We would like to thank the referee for the kind feedback and relevant comments. All the points will be addressed in blue, between the referee's comments.

The authors introduce a new concept called the Space CARBon Observatory (SCARBO), which aims to measure CO_2 and CH_4 from a constellation of ~20 satellites in sun-synchronous low Earth orbit, with a multi-angle polarimetric aerosol instrument to account for scattering effects. SCARBO will have higher spatial coverage and revisit frequency compared to existing greenhouse gas missions. The authors assess the performance of SCARBO for a variety of scenarios, both with and without the aerosol instrument. They find that systematic errors in column-averaged CO_2 and CH_4 (XCO_2 and XCH_4) retrievals can be greatly reduced by using aerosol information from the polarimeter. The authors also parameterize results as a function of relevant parameters in order to facilitate efficient computation of error maps for CO_2 and CH_4 flux estimation.

The manuscript is well written and the topic extremely relevant to the greenhouse gas remote sensing community. However, a few issues need to be addressed before it is ready for publication.

Lines 148-149: "Entanglements between CO_2, CH_4, O_2, H_2O and aerosols signals have been considered, with the assumption that albedo models are constant over all four spectral bands." What is the impact of varying albedo on the results? Also, only soil, vegetation and desert types are considered. What about water? Many emission sources (e.g., power plants) are near the ocean, so coastal areas would need to be considered.

Regarding varying albedo models

This sentence intent, at lines 148-149 (pre-print), is to explain the design hypotheses used for the NanoCarb concept version considered in this article. As it is the very first L2 performance assessment realised for the NanoCarb concept with a complete inverse radiative transfer scheme, the scope of this study lies within the current design hypotheses, and those will be challenged in upcoming studies as the NanoCarb concept gains maturity.

We adapted the revised manuscript at lines 153-156.

What would happen if varying albedo models were considered?

The narrow band filters, that select the incoming light to produce NanoCarb truncated interferograms, have central wavenumbers that shift towards larger wavenumbers with increasing incident angle with regard to the normal to the filter plane (pre-print line 469), i.e. with distance to the FOV center.

Thus, considering wavelength-dependant albedo models means that slightly different "effective" albedo values would have been used depending on the pixel position within the FOV (central symmetry according to its center) and on the strength of the albedo model wavelength-dependence (stronger for the VEG model than for SOL or DES). Consequently:

- it slightly changes the random error swath-dependence, due to slightly different baseline strength
- it results in perturbation of systematic errors if the wavelength-dependence cannot be perfectly retrieved (tests have shown that NanoCarb truncated interferograms currently – in the latest design – carry no-to-little information content on albedo wavelength-dependent slope) or if the wavelength-dependence is not perfectly known a priori (it is never the case at 2x2 km^2 resolution).

Regarding water surface type

The case of water has not been considered for this study because the NanoCarb instrument – as asked later, and indeed it was not mentioned in the pre-print – has been designed as a nadir-pointing instrument. Thus, it makes it impossible to track the specular reflection of the solar radiation over water, in order to get a satisfying signal-to-noise ratio over this surface type.

We have changed the sentence presenting NanoCarb in the introduction to directly state that it is a nadir-pointing instrument (revised manuscript line 81).

Lines 235-236: "The interfering impact of temperature has not been taken into account for the latest optimized OPD selection used in this work, and is not considered in the state vector." What is the impact of this assumption on the retrievals?

As for all CO_2 observing concepts, knowledge of the atmospheric temperature profile is required for the correct retrieval of CO_2 atmospheric concentration, and it is also the case for this NanoCarb concept. However, this interfering impact of temperature has not been taken into account for the optimized OPD selection (i.e. NanoCarb design) used in this study, thus temperature has not been included in the state vector.

Similarly to the answer to the previous question, the hypotheses used here for the L2 performance assessment are consistent with those used for designing the optimized OPD selection.

However, preliminary sensitivity tests (outside the scope of this article) have been conducted to prepare an upcoming iteration of the NanoCarb concept.

