

Interactive comment on “Information Content Analysis: The Potential for Methane Isotopologue Retrieval from GOSAT-2” by Edward Malina et al.

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General comments:

This paper explores the possibility to retrieve the ratio between the two main methane isotopologues from a future GOSAT-2 instrument. In itself, this is a very interesting study, because, if possible, satellite data could be used in the future to discriminate between natural and anthropogenic sources of methane on a global scale. However, the results and conclusions of this study depend heavily on many assumptions, some of which are not quantitatively investigated.

Main points:

- Impact of precision of current methane retrievals, authors assume here 6ppbv from

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Yoshida et al. (2011) which is an average and does not include forward model or instrument errors. However, an estimate of the methane precision from TCCON validation is around 15 ppbv (see e.g. Schepers et al. 2012 and Parker et al. 2015). This impact should be quantified or at least discussed.

- The authors experiment with different a priori covariance matrices, because no suitable one is known. It seems in this case Philips-Tikhonov regularization is more suitable than optimal estimation. Could the authors comment on that?
- The error analysis could be extended by perturbing the a priori $^{13}\text{CH}_4$ profile with the assumed a priori errors and comparing the retrieved $^{13}\text{CH}_4$ against the truth. Would this be the same as the derived precisions?

Specific comments:

- Abstract, page 1, line 22: Rephrase the following sentence for clarity: "Large unconstrained 'a priori' covariance matrices are required ... retrieval errors." Suggestion: "We find that large unconstrained covariance matrices are required in order to achieve sufficient information content, while the solar inclination angle has limited impact on the information content." The authors should avoid "retrieval errors" in this sentence, because that could suggest the solar zenith angle does not have an impact on the forward model retrieval error which is certainly incorrect.
- Introduction, page 2, line 19: This sentence seems incorrect: "Plant based photosynthesis enzymes discriminate against carbon dioxide during uptake..." Should it be: "Plant based photosynthesis enzymes discriminate against ^{13}C during carbon dioxide uptake..."?
- In general, the introduction should not contain formulas and derivations. I suggest to move Eq. (1) to a subsection where the requirements on the errors are derived. At the same time, the derivation of the minimum precision of 0.25 ppbv on the $^{13}\text{CH}_4$ retrievals should be made explicitly (e.g. assumed values, error propagation), since

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this is of such importance to the rest of the paper. In particular, the assumption of a precision of 6ppbv for methane retrievals from Yoshida et al. (2011) is too optimistic, since that is an average and errors up to 15 ppbv can occur. Also, the systematic error is not included in his work or in Yoshida et al. (2011) as stated in the paper, at least a discussion about the impact of the systematic error on the conclusion/results should be given.

- Introduction, page 3, 7: Rephrase/shorten long sentence: "Some measurements from balloon soundings ...to the scientific community"

- page 4, section 2.1: Mention here that the RTM does not include scattering.

- page 8, section 4.1: First the authors attempt to determine the variance in $^{13}\text{CH}_4$ by taking the maximum range of observed $\delta^{13}\text{C}$, this approach is a rough approximation at best. From that they derive $(3\%)^2$, but nevertheless take $(10\%)^2 - (100\%)^2$ in their study. This seems random. Please reformulate or justify better why $(10\%)^2 - (100\%)^2$ is reasonable. Also, it not explained in which cases a diagonal covariance matrix is more likely and in which cases an off-diagonal one.

- page 12/13, Figure 2 and 3: The color plots are not clear, please use other color scale or representation.

- page 17/18: It is mentioned that the combined band 2 and band 3 retrieval significantly increases computation time compared to band 2 or band 3 retrieval. Stating the CPU time for all cases would be useful to make that point.

- I am missing a discussion on how methane isotopologue retrievals, if successful, could be validated. Please include a discussion on possible validation strategies, e.g. using NOAA measurements.

Technical corrections:

- "plant-based" or " plant based", use one consistently throughout the text

- page 7, line 13: definite -> define

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- page 11: severally - > severely

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