The document lists the comments (written in small font) and our responses to **Reviewer #3**.

General comments:

This work study the performance of methane retrievals deduced by non-linear and linear methodologies from data obtained by airborne HySpex observations. Methods are applied in several spectral ranges in the SWIR, where methane absorption features are located. Within non-linear methods we find the Nonlinear Least Squares, the Separable Least Squares and the Generalized Least Squares and within the linear methods we find the Linear Least Squares, the Matched Filter, the Single Value Decomposition, and the Spectral Signature Detection. While non-linear methods are more time-consuming and get a best estimate, linear methods are faster and can be more suitable for real-time onboard measurements. This study is helpful in order to understand the limitations of HySpex in detecting methane emissions with several methods. A good understanding of these limitations can establish a strategy to get optimal methane concentration maps on real time and after the flight. The results introduced in this work are of remarkable interest and a great amount of work must have been involved. Methane retrieval and methane retrieval error figures are very self-explanatory and visual. Moreover, there are a great diversity of methodologies that have been explored, which is a decision that helps to determine more thoroughly the limitations of Hyspex for methane mapping. I find high value in the objectives of this paper and the figures, but I see strong shortcomings that make me decide to accept this paper with 'major revisions'.

Thank you for your thoughtful critique and feedback on our manuscript.

Major suggestions:

I find that the manuscript is really hard to read because several reasons:

- *It is long. Shortening the manuscript could make the text more accesible for readers. I would suggest the authors to optimize the content to the truly important data.*
- *There are a lot of information that could be removed without affecting to the quality of the manuscript. This information is often irrelevant and difficults the understanding of the essential the points of the manuscript.*
- *English can improve. Some expressions doesn't sound natural and there are large sentences that are difficult to read.*
- *The work presents a complexity that is not well developed. I suggest a more plain explanation of certain points. However, if the authors want to explain them with a high level of complexity, it should be better explained.*
- *Re-check on citing.*

We fully agree with your comments regarding the length of the manuscript and that it is necessary to shorten it in order to make it more accessible to readers. In response to your suggestions, we have revised the manuscript, trying to focus on the most important data. Please find all changes in the minor_changes.pdf file.

We have also improved the English language in the manuscript. Expressions that did not sound natural were revised and we broke down the large, complex sentences into smaller, simpler ones to enhance readability.

Moreover, we simplified explanations where possible to enhance overall clarity. For sections where a higher level of complexity is required, we have taken care to provide more detailed and thorough explanations.

The citing styles as well as the order of sources in the reference list were revised.

Minor suggestions:

L20 - with the passage of time the word 'latest' loses meaning.

The word 'latest' was removed.

L22 - it seems redundant: 1 decade and approximately 9 years. I'd try to unify these 2 concepts

The sentence was unified, removing redundant information.

L25 - concentration instead of content. I think is more appropiate.

DONE

L25-26: I think this sentence can be removed: 'Observations indicate an increasing trend in atmospheric CH4 content since 2007, the cause of which is still subject to scientific debate'

We removed the question. Is the sentence not true anymore? Is the reason for the global increase found in unaccounted anthropogenic emissions?

L29: to foster understanding OF the global methane cycle

DONE

L33: method of choice doesn't sound natural. Maybe... 'typically used methods'

Reformulated the sentence.

L43: point sources (Duren, 2019, Nature) instead of point-like sources

DONE

L43: just 'This limitation is due...'

DONE

L56-58: I don't think references are well written here. Besides, to cite EnMAP mission it is better to cite Guanter, 2015. And probably also PRISMA mission should be cited with another reference.

Added Guanter et al. (2015) and Cogliati et al. (2021) references.

L68-69. There is a specification for spectral resolution (¿1nm), but there isn't for spatial resolution.

In the context of CH4 we consider $<100\,\mathrm{m}$ as high resolution.

L70-72. Retrievals are the results. Maybe you mean methods to acquire the trace gas retrievals.

DONE

L77. Concentration enhancements*

DONE

L89 - 'often PRESENT sufficient accuracy'.

DONE

L89 - Every nonlinear method are iterative?

Affirmative, at least in this study.

L89 - I would reformulate this sentence. Sufficient accuracy seems a good enough accuracy. Then, why nonlinear methods?

Reformulated "... but often lack accuracy, ..."

L90 - I don't understand this: 'The retrieval methods are tailored to address the issue of albedo-related biases, which arises due to correlations with broad-band absorption features resulting from the instrument's low spectral resolution.' - I would try a more plain explanation.

