RC2: 'Comment on egusphere-2023-3047', **Anonymous Referee #2, 12 Feb 2024**

He et al. used the observations of Advanced HyperSpectral Imager (AHSI) on board the Gaofen-5B satellite (GF-5B/AHSI) to estimate methane emissions from coal mines in Shanxi province in China. The spectral shift in center wavelength and change in full-width-half-maximum (FWHM) was characterized to improve the accuracy of the spectra. Based on the improved dataset, the matched filter method was applied to calculate the enhancement ΔXCH_4, which is followed by the use of the integrated mass enhancement (IME) model to estimate the methane emissions. Besides these, an automated plume segmentation method was adopted to reduce the dependence of subjective judgement during the data processing phase, and the major factors that affect the uncertainties of the estimates are discussed.

We thank the reviewers for his/her constructive comments and suggestions to improve the quality and clarity of our manuscript. We have made careful modifications to the original manuscript according to all the comments and suggestions from the reviewers. The major changes include:

1. We added a paragraph to describe the new results with the wind error estimated from comparing ground-based measurements and ERA5. The comparison result shows an averaged difference of 1.297 $m \cdot s^{-1}$, which is then used as an absolute wind uncertainty for estimating the uncertainty in emission calculation. The updated results are shown in **Section 4.3.3** and **Figure E1**.
2. We also clarified some incorrect or unclear descriptions of the results and methods throughout the manuscript. The information about the backgrounds used in the flood-fill method and the plume identification have been introduced in more details.
3. We have updated the *k* value using the surfaced pressure that is representative for the detected plumes in Shanxi. In addition, all results in the revised paper have been updated based on this updated *k* value.

Item-by-item responses to the specific comments are provided below, in which the reviewers' comments are in blue, our responses in **black**, and modifications of the original manuscript are indicated by highlighting in yellow in the revised manuscript.

General comments:

1. It is apparent that the estimates are sensitive to the selection of background, which is acknowledged in the manuscript, and is also demonstrated with a good example using the same background region in Fig.5a&b. The question is how the background regions were selected in practice? i.e., where is "a background region in square (with length of 600 pixels, which is 18 km)" located?

Reply: We added the detailed information in Section 3.1.1 (**Lines 200-206**): To carry out the flood-fill method in plume extraction, a background region needs to be defined to calculate the mean and standard deviation of ΔXCH_4 which set the basis for identifying anomalous high

ΔXCH_4 in the plume relative to the background. In this study, for a specific plume, the origin is first pinpointed through visual interpretation. Then a background region is defined as a square using the source origin as the center for calculating the mean (μ) and standard deviation (σ) of ΔXCH_4. Finally, a threshold defined based on μ and σ is used for the flood-fill algorithm to effectively segment the point source plume. The exact numbers for the background square length, μ and σ are introduced in Section 3.3.3.

We have also revised the related descriptions in **Lines 234-237**: In practice, for estimating IME and its uncertainty for a certain plume, we used 6 different background square lengths (from 12 km to 24 km with an interval of 2.4 km) and 6 different segmentation thresholds (from μ+0.45σ to μ+0.55σ with an interval of 0.02 σ) for the flood-fill segmentation method (**Figure C1**). Different values of μ and σ are calculated for different background regions.

We have also added **Figure C1** in the Appendix to demonstrate examples of background selection.

