

Atmos. Meas. Tech. Discuss., referee comment RC2  
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## **Comment on amt-2022-271**

Anonymous Referee #2

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Referee comment on "Methane retrievals from airborne HySpex observations in the shortwave infrared" by Philipp Hochstaffl et al., Atmos. Meas. Tech. Discuss., <https://doi.org/10.5194/amt-2022-271-RC2>, 2023

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The manuscript of Hochstaffl et al. present an intercomparison of different CH<sub>4</sub> retrieval approaches for airborne hyperspectral measurements during an overflight of the HySpex instrument over a known CH<sub>4</sub> emission source in Poland. Gives a short overview over the different techniques and present the retrieved maps for specific scene which are then discussed. CH<sub>4</sub> retrievals from hyperspectral measurements is a quickly evolving field and there is merit in intercomparing different retrieval methods based on real, measured spectra.

The manuscript is in principle relevant and suitable for Atmos. Meas. Tech. but there are several shortcoming that limit its value. The manuscript is somewhat dominated by the method section while the discussion could be more detailed. In this section, a lot of material is squeezed in which makes it hard to read and I am not sure how much the reader gets out of it, especially since variables are not always well defined or used in consistent manner. The presented analysis is purely qualitative, very brief and limited to a single scene. The lack of ground truthing means that it is not possible to tell which method is best and thus the study is limited to comparisons against each other which then should be done more rigorously.

My main comments are:

- Several figures need to be improved and labelled consistently (see detailed comments below). Especially the map of retrieved methane should be shown for the same number of cross and along track pixels so that results can be compared. Also, give results in CH<sub>4</sub> for all methods and not as scaling factors.

- The analysis should be more quantitative. In the discussion, you state that the MF method can be used as reference, so let's also do this. You can apply simple methods to identify a plume (eg thresholding) which will then allow you to do contrast inferred plume shapes. Also, I would like to see correlation plots of CH<sub>4</sub> enhancements between different methods for example for pixels within the plume (eg defined according to the MF method).
- Also, check all equations and ensure that all variables are fully defined and used consistently. For example, beta is used to describe 3 different variables.

Specific comments:

Page 2, line 25: important greenhouse gas -> important anthropogenic greenhouse gas

Page 2 line 32: fossile -> fossil

Page 2 line 38: besides satellites, there are the global in-situ surface networks

Page 2, line 55: smaller emitting area. This does not refer to IR so it is reflecting rather than emitting.

Page 3, line 61: add reference for CHIME, eg. Rast et al., IEEE, 2021

Page 3, lines 60-63: add MethaneSat for completeness

Page 3, line 75: slowly varying part is also from scattering

Page 3, line 81: This study compares various retrieval schemes .... -> please add the the goal of study

Page 4, section 2.1: I suggest to add a table with the key instrument parameters for the HySpex instrument

Page 4, line 96: in detail in (IMF) -> missing reference ?

Page 4, figure 1b: The fonts on the figure are too small and can not be read in a hardcopy.

Page 4, line 97: in the following chapters -> in the following sections

Page 4, line 101: ...and if so how accurate... -> I don't think that this is addressed in this manuscript ?

Page 4, line 108: seen in Image 1a, -> Figure 1a

Page 5, line 109: wind data for the USCB area -> This needs to be defined separately to the definition in the abstract. However, I don't see the need to introduce this acronym as it is not used anywhere else.

Page 5, line 119: 967–2496 nm (4005–10338 $\text{cm}^{-1}$ ). Throughout the manuscript at some places wavelength and at other wavenumber is used. Since wavenumber is primarily used, I suggest to use consistently wavenumber throughout the manuscript and give everything in wavenumber and not wavelength.

Page 6, figure 2: a) please make fonts larger and lines thicker. In a hardcopy this figure is hard to read. Also, can you give a reference for the albedo data

b) Use either 'wavenumber' or 'wavenumbers' for the x-axis. Use either round or square brackets to give units. Label the y-axis with the shown parameter (not only units).

Remove the 2 extra digits on the x-axis labels.

Caption: CH4 -> CH<sub>4</sub>

I don't think that adding the vertical lines to indicate spectral pixels adds value and neither does overplotting all spectra into the figure. I suggest to remove the lines and show a mean spectrum and a standard deviation. You could add the one spectrum with the outlier.

Page 6, line 131, see absorption from methane's 2v3 band around  $6000\text{cm}^{-1}$  -> where do I see this. Can you label this in the figure ?

Page 7, line 136: under clear sky conditions (cloud free) -> also scattering free in general

Page 7, eq. 1: ds needs to be removed in the sum of the first equation. define all variables including tau, nu, p, T, s and m

Page 7, lines 145-150: I don't see how the extract on aerosol optical properties is relevant. I suggest to remove this and simply refer to a textbook. The use of wavenumber of wavelength in this section is unnecessary.  $K_{\text{aer}}$ : give units.