This sentence was removed from the first paragraph in the Methodology section, as it can lead to confusion.

Figure1-caption - It is difficult to distinguish between the dashed and solid lines. I would try to improve the figure in this aspect. What is 'a' in 'kt/a'? Besides, I think that there is some irrelevant information here for the study (QGIS, flight overpass time-stamps...)

The 'kt/a' stands for 'kiloton per annum'.

L96 - conduct or evaluate?

We removed the sentence to shorten the manuscript.

L99 . I think the comma ',' can be removed.

We removed the sentence to shorten the manuscript.

L100 - I think this is not the best way to cite.

Please provide an example how we can improve the citation style in this case.

L106 - What does observation mean? It is not clear. Is important to know that?

We removed the sentence to shorten the manuscript.

L106 - '320 across-track detector pixels': this is inherent to the Hyspex SWIR spectrometer measurement.

We removed the sentence to shorten the manuscript.

Figure 2-caption - detectors, not pixels. Pixel position?

Changed detector pixels to detectors.

Figure 2 - there is a lot to improve in this figure. There is overlapping of numbers, the font from labels makes it difficult to read, the mentioned 'center' is at the left side of the figure, there is two horizontal axis in b (not necessary).

We revised the figure according to the suggestions.

L111 - No need for specifying the equivalence in wavenumbers units.

It is at least needed for the spectral range because we later name the retrieval intervals 4K and 6K, which relates to wavenumbers.

L115 - not pixel, just detector

DONE

L126 - in general?

Removed "in general".

L129 - molecular m? not clear

Clarified this sentence by saying what m stands for.

L130 - 'Atmosph'erique'

DONE

L141 - not pixels

Detectors

L145-146 - I'd write 'The highest vertical resolution is found in those layers below...'

DONE

Figure3-caption - I don't understand 'mid-infrareddle panel'

Corrected - it should be "mid-infrared".

L163 - the new Python version of BIRRA that is used is based on...

Corrected.

L170 - 'The transmission by aerosols for different Ångstrom exponents according to is depicted in Fig. 3 (center)' - Incomplete sentence?

We removed this figure as it is not relevant for the retrieval setups (all non-scattering retrievals).

L174 - What is 'j'?

An integer.

2.3.1. - Here NLS, SLS, and GLS are introduced. But in L159 only NLS and SLS are mentioned.

The GLS method is not part of the classical/original BIRRA. We added this note to the sentence above.

L185 - Function 'L' is not defined.

Removed this function designator as it is not needed.

L188 - You say 'separable least squares solver' when you already defined SLS.

DONE

L198-L200 - How do you get C? Why the location of the point source and wind data must be known?

In order to not contaminate C with real methane enhancements as it should only account for correlations from the albedo below background atmospheric concentrations (and sensor noise).

Figure4-caption - Panel show $S^{-}1$, but the caption says: 'backgorund covariance matrix', i.e., C.

DONE *L209 - Jacobian matrix*

DONE

Eq 12 and 13 I don't understand where they come from

Clarified that they were generated by the LLS fit.

L263 - likelihood

DONE

L269 - per pixel doesn't seem possible (maybe per column)

It should say per measurement.

L284 - USVt is not explained

We added the corresponding explanations.

Figure 5 - Fontsize could improve.

Increased the figure width.

L329 - Figure 8b shows

Figure 8 shows the multi-window fits for scene 09 and 11.

Figure8-caption - here you shouldn't write 'Best results are acquired for GLS setup'.

Removed this phrase.

I don't think the retrieval from averaged data should be showed. They are not so important and can simply be commented in the text.

The binning of HySpex pixels is performed to reduce noise. Non averaged data is shown in Fig. 9.

L341 - but the and as?

We rewrote parts of this paragraph.

4K and 6K retrievals are shown in some methods and not shown in others. Why so?

As mentioned in the text, the quality of the linear methods in discriminating the plume from background pixels varies for the spectral intervals (see Table 2 and 3). An example is given in Fig. 12. Figures were chosen to highlight all examined aspects and to be comparable across the different algorithms. However, to show all maps would overload the manuscript (see Fig. 17) and not comply with your request to focus on the most important aspects.

L344 - to identify

DONE

L345 - the lowest

DONE

L347-349 - This should not be in this section

The paragraph was rephrased and shifted to Sec. 3.3

With best regards,

Philipp Hochstaffl and co-authors