We are grateful to the referee for this feedback and comments. Our answers are given in red between the referee's text.

General comments

In this paper, the authors perform a quantitative study assessing the estimated performance of a hypothetical shortwave infrared (SWIR) CO_2 satellite instrument, considering the impact of a range of instrument design parameters: spectral resolution, signal-to-noise ratio (SNR), and spectral band selection. They achieve this by applying an optimal estimation retrieval algorithm to synthetic spectra generated assuming a wide range of fictitious instrument concepts, defined by varying each of these parameters, and a number of different observation scenarios. In addition, they apply the same performance assessment framework to some ready-defined future mission concepts – MicroCarb, CO2M, and NanoCarb – providing useful context for the hypothetical concept assessment study. This paper is timely given the wide interest in new methodologies for measuring CO_2 emissions, driven by the need to independently verify Paris Agreement objectives, which are likely to include satellite remote sensing as a significant component. There are some particularly interesting conclusions which should help inform the conception and design of future SWIR CO_2 satellite missions, namely the relative importance of improving SNR vs. resolving power in order to improve XCO_2 precision, the importance of including an O_2 absorption band in a mission concept to account for aerosol absorption, and the sensitivity of low SNR and resolving power instrument concepts to a priori mis-knowledge. I think that this paper is suitable for publication in Atmospheric Measurement Techniques, and have a few suggestions for improvements which will hopefully help strengthen the paper's conclusions further.

Specific comments

1. As mentioned above, the inclusion of ready-defined mission concepts provides useful context for the fictitiously varying CO2M (CVAR) concept study. I think that the paper overall would benefit by also considering an existing mission – OCO-2 for example – along with the ready-defined future missions already included. This would provide additional context for the CVAR study by comparing their performances alongside the current "state-of-the-art", whilst also demonstrating that the assumed observation scenarios and the forward and inverse setups produce realistic results when compared with real observational data;

This comment is identical to the second one made by referee #2, thus we reproduce below a common answer to both comments.

The point raised here by the referee is very relevant. In the revised manuscript, we have included OCO-2 results in Figures 3, 4, 5 and 6, and in Figures S4, S5, S7-10, S12-17, etc.

We also introduce how we model OCO-2 observations in a Subsection 2.1.

Line 148 - 154	**The Orbiting Carbon Observatory-2 (OCO-2) has been providing X_{CO_2} observations from SWIR measurements for close to a decade (Taylor et al., 2023). We include this instrument in order to assess how the synthetic results obtained here relate to results obtained from real data. We model OCO-2 observations relying on instrument functions and noise models provided in OCO-2 L1b**

	Science and Standard L2 products of Atmospheric Carbon Observation from Space algorithm version 8 (ACOS, O'Dell et al., 2018). These files are not from the latest v10 version of OCO-2 data, but the v8 to v10 major reprocessing did not include significant changes on instrument parameters (Taylor et al., 2023), so we assess that our input data are acceptable for this synthetic study.

We finally discuss the obtained XCO2 precision for OCO-2 against the one reported in OCO-2 Standard L2 product in Subsection 5.1:

Line 643 - 653	**First, OCO-2 shows a noise-only related precision of 0.32 ppm corresponding to DOFs for CO_2-related parameters of 1.97. The OCO-2 results that we obtain are overall consistent with ACOS results for soundings with close band-wise albedo values (see Supplementary Figure S6). Besides, land nadir OCO-2 X_{CO_2} retrievals show an overall 0.77 ppm standard deviation compared to the Total Carbon Column Observing Network (TCCON) validation reference (Taylor et al., 2023). This difference with respect to the theoretical uncertainty computed from Optimal Estimation stems from all the forward and inverse modelling errors that are not accounted for in the retrieval scheme. Thus, this illustrates that the results provided in this study are a lower bound to the actual precisions that these upcoming concepts will have.**

Supplementary Figure S6 (reproduced here in Figure R2.1) provides the XCO2 uncertainty due to noise (field 'xco2_uncert_noise' in L2StdND oco2 files) and CO2-related DOFs. For each albedo model considered in this study, we explored the year 2016 ACOS v8 L2 data downloaded for the work performed in Dogniaux et al. (2021) and averaged precision and DOFs results for soundings that match our albedo models within ±0.05. The error-bars range from the 10th to the 90th percentile of each distribution. Our OCO-2 results have been linearly interpolated to match the average OCO-2 Solar Zenith Angle in the considered ACOS data, and the error bar range from the minimum to the maximum values obtained in our synthetic survey.

