

Comment on amt-2021-224

Anonymous Referee #3

Referee comment on "The Space Carbon Observatory (SCARBO) concept: assessment of X_{CO_2} and X_{CH_4} retrieval performance" by Matthieu Dogniaux et al., Atmos. Meas. Tech. Discuss., <https://doi.org/10.5194/amt-2021-224-RC2>, 2022

General comments

The authors present a simulation-based assessment of CO₂ and CH₄ column retrievals for a novel nanosatellite constellation concept called SCARBO. The constellation would involve 20+ small satellites each carrying a Fabry-Perot interferometer (NanoCarb) for CH₄ and CO₂ and a multi-angle polarimeter (SPEXone) for aerosols. The authors present extensive error analysis with a focus on aerosol-related retrieval errors and the ability of the SPEXone auxiliary instrument to mitigate those errors. They use for this purpose standard OSSE methods including Rodgers (2000) optimal estimation techniques, and show that their NanoCarb-SPEXone instrument design should be capable of delivering high-precision XCO₂ and XCH₄ retrievals. The paper is well written and a good fit for AMT. I recommend acceptance for publication subject to the following comments and questions.

Specific comments

- L. 36: Please clarify what is meant by "on small areas".
- L. 40: Can you provide a reference for 2x2 km² resolution being fine enough to resolve point sources? Of what magnitude? TROPOMI can resolve only extreme methane point sources at similar (5.5x7 km²) resolution (e.g., Pandey et al., 2019).
- L. 41: Extensive recent work has shown that plumes observed by imaging spectrometers do not look Gaussian. For example Cusworth et al. (2021) use an integrated mass enhancement method to quantify CO₂ emissions from individual power plants observed by the PRISMA satellite instrument, and the TROPOMI team and others have used a variety of methods to quantify CH₄ plume emission rates (eg, Pandey et al., 2019) at km-scale resolution, but Gaussian plume modeling seems poorly suited to the problem.
- L. 66: "requirements for operational top-down monitoring of anthropogenic GHG emissions" – What are these requirements and what does "operational" CO₂/CH₄ monitoring mean?
- L. 79: "geophysical parameters necessary to retrieve XCO₂ and XCH₄" – can you say

what these parameters are or point to them in the text?

- L. 80-81: "2.3 x 2.3 km² spatial resolution, enabling to detect emission plumes from megacities and hotspots (e.g. > 10 Mt CO₂ yr⁻¹ power plants)" – You seem to use "hotspot" and "point source" interchangeably. Megacities are examples of hotspots and power plants examples of point sources. For point sources, where does the 10 Mt/y threshold come from?
- L. 86: Please describe CO₂M.
- L. 95: "scattering error-critical atmospheric and observational parameters" – Are these the "geophysical parameters" you mentioned before? It would be helpful to list these out somewhere in the introduction if not too lengthy or point to them in the text.
- Ray Nassar and Dan Cusworth's works about satellite monitoring of CO₂ emissions from power plants should be cited somewhere. Same for TROPOMI methane plume papers (Pandey et al. and others) since there has been a lot of recent work on these topics.
- Can you explain why SCARBO uses an FP rather than grating? Is it about financial cost, instrument size/weight, something else? Also please cite other instruments/concepts that use FP - eg Jervis et al. (2021).
- L. 165: Not clear what "0.003" means, is it an error (1 or 2 sigma)?
- L. 173: What is an "emission clump"? This terminology is non-standard.
- L. 234: Are you referring to the instrument temperature?
- Table 2: How conservative is the 4 hPa (0.4%) error for surface pressure? It seems quite small.
- L. 271: I would suggest pointing to the appendix here because I initially wondered if the "combination" of single-pixel measurements was through averaging or something more.
- L. 289-290: "Errors arising from the interpolation have been assessed and are negligible (not shown)" – What is the magnitude of the error?
- L. 297-300: CH₄ falls off rapidly above the troposphere, so why use a uniform vertical profile? Is the impact of this unrealistic profile on the retrieval small enough to be neglected?
- Fig. 7: Is the much lower DOFs for FOD in the with-SPEX scenario merely due to using a much lower prior error for FOD compared to no-SPEX?
- L. 424-425: Do the albedo DOFs actually increase? They seem to be equal to 1 in both scenarios.
- L. 437-439: This seems odd since the albedo DOFs look to be almost or exactly 1.0.
- Fig. 8: It's not clear how you compute column averaging kernels when your state vector doesn't include a vertical column but rather a single scaling factor for each gas. If the state vector included CH₄ and CO₂ at different vertical levels then you would obtain $A = \hat{dx}/dx$ giving the AK for each vertical layer. How do you get column averaging kernels when optimizing just a scaling factor?
- Fig. 8: Also the column averaging kernels look quite smooth, what is the vertical resolution here?
- Several plots show regions where retrievals did not converge satisfactorily but I cannot find in the manuscript what method you use for the optimization. Is it Newton, Levenberg-Marquardt, something else?
- Fig. 13: Why is there striping in this figure? Because of the loss of precision with increasing transversal position?

Technical corrections

- L. 39: "large-swath"
- L. 51: "best fits"

- L. 151: "radiance spectrum"
- L. 164: "at 50 spectral band" seems like a typo?
- L. 178: "compromises"
- L. 276: "fasten" doesn't seem like the right word here. Do you mean "speed up" or something similar?
- L. 422: "in these situations" typo
- L. 612: "then" typo
- L. 637: "mentioned" typo
- Consider changing "scattering error-critical" to "scattering-error-critical" everywhere. If I understand correctly it's meant to be a compound adjective and might be clearer with two -'s.

References

Pandey, S., Gautam, R., Houweling, S., van der Gon, H. D., Sadavarte, P., Borsdorff, T., Hasekamp, O., Landgraf, J., Tol, P., van Kempen, T., Hoogeveen, R., van Hees, R., Hamburg, S. P., Maasackers, J. D., and Aben, I.: Satellite observations reveal extreme methane leakage from a natural gas well blowout, *P. Natl. Acad. Sci. USA*, 116, 26376–26381, <https://doi.org/10.1073/pnas.1908712116>, 2019.

D.H. Cusworth, R.M. Duren, A.K. Thorpe, M.L. Eastwood, R.O. Green, P.E. Dennison, C. Frankenberg, J.W. Heckler, G.P. Asner, C.E. Miller: Quantifying global power plant carbon dioxide emissions with imaging spectroscopy, *AGU Adv.*, 2 (2) (2021), <https://agupubs.onlinelibrary.wiley.com/doi/abs/10.1029/2020AV000350>

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