Including a global shift of the temperature profile in the state vector, with a standard deviation of 5K in the state a priori covariance matrix, results in an increase of XCO_2 random error of about +0.25 ppm, consistent with the well-known entanglement between CO_2 and temperature variables in inverse radiative transfer.

The impact on XCH_4 random error is negligible, as CH_4 is much less entangled with temperature variable. For instance TROPOMI - S5P ATBD, where temperature is optional in the state vector for its XCH_4 product (page 26): https://sentinel.esa.int/documents/247904/2476257/Sentinel-5P-TROPOMI-ATBD-Methane-retrieval, and not included for the official XCH_4 product (Lorente et al. (2021).

As this study focuses on scattering-related errors, the impact of atmospheric temperature misknowledge on systematic errors is not examined. We can however expect a perturbation of scattering-related systematic errors if we were to include a global shift of the temperature profile in the state vector, as the misknowledge of scattering-related variables would propagate differently through the averaging kernel matrix to CO_2 and temperature related variables, which are somewhat entangled.

What is the impact of retrieving profile scaling factors for CO_2 and CH_4 as opposed to retrieving the vertical profile (that is traditionally done by OCO-2, for example)? Have the authors assessed the impacts on accuracy and on downstream flux estimation?

The choice of using a scaling factor to represent GHG variables in the state vector, rather than a profile like the ACOS algorithm, has been made after early preliminary tests that showed the low information content for GHG related variables (DOFs < 1), thus not requiring to offer – with a profile – the possibility to reach DOFs > 1, like the ACOS algorithm for OCO-2, for which CO_2 related variables amount to DOFs ~2. Reducing, in this way, the representation of GHG in the state vector to a unique element per gas helped to better identify the entanglements between albedo and GHG variables.

As for the impacts of this choice, those can be exemplified by running a simple performance study for ALB=VEG, SZA=50°, CLH=2km, COD=0.02 and FOD=0.05. Let us consider a similar state vector as the one used in the article, but for CO_2 related parameters. Let us consider two cases: (1) CO_2 is represented as a profile scaling factor with an a priori random error equivalent to 13.95 ppm for XCO_2 (2) CO_2 is represented as a 19-layer vertical profile, with an a priori covariance matrix similar to ACOS, yielding an a priori random error of 13.95 ppm for XCO_2. Table R1.1 gives the CO_2 related DOFs and combined XCO_2 random error for the transversal position at the center of the FOV.

Table R1.1 DOFs and XCO_2 random errors for two different representations of CO_2 in the state vector

	(1) Profile scaling factor	**(2) 19-layer vertical profile**
DOFs	0.86	0.91
XCO_2 random error	0.56 ppm	0.45 ppm

The implicit strong covariance between atmospheric levels in the scaling factor case offers slightly less degrees of freedom than when using a 19-layer vertical profile (ACOS covariance matrix used here), thus resulting in higher random error for the scaling factor case, compared to the vertical profile. Consequently, the results presented in the pre-print are conservative in information content and random errors.

This choice also has an impact on the averaging kernel shape, which is shown in Fig. R1.1. Using a profile instead of a scaling factor tends to diminish the vertical sensitivity values compared to when using a scaling factor. Above 1 values when retrieving a scaling factor are usual, as it can be seen for instance in Fig. 2. in Buchwitz et al. (2005).

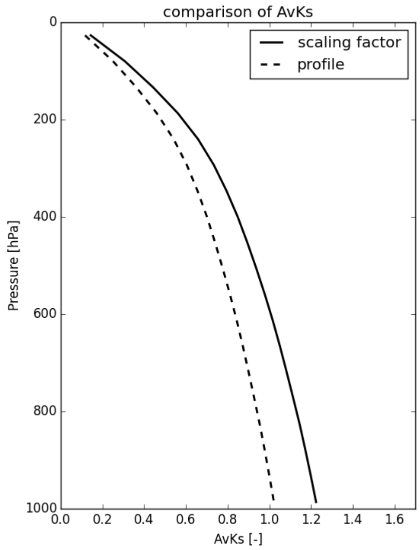

Figure R1.1 XCO2 averaging kernels in the case of retrieving a CO2 profile scaling factor (full line) and a 19-layer vertical profile (dashes).

