Responses to reviewers: "Detecting and quantifying methane emissions from oil and gas production: algorithm development with ground-truth calibration based on Sentinel-2 satellite imagery"

We appreciate the reviewers for their comments and revision suggestions. Below we offer our point-by-point responses explaining how we addressed the comments.

The revised text as it appears in the manuscript is written in normal blue text, with new contents underlined and removed contents struck through.

Response to comments from Anonymous Referee #1

The authors developed a multi-band-multi-pass-multi-comparison methane retrieval algorithm that enhances Sentinel-2 sensitivity to methane plumes. The new algorithm is based on the algorithm developed by the same author but enhances its sensitivity to methane plumes and reduces false detections. The manuscript is well written. The method looks sound. I recommend publication after minor revision.

General comments:

1. Section 3.1. Line 250-259. What is the relationship between "two-step application" and MBMPMC? It is not clear to me.

   Answer: The "two-step application" method is a way we propose to apply the MBMPMC algorithm in order to achieve higher quantification accuracy while keeping high yes/no detection accuracy. In the "two-step application" method, we run the MBMPMC algorithm to get the first round of emission rate estimates, and then redo the plume mask extraction step by raising the value of parameter *p*, and finally update the emission rate estimates. Different with direct application of the MBMPMC algorithm, this method is specifically designed to address the trade-off issue between quantification accuracy and detection accuracy. We updated the text in L250-257 to make it clearer for the readers.

   As a compromise, we developed a method to apply ~~approaches~~ the MBMPMC algorithm in sequence to reduce the quantification error further while keeping a high F1 score…So a consistent bu and n greatly reduces the computation workload as we only need to redo the mask extraction. Different with direct application of the MBMPMC algorithm, this method is specifically designed to address the trade-off issue between quantification accuracy and detection accuracy. Table 1 shows an example of the two-step application ("Two-step hybrid" scenario) with the "Base case" scenario.

2. Figure 7. The improvement compared to the previous 3 methods are very impressive. Please try to briefly summarize the reasons for the improvement compared to each method.

   Answer: Thanks for the suggestion. We added a summary of the improvement reasons into the manuscript (L. 264-266).

The MBMP method has true negative detection in 10/17/2021, but shows a small false positive detection in 10/19/2021. Its emission rate estimate in this date is also much lower than the ground truth. This implies that the steps of normalization and inclusion of multiple comparison dates in the MBMPMC method contribute to a higher sensitivity to the true plume than the MBMP method. MBSP and SBMP retrievals perform worst with multiple large-area false positive plumes. SBMP method is likely to produce false detections if the surface albedo changes across different passes, and MBMPMC method reduces the effect of changing surface albedo by including different spectral bands and multiple comparison dates. MBSP method can produce false detections because of the wavelength separation between two spectral bands, and MBMPMC method largely removes these artifacts by subtracting the MBSP retrieval between different passes.

Specific comments:

1. There are two "also" in the last two sentences. Please try to rephrase them.

   Answer: We rephrased the last two sentences in Abstract (L. 15-18).

   We ~~also~~ illustrated a two-step method that updates the emission rate estimates in an interim step which improves quantification accuracy while keeping high yes/no detection accuracy. We also validated the algorithm's ability to avoid false positives by applying it to a nearby region with no emissions.

2. It is useful to clarify the ratio of anthropogenic to natural emissions as well.

   Answer: Thanks for the suggestion. We added a sentence clarifying the anthropogenic methane emissions ratio.

   During the 2008-2017 decade, around 60% of global methane emissions are from anthropogenic sources (Saunois et al., 2020). Of these sources, ~~In recent years,~~ fossil fuel (coal, oil and gas) production and use was estimated to have contributed 81-154 Tg CH4 a−1 of methane emissions, accounting for around one third of the global anthropogenic methane fluxes (Saunois et al., 2020).

3. Section 2.1. Please mention that there is a flow chart to illustrate the steps of MBMPMC when first discussing them.

   Answer: We added a sentence mentioning the flow chart in the manuscript.

   The new algorithm follows the same logic of retrieving the vertical column concentrations of atmospheric methane ΔΩ (kg · m−2) from Sentinel-2 SWIR reflectances ~~(see Figure 1)~~. Main steps are shown in the flow chart of Figure 1.