

Review of the manuscript

“Greenhouse Gas Retrievals for the CO2M mission using the FOCAL method: First Performance Estimates”

Comprehension

The manuscript presents an assessment of the FOCAL-CO2M retrieval algorithm’s capabilities in quantifying CO2 and CH4 enhancements from space. The study communicates its limitations, is concise and articulated with good clarity throughout most parts. However, there are some aspects that should be improved.

General comments

The SCIATRAN setup does not fully represent the complex and varied conditions of the actual atmosphere. While useful for controlled testing and isolating error analysis it raises questions about the algorithm's performance in real-world scenarios, especially under unpredictable atmospheric conditions. I am concerned that the budget, especially in terms of the mean noise error, could be depleted if we incorporate additional error sources.

I'd like to see a more in-depth exploration of the limitations. To examine meteorology's influence, one could alter variables such as humidity and temperature profiles in SCIATRAN, aligning them with their respective uncertainties.

Are there alternative reference spectra for CO2M that employ a more sophisticated instrument model? Assuming a perfect instrument model presents a limitation.

It might be beneficial to create a distinct section for the post-processing phase, as it involves more than just basic threshold filtering, unlike the pre-processing step.

Does SCIATRAN's treatment of aerosols or the aerosol input include assumptions or simplifications that are advantageous to the FOCAL setup? Additional details would aid in interpreting the results, especially regarding Figures 13 and 14.

What is the consequence of an imperfect cloud screening during the pre-processing phase? In reality, there may be subpixel residual clouds (smaller than 400 x 400 m²) that go undetected.

I can't find a discussion how a priori estimates affect the error margins in the FOCAL retrieval. Are the priors used in the FOCAL fit, other than the target quantities, equivalent to their true values?

Once real data becomes available in 2026, what will the post-processing strategy entail? Will parameters be computed on a monthly, quarterly, or yearly basis? Could you provide insights into any existing plans or considerations on this matter?

What is the rationale behind selecting a 5-layer profile fit? What kind of analysis lead to this choice. Could you provide information on the errors associated with each of these layers?

To what extent is the 400 ppm a priori profile scaled in each atmospheric layer, and does the lowest layer contain the majority of the enhancement? Additionally, what advantages does fitting five layers offer, particularly in the study of anthropogenic emissions, when it's known that most emissions are concentrated in the lower levels?

A more fundamental error analysis such as information on the reduction in uncertainty from priori to the a posteriori state would be appreciated.

Is the term "full physics" (FP) appropriate when the forward model in FOCAL is notably simpler than models like SCIATRAN and relies on approximations and parameterizations for various physical aspects? Additionally, considering that bias correction in the post-processing step is primarily necessary due to the limitations of the forward model, the use of the term "full physics" may be open to question. Nevertheless, I understand that it's a recognized term within the scientific community.

Specific comments

5: XCO₂ and XCH₄, but no XNO₂?

15: Any reason for choosing 2015?

15: Maybe "caused" instead of "due"?

19-20: Does this imply that the mission requirements could potentially be met without the MAP instrument?

26: Is "However, ..." applicable here? Consider rephrasing.

41-44: In principle, would a single satellite be sufficient to fulfill the mission? Is the MVS considered operational with just one CO₂M satellite instrument in orbit?

125: Is the thickness of the single scattering layer dependent on the vertical atmospheric grid utilized in the forward model? Could you please specify the thickness of the layer in the context of this study?

143-144: Does this require an updated FOCAL version which includes MAP instrument data?

145: Why is a single Signal-to-Noise Ratio (SNR) threshold established when the requirement on line 64 specifies different reference albedos for various channels? Additionally, is the average SNR within each band used, or is the SNR specified at a particular channel position taken into account?

166: Does this paragraph refer to the second filtering step?

170: This should be mentioned earlier, maybe already around line 164 or 166.

175-179: Consider to improve clarity.

195: Consider providing additional details on how the forward model error differs when applied to real data compared to theoretical or simulated data.

241-243: Consider to rephrase, in particularly "It should be noted ..." as is not very clear to me.

242-243: The standard deviation after application of filters is 0.2 and 0.5 ppm. Confirm that the latter represents the mean noise error? Also confirm that the smaller mean difference value suggests that the high-pass standard deviation is dominated by (random) noise?

263: Please confirm whether the 0.5 ppm standard deviation, observed after applying filters, represents the mean noise error. Also, does the smaller mean difference value indicate that the high-pass standard deviation is predominantly influenced by random noise?

Fig. 8: Do you have an estimate of the extent to which an inaccurate prior (a priori that doesn't represent the truth) might impact the fitting of CH₄ on the various levels?

278-280: Is there a specific reason why a recalculation of the post-processing database for the entire year 2015 is not being conducted? Is it due to cost constraints, technical limitations, or other factors?

Fig. 9: Any idea, what causes the positive or negative biases in some areas?