The differences between profile scaling factor and layer profile retrievals undoubtedly lead to differences in systematic errors caused by a priori misknowledge of scattering particles. However, as the goal of this study was to realise the very first assessment of the SCARBO concept performance, and identify its forces and current limitations, we did not explore the impact of state vector design. Such questions will be addressed in later studies when the NanoCarb concept will have matured and its current limitations (see article conclusions) will be overcome.

The downstream flux estimation performance study only relies on the L2 parameterization which principle is detailed in Sect. 6 of the pre-print. Thus, the full impact of the state vector design on flux estimation performance has not been studied.

Lines 300-301: "For this synthetic performance study, constant trace gas concentration profiles have been used: 394.85 ppm for CO2 and 1855.3 ppb for CH4." This seems (unnecessarily) restrictive (see also previous comment). There needs to be an assessment of how results change for realistic CO2 and CH4 profiles.

This study presents the first performance assessment of the SCARBO concept, which is still being developed. This hypothesis of constant CO2 and/or CH4 profiles used for performance assessments is a usual one. For instance, the CarbonSat performance assessment study realised Buchwitz et al. (2013) – that inspired the method used for this SCARBO assessment – does not precise the a priori CO2 profile it uses, but appears to rely on the pre-existing work performed by Bovensmann et al. (2010), that assumed a constant vertical CO2 background.

However, we agree with the referee that realistic CO2 and CH4 profiles must eventually be considered for a final SCARBO evaluation study, that could be a full OSSE and that would demonstrate its maturity to fly and accomplish its mission.

We adapted the paragraph describing the a priori atmosphere to include these previous comments (revised manuscript line 313-315).

Aerosols: the authors might want to say that the fine mode particles are assumed to be spherical. It would also be useful to have a sentence describing how the aerosol single scattering properties were calculated (e.g., Mie for spherical, T-Matrix for spheroidal?).

Nonspherical aerosols are described as a size–shape mixture of randomly oriented spheroids (Hill et al., 1984; Mishchenko et al., 1997). We use the Mie- and T-matrix-improved geometrical optics database by Dubovik et al. (2006) along with their proposed spheroid aspect ratio distribution for computing optical properties for a mixture of spheroids and spheres.

We added more information (see revised manuscript lines 325-329).

Is SCARBO only going to make measurements in the nadir mode? If not, the viewing zenith angle needs to be a parameter that is considered in the evaluation of the scattering error.

As answered for the first comment of this review, only nadir measurements are considered for the SCARBO concept at this time. The introduction presenting the SCARBO concept was adapted accordingly in the revised manuscript.

Grammatical Errors / Typos:

Thank you very much for catching these typos and English mistakes, we provide the line(s) in the revised manuscript where they have been corrected.

Line 118: Acronym OPD already defined

We removed this redundant acronym definition (revised manuscript line 123)

Line 151: FOV (2) an analytical approximation -> FOV, and (2) an analytical approximation

We fixed the punctuation (revised manuscript line 158).

Lines 152, 258: “line-by-line” would be more appropriate than “pseudo-infinite”

We changed to “line-by-line” (revised manuscript lines 159, 268).

Lines 171-172: “The constellation sizing aims at ensuring intra-daily revisit of the largest possible amount of anthropogenic CO_2 emission hotspots which emission rate is compatible with the 1 ppm SCARBO ð ‘‹!!! precision objective.” Awkwardly phrased

We revised this sentence into two sentences (revised manuscript line 178-179).

Line 173: “performed” -> “compiled”?

We changed the word (revised manuscript line 181).

Line 178: remove “a” before “global coverage” and “daily revisit”

We removed the articles (revised manuscript line 186).

Line 179: compromise well -> provides an optimal compromise

We changed the formulation (revised manuscript line 187-188).

Line 191: measures -> measurements

We changed the word (revised manuscript line 199).

Lines 197-198: what is meant by “without artificial noise”? The text indicates that instrument noise is considered in the retrievals. I would recommend removing this phrase to avoid confusion.