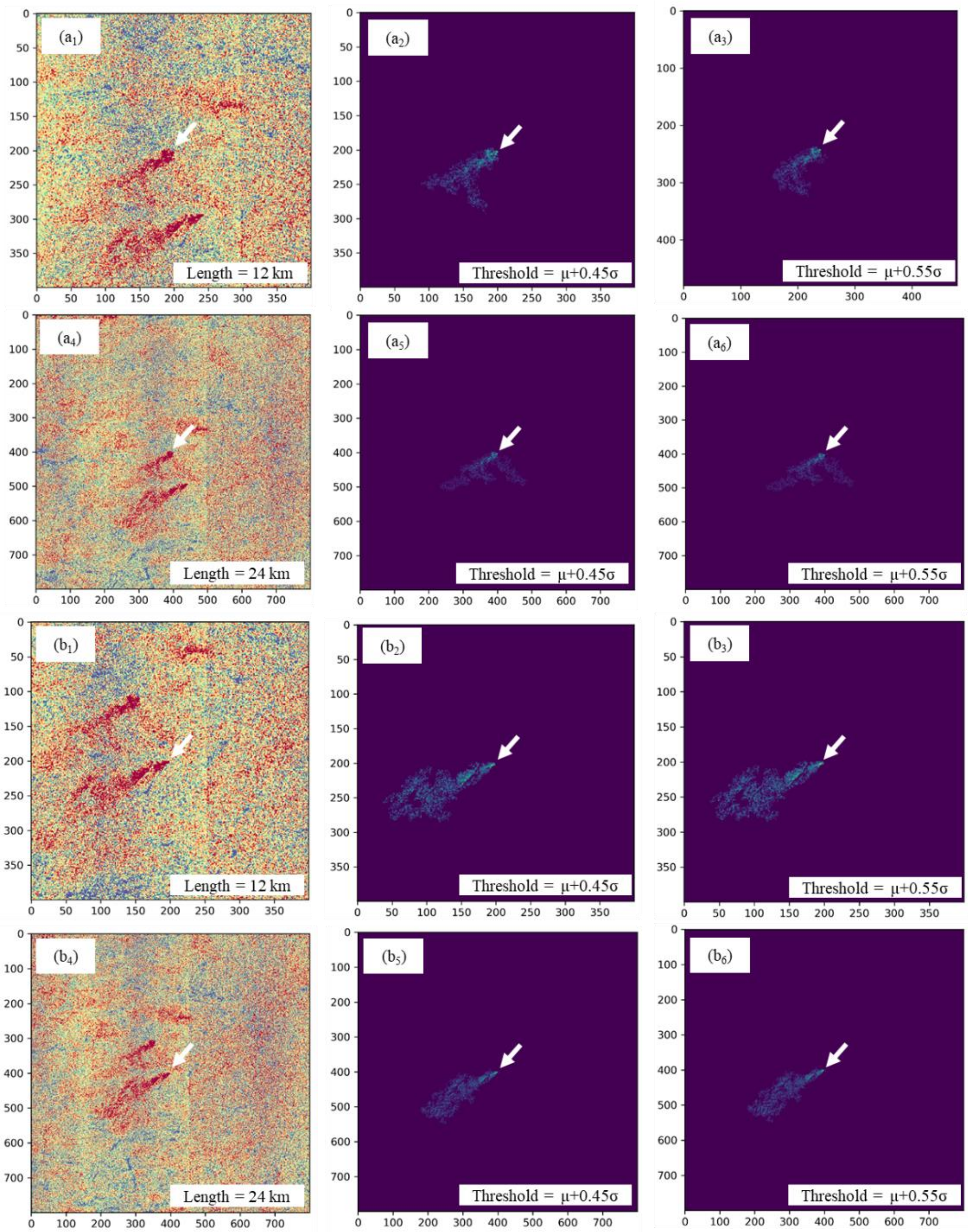

Figure C1. Examples of plume segmentation in flood-fill method using different lengths for the background square and different segmentation thresholds. Two plumes are given in a_1-a_6 and b_1-b_6 as examples, in which a_1-a_3 and b_1-b_3 are for the length of 12 km and a_4-a_6 and b_4-b_6 are for the length of 24 km. Two different thresholds, $\mu+0.45\sigma$ and $\mu+0.55\sigma$, are given for the two plume examples.

2. Are the estimates of methane emissions correlated with wind speed? As the wind speed is low, the dispersion of the methane plumes may be very uncertain, and the estimates may be biased.