We can notice that we obtain DOFs that are quite close to ACOS (a little higher because we fit less geophysical parameters in our state vector), and produce noise-related precision results that are close or lower compared to ACOS. Besides, case-to-case differences are also overall consistent between our results and ACOS (SOL and VEG cases show lower DOFs and higher uncertainties than DES cases). However, as many aspects differ in aerosol models, state vector composition, radiance and noise levels, etc, between the OCO-2 soundings that we average here and our 12 explored observational situations, we refrain from comparing further our results and ACOS', and assess that we find an overall agreement that seems acceptable given the differences between the synthetic evaluation performed here, and the ACOS inverse scheme.

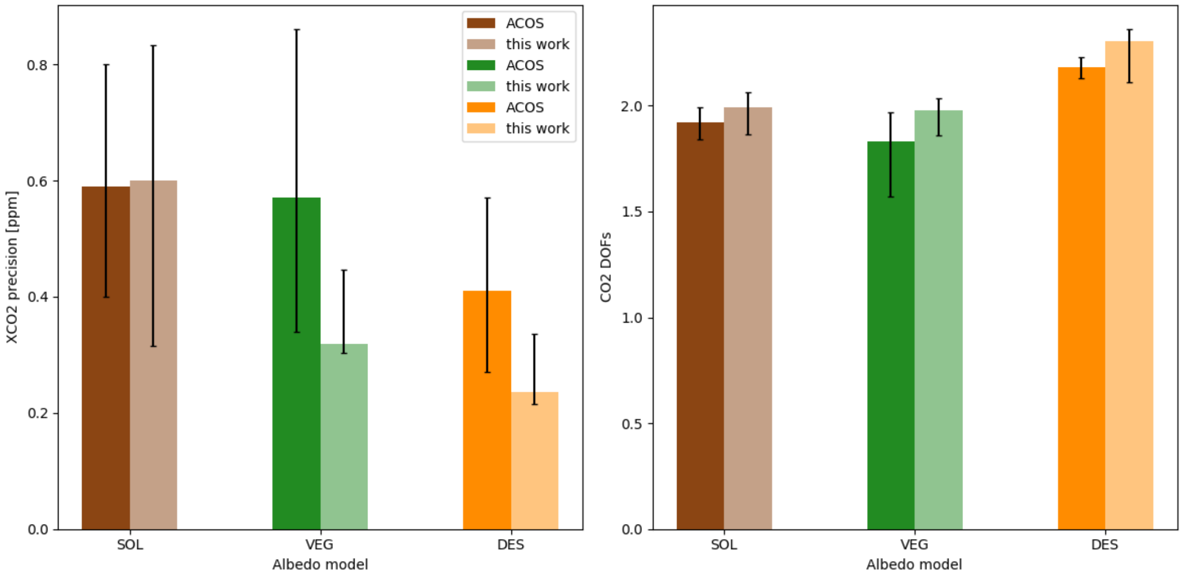

Figure R2.1. XCO2 uncertainty due to noise and CO2-related DOFs from ACOS v8 L2 data (full colors) and from our synthetic study (light colors). For each albedo model considered in this study, we explored the year 2016 ACOS v8 L2 data downloaded for the work performed in Dogniaux et al. (2021). We averaged the precision field 'xco2_uncert_noise' (in L2StdND oco2 files) and DOFs results for soundings that match our albedo models within ±0.05. The error-bars range from the 10th to the 90th percentile of each distribution. Our OCO-2 results have been linearly interpolated to match the average OCO-2 Solar Zenith Angle in the considered ACOS data for each albedo model, and the error bar range from the minimum to the maximum values obtained in our synthetic survey.

I think some further justification/clarification would be useful for the atmospheric situations used in the study. For example, are the temperature and water vapour profiles from the TGIR climatology representative of the current climate? Similarly, I think it would strengthen the conclusions if a realistic profile of CO_2 concentration were used instead of a constant profile, especially given that the study considers the vertical sensitivity of the instrument concepts;

The thermodynamic (temperature, water vapor) atmospheric profile used in this work and taken from TIGR is identical to the one used for the initial NanoCarb L2 performance assessment in Dogniaux et al. (2022). The TIGR profiles are appropriate to describe the current climate in the context of spaceborne greenhouse gas monitoring. For example, they are used to build the training dataset of the neural networks used to retrieve mid-tropospheric columns CO2 and CH4 from IASI thermal infrared observations (Crevoisier et al, 2009a,b). These are included in the CAMS greenhouse gas analysis running from 2003 to 2020 (Agustí-Panareda et al., 2023).

Regarding realistic CO2 concentration profiles, we agree with the referee that the study could have included various vertical CO2 profiles, especially with and without anthropogenic enhancement of CO2 concentration in the lower layers. However, as this study is dedicated on evaluating the impact of instrument design parameters on XCO2 retrieval performance, and as it includes NanoCarb which is still in early stages of L2 performance evaluations, we decided to stick to the simple vertically constant CO2 profile for with which we performed the initial initial NanoCarb L2 performance assessment in Dogniaux et al. (2022). Clearly stating further steps of including more realistic CO2 profiles should be included in the conclusions, and it was not in the original manuscript. We did so in the revised version.