We mean that we do not add a random draw of artificial noise on these artificial NanoCarb truncated interferograms. The revised manuscript has been adapted to better reflect this idea (revised manuscript line 205-206): it is important to distinguish random perturbation of an artificial measurement with a noise model, and the accounting of the noise model in the Optimal Estimation framework.

Line 260: measure -> measurement

We changed the word (revised manuscript line 269).

Line 268: Acronym FOV already defined

We removed this redundant acronym definition (revised manuscript line 278).

Line 276: fasten -> speed up

We corrected this (revised manuscript line 287).

Line 368: “more disadvantageous” is too vague. Please use a more descriptive term.

We changed “more disadvantageous” to “lower” (revised manuscript line 385)

Lines 369-360: “more favourable” please use a more quantitative term (more forward scattering?)

Spaceborne aerosol instruments mostly sample the backscatter region of the aerosol phase function. Having large SZA helps to have a larger scattering angle range to sample the aerosol phase function, and it also helps to have this angle range closer to a 90° scattering angle, see Hasekamp et al. (2019). We adapted the text according to this explanation (revised manuscript line 386-387).

Line 448: of all atmospheric layers -> in all atmospheric layers

We corrected this mistake (revised manuscript line 466).

Line 498: on the optical path -> in the optical path

We corrected this mistake (revised manuscript line 516).

References

Lorente, A., Borsdorff, T., Butz, A., Hasekamp, O., aan de Brugh, J., Schneider, A., Wu, L., Hase, F., Kivi, R., Wunch, D., Pollard, D. F., Shiomi, K., Deutscher, N. M., Velazco, V. A., Roehl, C. M., Wennberg, P. O., Warneke, T., and Landgraf, J.: Methane retrieved from TROPOMI: improvement of the data product and validation of the first 2 years of measurements, Atmos. Meas. Tech., 14, 665–684, https://doi.org/10.5194/amt-14-665-2021, 2021.

Buchwitz, M., de Beek, R., Burrows, J. P., Bovensmann, H., Warneke, T., Notholt, J., Meirink, J. F., Goede, A. P. H., Bergamaschi, P., Körner, S., Heimann, M., and Schulz, A.: Atmospheric methane and carbon dioxide from SCIAMACHY satellite data: initial comparison with chemistry and transport models, Atmos. Chem. Phys., 5, 941–962, https://doi.org/10.5194/acp-5-941-2005, 2005.

Bovensmann, H., Buchwitz, M., Burrows, J. P., Reuter, M., Krings, T., Gerilowski, K., Schneising, O., Heymann, J., Tretner, A., and Erzinger, J.: A remote sensing technique for global monitoring of power plant CO2 emissions from space and related applications, Atmos. Meas. Tech., 3, 781–811, https://doi.org/10.5194/amt-3-781-2010, 2010.

Buchwitz, M., Reuter, M., Bovensmann, H., Pillai, D., Heymann, J., Schneising, O., Rozanov, V., Krings, T., Burrows, J. P., Boesch, H., Gerbig, C., Meijer, Y., and Löscher, A.: Carbon Monitoring Satellite (CarbonSat): assessment of atmospheric CO2 and CH4 retrieval errors by error parameterization, Atmos. Meas. Tech., 6, 3477–3500, https://doi.org/10.5194/amt-6-3477-2013, 2013.

Dubovik, O., et al. (2006), Application of spheroid models to account for aerosol particle nonsphericity in remote sensing of desert dust, J. Geophys. Res., 111, D11208, doi:10.1029/2005JD006619.

Hasekamp, O. P., Fu, G., Rusli, S. P., Wu, L., Di Noia, A., aan de Brugh, J., Landgraf, J., Martijn Smit, J., Rietjens, J. and van Amerongen, A.: Aerosol measurements by SPEXone on the NASA PACE mission: expected retrieval capabilities, J. Quant. Spectrosc. Radiat. Transf., 227, 170–184, doi:https://doi.org/10.1016/j.jqsrt.2019.02.006, 2019.