Reply: Based on the wind speeds from ERA5 and the corresponding CH_4 emission estimations, we made a scatter plot as shown in the following **Figure**. No clear correlation can be seen from the data, suggesting the emission estimations are not biased due to wind speeds. We have added the following figure and related statements in the revised manuscript.

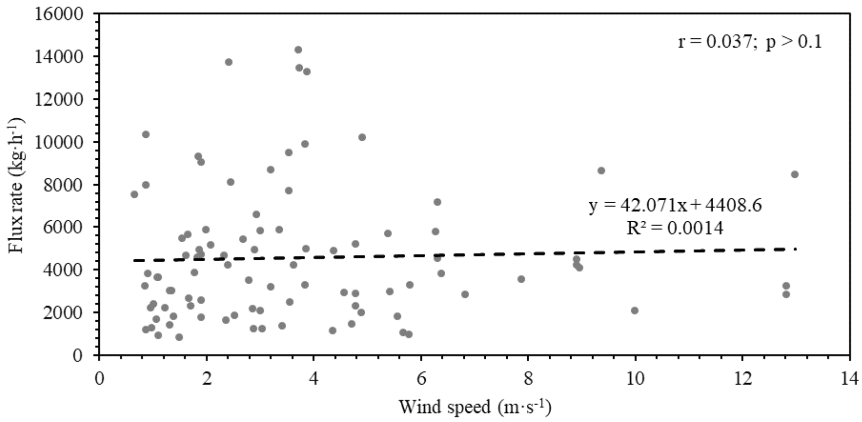

Figure. Scatter plot between the estimates of methane emissions and wind speed in this study.

3. I understand that the overall emission flux rate of 13.26 ton h-1 in Shanxi refers to the 32 coal mines between 2021 and 2023. How does it relate to the total coal mine emissions? How does it compare with the estimates from TROPOMI? What's the detection limit of GF-5B/AHSI?

Reply: We have removed this sentence in the revised manuscript to avoid ambiguity, since such an estimate does not include null detection and an assumption of simultaneous emission of all emitters at the detected rates may be highly uncertain. Because the temporal emission timeseries of each specific emitter is unclear, and more observations overpass at different hours would be needed for estimating the total emissions.

For example, **Chen et al. (2022a)** used high density (26292 active wells) and highly repeated (115 flight days) measurements from aerial instrument to quantify methane emissions from the whole regional study area of New Mexico Permian Basin with persistence-averaged method. The persistent emission rate from a single point source was calculated with the emission detection probability derived from highly repeated observations. In this study, this may not be feasible, because the observations are too few to calculate the possibility of emission detection. We have added the above statements in the revised manuscript.

We have made a comparison of emissions estimated from TROPOMI (**Schuit et al., 2023**) and this study as shown in the following **Figure**. Notably, the emission rate of plumes from GF-5B AHSI are very different from results by TROPOMI. For the detection limit, the emission rates of all detected plume are shown in this study (Figure 7), we can see that the smallest plume has an emission rate of 761.78 ± 185.00 $kg \cdot h^{-1}$ which may represent the detection limit of GF-5B AHSI.

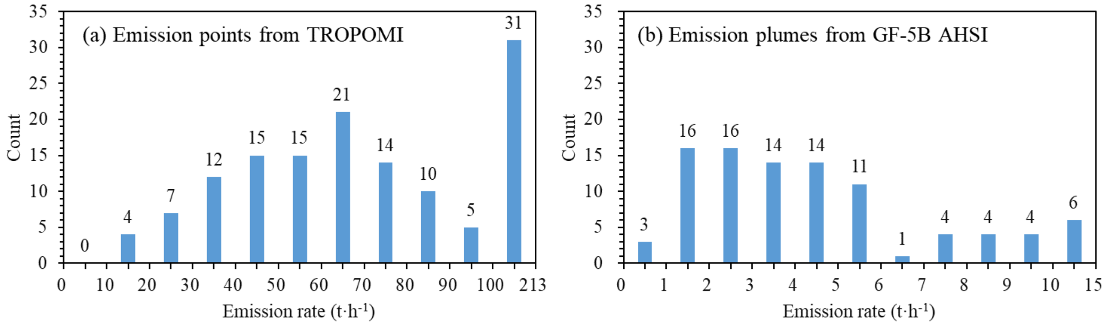

Figure. Comparison of point source emission statistics between TROPOMI (a) and GF-5B AHSI (b) in Shanxi, China. TROPOMI detected a total of 134 points (Schuit et al., 2023), while GF-5B AHSI identified 93 plumes in this study.

