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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

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Referee #1 Comments Response:

On behalf of myself and my coauthor I would like to thank you for taking the time to review and provide feedback on our paper. Your feedback was very helpful and much appreciated. We know that your feedback will help make our revision a better discussion of our work.

General comments: The manuscript uses three methods to evaluate the performance

of a multiband uncooled radiometer imager, which would be cost-effective compared to a cooled hyperspectral instrument. The reasoning is sound, with interesting results for the community. There are however several clarifications that needs to be made regarding the aim of the study and for the evaluation of the instrument using the different methods to be more clear for the reader.

AR General Comments: Thank you for your summary and we agree the results will be of interest to the community. We have made a number of changes in response to reviewer comments and the revised version is more clear.

Specific Comments: 1a. Is the goal of the study to be able to quantify CH_4 concentration? This should be made more clear. E.g. comparisons are made between MURI and HyTES, applying similar methods, but some studies using HyTES data have been able to quantify CH_4 average concentrations using radiative transfer modeling (e.g. Kuai et al. 2016). If quantification is the aim, then e.g. for the Single Pixel NEdT Comparison: how would the method be able to differentiate between a change in temperature contrast and an actual increase in methane for the two cases (background and plume case). The brightness temperature would be affected by the background temperature, the CH_4 temperature, and the CH_4 column density. How can these three parameters be found from one brightness temperature? It is also likely that the background temperature (and thus the background vs CH_4 temperature contrast) would be different between the two cases (no plume and plume).

AR1a. The goal of this study is to detect enhanced levels of atmospheric CH_4 without quantification. The purpose of the single pixel NEdT is to identify possible scenarios that lead to absolute brightness temperature differences higher than MURI's band one Noise Equivalent delta Temperature. We have changed some of the language in each section to clarify these goals.

1b. One of the aims of the study seems to be providing a novel, cost-efficient system for satellites, utilizing low cost microbolometers and not requiring an expensive cooling system. Is the developed system (MURI) mainly to be used for satellites (which are expensive anyway with many other high costs) or is the idea to use the system for ground-based (possibly airborne) measurements as well? (where reducing the cost could have a higher impact). This should be made more clear.

AR1b. The MURI system was designed to demonstrate the value of utilizing low cost microbolometers in environmental applications for satellite and airborne use. An airborne demonstration instrument was constructed, and the studies performed here reflect anticipated performance of the airborne demonstration device. We have added a sentence to clarify that.

2. Section 2.3 (Normalized Differential Methane Index). The method does not account for varying ground emissivity, the background vs gas temperature contrast, or the H2O and N2O column densities (are there strong absorption lines from these in the SB1 and SB2 bands?). These would affect the efficiency to detect CH4 (and for sure retrieval of column densities if this is a goal). If only detection, there could be false alarms from e.g. high H2O concentrations (which has lines overlapping the 7.7 micron CH4 band). Emissivities could also be different between different background materials.

AR2. Your comment does identify some of the limitations of our approach for which we are aware. However, because the approach utilizes a relative measurement the effect of surface emissivity and surface temperature changes will be less than with an absolute measurement. There are H2O absorption lines present, but there are considerably fewer and weaker features than the methane absorption lines in the same region. Band 6 also contains weak H2O absorption lines. The effect of H2O on masking detection using NDMI has not been fully characterized and could be the subject of a future investigation.

3a. Section 4.1. There are three relevant temperatures for this test: background, ambient, and plume. The efficacy to detect a plume would be very dependent on the background - plume temperature contrast, and if this contrast is 0 deg the plume could

not be detected regardless of the sensitivity of a sensor as all the CH4 absorption lines C2 in the plume emits as much light as is removed (resulting in no absorption and no detectable difference in brightness temperature). In Figure 5, the 0 K curve (plume - ambient contrast is 0) would be a horizontal line if Tambient = Tbackground. It should thus be made more clear what temperature difference has been assumed between the ambient and background. Also, caption to Fig. 5 should explain that the curves are different contrast of ambient and plume temperature. In winter it could very well be emissions features, with the plume increasing the brightness temperature with e.g. a background of ice on a lake. The sentence (P11, first row) "The results here indicate that a plume with a temperature difference as high as +10 K to ambient temperature is absorbing energy" - this again depends on the ambient - background temperature (which is not given as the ambient temperature is not given). This should be made more clear.

AR3a. Of the three relevant temperatures, Figure 5 describes the difference between plume temperature and ambient atmospheric temperature. In this scenario ambient atmospheric temperature does not equal background surface temperature and this has been clarified in Table 2. These were framed as plume to ambient atmospheric temperature differences as this is how our models are defined and for consistency throughout the paper. The background surface temperature in all cases is higher than plume temperature and therefore absorption is to be expected and this has been clarified. Supplemental material includes Figure 5 in terms of the temperature difference between the plume and the background surface.

3b. Similarly, in the conclusions (P12) it is stated "The single band investigation confirmed that methane plumes with large concentrations and temperature differences compared to ambient atmospheric conditions lead to detectable contrasts". I agree with sufficiently large concentrations, but the important temperature difference is not the ambient and plume temperatures, it is the background and plume temperatures. This should be made more clear/rewritten. One could easily have the case of a very large plume-ambient temperature difference (say 10 K) but also a 10 K background-ambient temperature difference, leading to no absorption lines and no difference in brightness temperature.

AR3b. This comment is greatly appreciated. Our use of ambient to plume temperature as the point of comparison was based off how our models are defined and also allowed us to maintain consistency. However, clarifying our results by discussing the background/plume contrast is included in our revision. Additionally, a supplemental figure showing our results in terms of plume/background temperature difference has been included.

Technical corrections: - Wrong table number. Page 9, 4.1. states "Table 3 contains...", this should be Table 2? (there is no Table 3) - Abstract: 7.68 um -> 7.68 μm. Also in other parts of the text (e.g. Table 1) using u instead of μ - Table 1: Write μm in the headers instead of every row - Introduction: Use CH4 instead of methane after first having introduced "methane (CH4)". This is also the case for many other parts of the text. - P5L17. "from pair" - > "from pairs"

AR Technical corrections: Thank you very much for addressing these technical errors. These have been addressed in our revision.

Please also note the supplement to this comment:
https://www.atmos-meas-tech-discuss.net/amt-2020-53/amt-2020-53-AC1-supplement.pdf

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