to model the absorption line profile).