Added reference: Chen, Y., Sherwin, E. D., Berman, E. S. F., Jones, B. B., Gordon, M. P., Wetherley, E. B., Kort, E. A., and Brandt, A. R.: Quantifying Regional Methane Emissions in the New Mexico Permian Basin with a Comprehensive Aerial Survey, Environmental Science & Technology, 56, 4317-4323, 10.1021/acs.est.1c06458, 2022a.

detailed comments:

L138-139: the matched filter method and the IME model are actually combined to estimate the CH_4 emission rates. Therefore, they should not be considered two methods.

Reply: Thank you for your comment. You are correct that in our study, the matched filter method and the IME model are indeed combined to estimate CH_4 emission rates. We have revised the text accordingly to accurately reflect this aspect of our methodology in **Lines 139-140**.

L184: change "be very differ" to "be very different", what are the possible reasons of the mismatch?

Reply: We changed "be very differ" to be "be very different" in **Line 186**. The reasons for the mismatch are explained in **Lines 187-188**: Several factors could contribute to this mismatch, including the temporal and spatial resolution of the reanalysis data, local topographical features, and microscale meteorological phenomena that are not fully captured by the reanalysis data.

L204-205: k may be affected by a few factors, such as surface pressure, temperature, and water vapor. How would these affect the estimate?

Reply: Thank you for your great suggestion, we have updated the *k* value using the surfaced pressure that is representative for the detected plumes in Shanxi. In addition, all results in the revised paper have been updated based on this updated *k* value.

We revised the related descriptions in **Lines 215-221**: *k* is the scaling factor converting ΔXCH_4 from volume mixing ratio to mass based on Avogadro's law, considering the pixel resolution of GF-5B/AHSI to be 30-meter. In **Guanter et al. (2021)**, k is defined as $5.155\times10^{-}$

[3] kg·ppb-1derived from surface pressure of one standard atmosphere. However, the average elevation of the identified plumes is 942.41 meters (**Figure B1**), whose surface pressure (900.64 hPa) is about 10% less than one standard atmosphere. Therefore, we calculated a new k based on the derived averaged surface pressure for all the identified plumes. The derived k value (4.565×10^{-3} kg·ppb^{-1}) is then used for estimating IME in this study.

All the IME and CH_4 emission rates throughout the revised manuscript were updated with the new scaling factor of *k* used in this study.

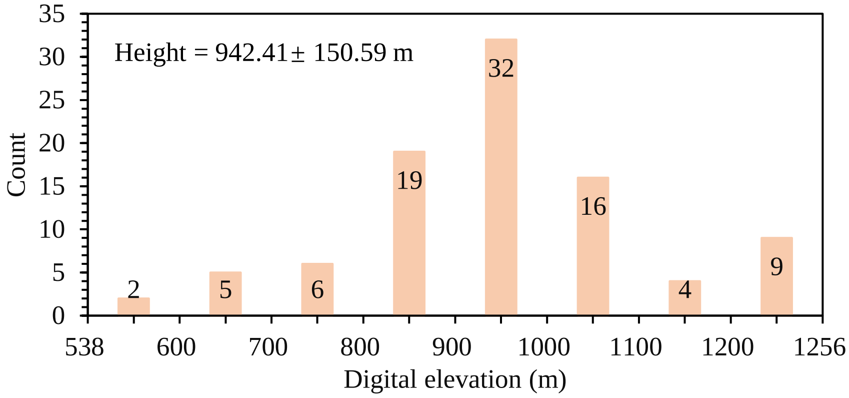

Figure B1. Histogram of the elevation for the detected plumes in Shanxi. The elevation data is from the DEM shown in Section 2.3.

