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Atmospheric Measurement Techniques Discussions

Interactive comment on "An Examination of Enhanced Atmospheric Methane Detection Methods for Predicting Performance of a Novel Multiband Uncooled Radiometer Imager" *by* Cody M. Webber and John P. Kerekes

Anonymous Referee #2

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1 General Comments

The manuscript (Webber and Kerekes 2020) compares the performance of three different analytical methods for detecting methane in remote sensing imagery taken using an uncooled multispectral infrared (IR) radiometer. Given the prohibitive cryogenic requirements of traditional thermal IR imagers, an uncooled instrument would lower barriers to deploying imagers for atmospheric methane detection. This paper provides a useful evaluation of this system for methane detection; however, the paper has gaps in

the description of the methodology, and the discussion and conclusions require more development. In particular, more quantitative details about assumptions made and model input used should be included, and reasons for the values chosen should be explained.

2 Specific Comments

Page 2
l. 9-10: The phrasing that HyTES has been used to develop an algorithm that can predict methane concentration from thermal imagery is somewhat vague and therefore confusing. It would be more helpful to identify the improvements in the HyTES retrieval algorithm in Kuai et al. (2016) that are most relevant to the research described in this paper.
l. 19: Given that sensors that operate in various regions of the IR spectrum are discussed, it would be helpful to briefly clarify why traditional thermal IR sensors require cooling and the advantage of thermal IR over shortwave infrared (SWIR) sensors, which also measure methane but do not have the same cooling requirements.
l. 21: What defines a "satisfactory performance"? What is the level of sensitivity, precision, accuracy, or another relevant metric needed for methane detection applications of MURI?
l. 23: What is the difference between the airborne and satellite system? Are they using the same FPA?

Page 3
l. 13: What assumptions were made about environmental conditions, particularly the concentrations of interfering molecules such as water vapor?

Page 4
l. 5-9: More details are needed for the methodology, particularly what assumptions were made in modelling the background and plume-present cases and why those assumptions were chosen. A discussion of the sensitivity of the model output to these assumptions should be included here if some a priori knowledge of the sensitivity factored into the choice of assumptions, and/or in the Results/Discussion section if relevant to determining the validity of the results.
l. 8: What is the magnitude of the increased concentration of methane? How does this compare to the Noise Equivalent Concentration Length (NECL) and/or minimum detectable column density of the sensor?
l. 13-15: Since only a single band is allocated to the methane feature, what is the purpose of the other bands? Section 2.3 demonstrates that the other bands can help constrain the methane retrieval, but if they have additional functions, those functions should be listed (in this paragraph, in the general description of the instrument, or in Table 1).
l. 21: Units associated with each of the variables would be helpful to conceptualize the relationships in Equation 3 and clarify what is meant by "signal", which can refer to multiple aspects of the data stream.

Page 5
l. 9-11: Is the threshold applied to the CMFI value, or some statistics associated with it, such as a confidence interval or t-stat? Also, please provide a short explanation of how the ROC curve is used to assess the effectiveness of the method.
l. 23-27: This explanation is somewhat confusing. Is this paragraph describing whether the methane feature is giving an absorption versus emission signal in the detection? The way that NDMI is described, it seems like it would be possible to have negative values that can be indicative of a methane plume, and if no plume exists, the NDMI would be zero. If so, it seems that a higher absolute value of the NDMI would indicate

higher methane. Please clarify.

Page 6
l. 4: Please specify what band 2 has a comparatively higher transmission of: the atmosphere, instrument filter, etc.
l. 17: It's unclear what is meant by "on and off plume spectra". Are these the spectra for a single background pixel and a different pixel that has a methane detection? Also, what are the assumptions that were made for the MODTRAN simulated recreation of the data? If these are the same assumptions used in Table 2, please refer to that table in this paragraph.
l. 18: Based on the radiance values in Figure 3, the RMSE for the methane plume case is about 2.5% – How does this contribute to the uncertainty in the methane column density amount?
l. 19: How is "reasonable" defined? High confidence? If so, what is the threshold?

