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Discussions

Interactive comment on "A strategy for the measurement of the CO_2 distribution in the stratosphere" *by* Massimo Carlotti et al.

Anonymous Referee #2

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This paper presents a reasonable strategy for retrieving the vertical distribution of CO2 in the stratosphere. An alternative strategy would be to use solar occultation instead of thermal emission for these same bands. This could improve the shot noise and the vertical resolution since:

1) The sun will always be a stronger source of radiation than the Earth's atmosphere at any wavelength.

2) For solar occultation, the vertical resolution is not tied to the vertical structure of the temperature (see Fig. 7 bottom left of Carlotti et al.), and therefore would not worsen severely in the tropopause region as is the case for thermal emission as expected.

For CO2, given the main interest of the authors to observe the long-term slight increases in VMR in the stratosphere, frequent measurements are not required and thus

space-based solar occultation could be applicable. The authors could consider the O_2 lines in the TIR as well, which are useful in the stratosphere up to ~38 km, based on ACE-FTS O_2 retrieval accuracy. This could alleviate the need for two detectors regardless of whether thermal emission or solar occultation is used. There are three main problems with this paper:

1) The error budget is incomplete, specifically with regard to sources of systematic uncertainty.

2) O_2 does not appear to be adding much p T information outside of the 20-35 km range, raising the question about strong correlations between CO_2 VMR and T.

3) Related to problems 1 & 2, the authors present their method as one that has small systematic uncertainties and an accuracy of 1 ppm (P2L30 & P12L3), yet ignore many significant systematic sources of uncertainty and consider only minor ones.

This paper is publishable after major revisions. The major revisions involve accounting for more sources of systematic error and switching back to sequential retrievals (see below). Furthermore, the statement that CO_2 VMR is retrievable to 1 ppmv between 10 and 50 km is grossly misleading in my opinion. There is no point to getting the community excited about an instrument that can supposedly measure CO_2 profiles to ~1 ppm, when it hinges on line intensities of CO_2 to be measured to 0.25%. Also, it hinges on O_2 line intensities to be measured extremely accurately: a 1% bias in O_2 line intensities will lead to a 70 m bias in TH (or a 1% bias in pressure). This will translate to a ~1% bias in CO_2, much larger than the sources of systematic error that the authors have selected. The combined biases in CO_2 and O_2 spectroscopy could either cancel or lead to a 2% bias in the worst case.

The claim that dedicated spectroscopic measurements will be made in the future is not acceptable to me for the present manuscript. I would assume the spectroscopists previously involved in measuring line intensities were dedicated to achieving the best accuracies possible. See table 3 of Tashkun et al. (2015). Searching through the

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systematic uncertainty column (2nd last column) of this table, I see values as low as 2% (e.g. by Delière et al., 2012) for the lines in a region overlapping the spectral region proposed by the authors. The latter study was dedicated to a specific band and is recent (2012). I take this to be a reasonable or even favourable estimate of the expected uncertainty in CO2 spectroscopic line parameters in the OXYCO2 experiment. Some bias correction can be applied by first validating against CO2 measured using techniques accurate to <1 ppmv but the authors would need to discuss this, especially since they insist on using the term 'accuracy' instead of 'precision' in a couple of spots (see above) in the paper.

The authors correctly state (P2L13) that strong correlations exist between retrieved T and retrieved CO2 when retrieving T from CO2 lines and this correlation "prevents" the retrieval of CO2 from these same lines. I believe the authors have the same issue over a large portion of their retrieval range since Figs. 5 and 6 show that the CO2 VMR precision is not changed much if the O2 lines are used or not outside of ~20-35 km. The 20-35 km corresponds to the region where the information load (IL) is large, whereas outside this altitude range, both above and below, there is a sharp decrease in IL. I believe that the pT information is coming predominantly from CO2 lines (whose IL tends to be larger in the upper stratosphere) and that strong correlations will result. I consider only the region between 20-35 km to be appropriate for retrieval and I believe the authors should "prevent" themselves from retrieving outside of this range, given their retrieval setup. The authors also admit (P8L2) that when they tried the sequential estimation, they could not retrieve CO2 VMR precisions that approach the target value because of problems retrieving T exclusively from the O2 lines. I believe the authors should restrict the vertical range to ~20-35 km and demonstrate that they can retrieve CO2 in a sequential setup over this 'sweet-spot' range. By going to simultaneous retrievals of CO2 VMR and pT, the authors could be confusing themselves in terms of the benefit of the O2 lines.

Figures 5, 6, and 8 are of low quality (and I am not very picky).

Figure 1 does not serve the intended purpose. It shows me that the O2 lines are not prominent, which contradicts the claim by the authors (P1L26).