L227: change "evaluations" to "evaluation"

Reply: We changed the "evaluations" to be "evaluation" in **Line 241**.

L235: not "emissions" but "the direction of plumes"

Reply: We have revised the statement to emphasize the significance of the observed differences and the importance of repeated observations for accurate emission estimation (**Lines 249-250**).

L241-243: "as the plumes appears at different locations of the imaging scene. The plumes appear at the bottom of the scene in Figure (f) and at the top in Figure (g)", why does the position of the plumes in the scenes matter?

Reply: The retrieval of ΔXCH_4 relies on the quality of the spectra, as quantified by its signal to noise ratio (SNR). When plumes appear at different locations of the imaging scene (as illustrated in the following **Figure D1**), they may be observed by different detectors with different SNR of the instrument. Therefore, as we explained in the manuscript, the difference in ΔXCH_4 may be slightly caused by the different signal noise ratio of the detectors.

We have changed the statement in the revised manuscript to:
"as the plumes appear at different locations of the imaging scene. They may be observed by different detectors with different SNR of the instrument that affect the detection accuracy of the plumes."

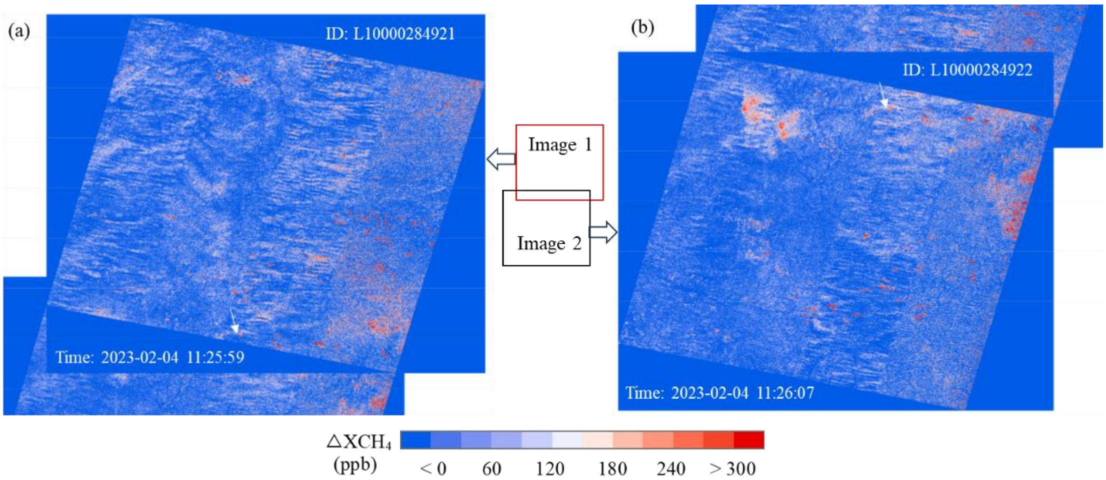

Figure D1. The full images of ΔXCH4 for Figure 3f (a) and Figure 3g (b). The plume target (pointed by the white arrow) appears at the overlapping region of the two images.

L310: 13.26 t*24*365 /yr

Reply: In the revised manuscript, we remove summation of the total emissions in Shanxi based on the assumption of simultaneous emission to avoid ambiguity, since such an estimate does not include null detection and an assumption of simultaneous emission of all emitters at the detected rates may be highly uncertain. Because the temporal emission timeseries of each specific emitter is unclear, and more observations overpass at different hours would be needed for estimating the total emissions. Related statements have been added to the revised manuscript.

L356: consider combining or to combine

Reply: We changed the "combine" to be " combining" in **Line 384**.