Page 8
l. 11: Is "only small amounts of CO_2" referring to the ambient concentration input into MODTRAN? Please provide the actual value used and why it was chosen. If these results are not sensitive to the assumed concentration of CO_2, please state that; if the chosen concentration of CO_2 impacts the results, however, provide justification for the value chosen (e.g. regional average concentrations taken from in situ or satellite measurements).
l. 12: What is the level of enhancement in the "enhanced concentration plume"? Please be quantitative.

Page 10
Table 2: Change "Plume Height" to "Plume Altitude", as the former could be confused with "Plume Thickness". Also, please add a row with the assumed ambient tempera-

ture.
Section 4.1: Please provide rationale for the model inputs listed in Table 2 in this section. For instance, was the plume thickness derived from data, a model, or experiments? Was the ambient temperature measured locally, or taken from a model, and if so, which one? Assumptions that don't have a significant impact on results can be stated as such; however, justification should be provided for assumptions that alter the results and especially conclusions of this paper.

Page 11
l. 1-6: It is unclear why the sensitivity described was framed in terms of the temperature gradient between the plume and the ambient air, as it is the temperature gradient between the surface and the plume that drives the sensitivity in hyperspectral imagery. There might be a reason to frame the conclusions in the terms used, but it is difficult to evaluate those conclusions without knowing what ambient air temperature was chosen. The minimum detectable concentration of methane is lower when the thermal contrast between the plume and the surface is high; for example, a very hot plume should be more detectable over a low-temperature surface. Thus, the assertions made in this paragraph would not apply in all cases and would depend on the relative ambient, surface, and plume temperatures. Since the paper is evaluating the performance of new instrumentation, characterizing which conditions the conclusions hold for would be helpful in evaluating the applicability of these techniques for conditions that deviate from those chosen for this study.
l. 12-14: When determining the false positive rate, what is used as truth? Is there ground-truth, or is the HyTES detection mask considered truth? Also, what is the region of interest threshold chosen? That is, does the algorithm require a certain number of contiguous pixels with methane detection before the plume is accepted?

3 Technical Suggestions

Page 1
l. 16-17: A citation is missing after "While the concentration of methane is lower than that of CO2, the world has seen a rise in methane emissions since 2007, primarily from anthropogenic sources."

Page 2
l. 3: "Thrope" should be changed to "Thorpe".
l. 5: It would be useful to specify that HyTES is a longwave infrared (LWIR) imager.
l. 18: Since the abbreviation for methane, CH_4, is used earlier in the paper, it should be continue to be used consistently. This applies to the remainder of the paper, as well.
l. 11: A comma is missing after "(GOSAT)".
l. 17: A comma is missing after "infrared".
l. 24: "FPA" should be changed to "focal place array (FPA)".
l. 25: A comma is missing after "channels".
l. 28: Both μm and um are used in this paragraph. One convention should be chosen for the entire paper.

Page 3
l. 5: Elsewhere in the paper, pixel is also used to describe both the physical pixel on the FPA (e.g. page 2) and the spatial pixel in the image (e.g. page 4). For clarity, change this instance and other references to the spectral pixel to "channel", which is used later in the paper.

Page 4
l. 16: Add "spatial" between "N" and "pixel".

Page 5
l. 21-22: Specify whether SB2 or SB1 includes the methane feature.

Page 6
l. 11-12: Specify what "after" is referring to in the sentence "[...] a scenario in which a rogue emission source has been detected was chosen to model the simulated data after."
l. 15: Change "Prupulsion" to "Propulsion" (applies to other instances of this citation in the manuscript).

Page 7
Figure 1: Specify units after "7.68". Also please add the ground sampling distance (GSD) of the image.

Page 8
l. 10: Remove the typo in "for at sensor radiance".

Page 9
l. 7: Change the reference to "Table 3" to "Table 2".

Page 10
l. 1-2: Citations are needed after "Modern estimates of ambient atmospheric methane concentration are at about 1.8 ppm, dangerous levels for 8 hours of daily exposure to methane for humans is 1000 ppm, while the lower explosive limit is around 50,000 ppm."
l. 8: Remove "or" before "the methane feature band".

Page 11
l. 15: An adjective is missing between "very" and "false".

Page 12
l. 14: Change "pixel" to "channel" or "band" if spectral pixel is what is meant.

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