Lines 842 - 849	**Given its scope focused on exploring the impact of concept design parameters on X_{CO_2} retrieval performance, this study could not include all the dimensions of a comprehensive mission performance assessment. For example, the accuracy of X_{CO_2} retrieval has not been studied, and a greater variability of possible atmospheric conditions (different aerosol types, layers, contents, etc., different thermodynamical profiles and CO_2 concentration vertical profiles) could be encompassed, as is usually performed in comprehensive Observing System Simulation Experiment. Besides, this work could not also obviously explore the whole extent of possible design parameters (e.g. band-wise variations of spectral sampling ratios, varying wavelength interval for spectral bands, combination of different instruments, etc.) that impact X_{CO_2} retrieval performance, and its implication for anthropogenic plume imaging. These limitations warrant further studies.**

2. Whilst this study does not explicitly consider spatial resolution, I think it would be worth commenting on the implications of some of the conclusions on the feasibility of CO_2 imaging concepts, which trade off reduced SNR and/or resolving power in favour of high spatial resolution in order to be able to quantify emissions from ever-smaller plumes of CO_2 emitted by point sources. To pick one example from the results in Section 4, Figure 9 shows how concepts with low resolving power would be quite sensitive to a priori mis-knowledge of aerosol optical depths, depending on the spectral band selected and whether an O_2 absorption band is incorporated into the instrument concept.

We agree with the referee that such points are indeed interesting, and were discussed in Sect. 4.2.3 of the original manuscript. They could have been included in the conclusions as well. We adjusted the conclusions in the revised manuscript to reflect this discussion point as well.

Lines 805-809	**These results highlight how the precise (and accurate to some extent) retrieval of X_{CO_2} from SWIR observations relies on the amount of information carried by these observations. Reducing spectral resolution and/or the number of spectral bands to improve spatial resolution increases errors that may be removed when imaging local relative enhancements of X_{CO_2}. However, they may still hamper absolute X_{CO_2} retrievals in plume-free scenes, thus potentially making these observations hardly useful for anything else than anthropogenic emission imaging.**

Further investigation looking at the ability of SWIR hyperspectral imagers to image emissions plumes and infer CO_2 emission rates, using the performance assessment framework described here across a range of instrument parameters including spatial resolution would be very interesting, but I appreciate that would be beyond the scope of this study.

We agree with the referee that including a plume-imaging angle to this study would have been a further interesting angle, but it would indeed have extended this work far beyond its intended scope. However, these further steps are relevant to include as perspective in the conclusions, that were not complete in the original manuscript. We extended them in the revised manuscript.

Lines 842 - 849	**Given its scope focused on exploring the impact of concept design parameters on X_{CO_2} retrieval performance, this study could not include all the dimensions of a comprehensive mission performance assessment. For example, the accuracy of X_{CO_2} retrieval has not been studied, and a greater variability of possible atmospheric conditions (different aerosol types, layers, contents, etc., different thermodynamical profiles and CO_2 concentration vertical profiles) could be encompassed, as is usually performed in comprehensive Observing System Simulation Experiment. Besides, this work could not also obviously explore the whole extent of possible design parameters (e.g. band-wise variations of spectral sampling ratios, varying wavelength interval for spectral bands, combination of different instruments, etc.) that impact X_{CO_2} retrieval performance, and its implication for anthropogenic plume imaging. These limitations warrant further studies.**

Technical corrections

Line 232: replace “Its” with “It is”;

There is no spelling mistake here. We are referring to the a posteriori covariance matrix *of* the state vector.

Line 243: replace “degree” with “degrees”;

We fixed this mistake, thank you.

Line 372: please provide a reference for the “usual” hypothesis that aerosol properties are fixed across spectral bands;

For example, ACOS uses fixed aerosol optical properties, we added a reference.

Line 513	This result is made possible by the usual **(see OCO-2 processing algorithm ACOS for example, O’Dell et al., 2018)** hypothesis of fixed aerosol optical properties, which enables sharing optical path information across spectral bands.

Line 493: replace “MC123” with “MC234”.

We fixed the mistake, thank you very much.

References

Crevoisier, C., Nobileau, D., Fiore, A. M., Armante, R., Chédin, A., and Scott, N. A.: Tropospheric methane in the tropics – first year from IASI hyperspectral infrared observations, Atmos. Chem. Phys., 9, 6337–6350, https://doi.org/10.5194/acp-9-6337-2009, 2009.

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