A nice addition to Figure 2 would be the IL for TIR + FIR.

I'm impressed by the ability of the authors to calculate horizontal resolutions and by the two sets of IL calculations provided in Fig. 2.

Specific scientific comments

P1L21 The authors should not judge whether the retrieval accuracy is dominated by systematic or random components until they have added major sources of error. Ironically, when some of the same authors including the lead author, presented CO2 error budget for MIPAS (http://www2.fci.unibo.it/∼enzop/FILES/CO2.pdf), they included many additional sources of error. 'SPECDB' ironically appears to be spectroscopic database errors, which are important and lead to 1-6% errors according to the online presentation. Other sources of error include 'gain', which is up to 4%. Perhaps, the OXYCO2 instrument will have smaller uncertainty related to gain, but to disregard this source of error entirely seems biased toward minimizing retrieval inaccuracies. Other sources such as 'SPREAD', 'SHIFT', and 'CTMERR' should be considered here if relevant. Something should be said about the impact of thin clouds, particularly on the TIR radiances, since the authors talk about retrieving in the troposphere many times. Wavelength calibration can be a slight problem for FT spectrometers and should be considered. Imperfect knowledge of the instrumental line shape is another source of error that could be considered.

P2L15 The authors could refer to Emmert et al. in Nature Geosci. for the mesospheric ACE-FTS CO2 measurements.

P2L19 There is no such discussion in Bernath et al. (2005).

P4L8 1.5 cm2 sr is a very large throughput. I'm wondering if this is a typo. Could the authors specify the solid angle subtended by the field of view?

C4

P7L1 State clearly whether A and phi are variable or constant along the OC. I assume they are variable from this line.

P9L17 Are these the B values used in Figure 2?

P9L19 values -> absolute values

P24 As mentioned above, there does not appear to be much relaxing of the strong correlation (P2L23) outside of 20-35 km since the red and green lines are not very different. The authors need to show that the strong correlation of T and CO_2 VMR is not a problem outside this vertical range.

Minor comments

P1L12 Vibro-rotational -> rovibrational (correct this throughout the paper).

P1L15 operational limb sounders -> an operational limb sounder. (I see MIPAS as the only operational limb sounder).

P1L27 biosphere -> atmosphere

P1L28 on board of -> on board

P1L30 have demonstrated -> "have been demonstrated"

P2L3 Chedein -> Chedin

P2L8 "(e.g." -> "such as" (to avoid too many parentheses).

P2L9 Fischer et al., 2008 -> (Fischer et al., 2008) (repeat for Gille et al.)

P2L12 "...known; assumption..." -> "...known. This assumption..."

P2L15 All leading prepositional phrases should be followed by a comma, e.g. "In these measurements,"

P2L19 ", can be found" -> "can be found"

P2L25 "line strength is" -> "line strengths are"

P2L29 "capable to"->"capable of"

P3L14 No need to cite Fischer et al. again.

P3L16 Hydroxil -> Hydroxyl

P4L9 Can the authors be clearer that this is one component of the overall noise, related to the detector? Also, I understand the units, although they don't appear to be power units and this may confuse some readers.

P4L11 change from square brackets to curvy ones here and in the next line.

P4L11 active -> an active

P4L26 "adapting to our specific needs the algorithm . . .2002." -> "adapting the algorithm . . . (2002) to our specific needs".

P5L1 increase -> "an increase"

P5L2 "that correspond" -> ", which corresponds"

P5L21 "all the" -> "all of the" (occurs elsewhere).

P5L22 "Fig.s" -> "Figs."

P6L16 round -> root (?)

P6L19 point -> step

P8L33 VCM: spell out acronym here.

P15L2 that -> whom

P15L6 P. F. -> P.-F.

P15L7 Mc-Connel -> McConnell

P15L9 Semeniuxk -> Semeniuk

P15L10 Zou, T. -> Zou, J. (plus add spaces before 'Walkty', 'Wardle', and 'Wehrle')

P15L12 add "and" before last name of final author. (elsewhere as well).

P15L18 Borrowsandi -> Burrows

P15L18 Krner -> Körner

P15L19 SCHIAMACHY -> SCIAMACHY

P17L2 SPIE -> Proc. SPIE 8176

P18 It would be helpful if Table 1 referred to section 2.1 for vertical sampling. A footnote could be used.

Reference

S. A. Tashkun, V. I. Perevalov, R. R. Gamache, J. Lamouroux, CDSD-296, high resolution carbon dioxide spectroscopic databank: Version for atmospheric applications, Journal of Quantitative Spectroscopy & Radiative Transfer 152, 45–73, 2015.

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