Page 7, line 153: composed by pure -> composed of pure

Page 7, lines 154-155: define z, also I don't see the need to use  $z_{\text{mol}}$ ,  $z_{\text{sc}}$  instead of simply z.

Page 7, eq.5, define  $\tau_{\text{bg}}$  and  $\tau_{\text{pl}}$ . What is alpha here ?

Page 8, line 161: The CH4 background as well as the CO2 initial guesses -> The CH4 background profile as well as the CO2 initial guess profiles

Page 8, figure 3: BoA, TOA -> BOA, TOA

At least for CO2 and CH4, a mixing ratio profile would be more meaningful

Page 9, line 186: is SRF different to ISRF ? This are examples for the many acronyms introduce but not used in the manuscript.

Page 10, figure 4: remove unnecessary digits on x label. Thicker lines in panel b would be helpful

Page 10, line 194: Jacobian matrix -> define Jacobian

Page 11, Figure 5: give the definition of alpha and r in caption . Remove unnecessary digits

Page 11, line 202: the converged spectrum-> the converged spectrum I

Page 11, line 206: from the diagonal elements -> from the square root of the diagonal elements

Page 12: beta is already used as Angstrom coefficient on page 7. Please use another variable name here.

Page 12, eq. 11: define meaning of y hat.

Page 13, define alpha tilde is.

Page 13, line 231: What is a scene average scaling factor. I don't believe that the given references apply such a scene average scaling factor.

Page 13, eq. 12: usually the CH<sub>4</sub> to CO<sub>2</sub> ratio is multiplied by a 'known' CO<sub>2</sub> profile. If you use the CO<sub>2</sub> scaling factor directly as a correction for light path modifications then you assume that the CO<sub>2</sub> profile is perfect and that alpha is 1 in absence of scattering.

Page 14, line 256: the (saturated, see... -> the saturated (see...

Page 14: eq 14: what is the meaning of the up and down arrows in the optical depth. Why is there a beta factor in the Taylor expansion why is not in the exp function. Also, how is beta defined. Note that beta is used already twice with other meanings.

Page 14, lines 261-261: M and N is now used in capital but was used before in small letters m and n (page 11)

Page 14, line 269, condition number of 885 -> Please put this in some context. Which condition number is sufficient and which not.

Page 15, eq. 16: isn't  $(J - \mu)$  the target spectrum  $t$ . If so, then use  $t$  in equation.

P15, l284: here  $\tau$  and  $\beta$  is defined which would already be needed with eq. 14

P 15, eq. 18: is  $t$  here now the Jacobian. Jacobian so far is called  $J$  while  $t$  has been used as target spectrum in section 2.5.1.

Page 16, figure 7: What does stand. rad. mean? State in caption that  $u_1$ - $u_4$  are singular vectors ?

Page 17, eq. 21: meaning of  $\beta$  ? I assume this is again different to the 3 previously define  $\beta$ 's?

Page 17, line 343: retrieval's -> retrieval's

Page 18: lines 348: changing the resolution will typically also change the SNR

Page 18, table 1: condition numbers need to be put into context.

Page 18, line 351: The state vector  $x = (3m, 3r)$  was found to be robust toward low SNR... -> what do you mean by robust?

Page 18, lines 354: use wavenumber here and not wavelength so that it is consistent

Page 20: figure 8: can you add figure with retrieved surface reflectivity.

Page 21, Figure 9 : make figure the same along track and across track range as figure 8. Please make all the plume figures the same range for comparability. Also, give CH4 on maps and not the scaling factors (figure 13 and 14, 15).

Page 22, figure 10: Hard to see anything. I suggest to plot only lines instead of lines+symbols.

Page 26, lines 424: The relative enhancement is slightly better represented in Fig. 14a.-> I don't think you can tell what is better as you don't know the truth.

Page 27: The method yields consistent results for both spectral intervals. -> results shown in Figure 16 are very different. In which way are they consistent ?

Page 28, line 444, should Figure 16 have 3 rows for zero, 1 and second order ?

Page 29, Figure 16: can you use same colour scale and format to increase the comparability ?

Page 30: A validation from independent measurements is hence outside the scope of this study -> A validation from independent measurements is outside the scope of this study

Page 30, lines 461: the results from the well established MF method can be considered

some sort of verification -> what is the justification for this. Is there a reference that can be used in support ? Also, the results from MF are not used as reference for the analysis.

Page 30, line 463: and the results agreed well with  $\approx 3\%$ . -> where is this shown ?

Page 30, line 467: was found to be the most sensitive method for the detection of enhanced methane -> how is this conclusion drawn ?

Page 30,line 478: and potentially quantified from HySpex -> you have not shown this.

Page 31: line 494: agree well on the plume's shape. -> this is not shown in the manuscript

Page 30, conclusion: can you discuss if the findings from this study are only applicable to Hypex or also to wider range of hyperspectral sensors for example on satellites,