6 September 2025

Subject: response to referee report

We thank both referees for their helpful comments. We have implemented most of the recommended edits. To address concerns about the manuscript's length and readability, we have reduced the scope of the paper to a first assessment of Tanager-1 performance and moved some detailed supporting text and figures to a Supplemental Information appendix. The sections on observing system completeness and predicted spatio-temporal coverage of the Tanager constellation were removed and will be covered in greater depth in a subsequent manuscript.

Additional specific responses are summarized below.

Best regards,

Riley Duren on behalf of the co-authors

Referee 1

(1) Observation strategy, given Carbon Mapper completeness goals, target lists and instrument performance.

In response to the referee recommendations, we have reduced section 2.1.1 to an introduction of the observing system completeness metric and the C_D parameter. We feel this is sufficient to provide insight into our measurement strategy and design drivers without offering a more in-depth treatment that merits a dedicated manuscript. Similarly, we have removed section 4.3 entirely.

(2) Questions and concerns on the aspects related first on-orbit performance results

I have several questions/concerns about this effort:
1. How were chosen the scenes used to conduct the analysis? The authors report that 5200 images have already been observed by Tanager (Figure 13 caption), but only "over 300" (line 1071) images were included in this analysis. Not including every image is fine, but the selection process would need to be detailed. Can you also provide a (supplementary) map showing where the scenes come from? Besides, can you please provide the exact numbers of data points included for both imaging modes?

We have clarified the criteria used to select points in figures 20 and 21(now figure 14) and added a map (figure 13) showing the geographic distribution of the scenes used in this analysis. We also clarified the number of data points per imaging mode as requested.

2. I also wonder to what extent images can be only boiled down to a reflectance value and an SZA: how heterogenous are the scenes included in this analysis? For example, I would not expect noise levels to be identical between an homogenous desert image and a heterogeneous urban area in a desert, with dark vegetation spots and bright warehouse roof tops.

We have increased the sample size significantly to improve the statistical robustness of this analysis. We also added the following language: Some scenes exhibit highly variable albedo due to strong surface heterogeneity (e.g., urban landcovers), however scene-averaging over a large population allows a preliminary estimate of how noise generally relates to environmental conditions in Tanager observations.

3. I think the discussion of the Maximum Sensitivity mode could benefit from more data points, especially also covering the lower albedo surfaces (< 0.1) where I would expect it could yield the best improvements compared to Standard. I realize this is somewhat of a "first-data" paper, but I suggest authors to include more points in this Maximum Sensitivity mode in the revised manuscript if more have been observed.

We have maximized the number of points available in this first data paper from 300 to over 4200 scenes, 278 of which are in Maximum Sensitivity mode. As shown in the new figure 14, this significantly expanded the number of low albedo points (< 0.1).

• The caption of Figure 24 mentions that "most observations shown here were using the standard sensitivity mode". Can the authors be explicit about the exact numbers of each sensitivity mode observations included in the controlled release experiment? Can you also color the points of Figure 24 by sensitivity modes? I especially wonder whether maximum sensitivity translates into lower emission rate uncertainties. This may not always be the case because wind speed plays a major role in emission rate uncertainties but still, these additional details would help readers reflect on these questions.

We have revised figure 24 (now figure 17) as suggested and clarified the number of observations in each sensitivity mode. We added a note confirming that maximum sensitivity mode translates to lower emission rate uncertainties due to the improved measurement precision, which indeed is evident in the revised figure.

• I suggest authors to cut the technical gas release details from the main text, and either refer to existing references in the literature, or move the details to supplements to lighten the read of this section.

As suggested, we have moved details on the controlled release test to the SI section.

- Finally, I am quite curious about a performance point that has not been mentioned in this section: could the authors consider giving an overview of the manual plume verification statistics and, if they can, how they may possibly depend on e.g. expected target emission intensity, surface heterogeneity surrounding the target, meteorological conditions (wind speed, cloudiness), imaging sensitivity mode, etc.? I think giving a sense of how hard manual verification/detection can be in specific difficult conditions could be a very valuable addition to the scientific literature.

  While we agree that this would make a valuable addition to the scientific literature, we feel that a proper treatment of those topics is beyond the scope of this paper and would be in conflict with other requests to shorten the manuscript. We are also aware of other plans (e.g., by NIST et al with input from many methane satellite teams) in progress to publish consensus standards on this topic.

(3) ***Questions and concerns on the demonstration of Tanager capabilities based on first observations***

Regarding data description, I find that Figure 13 top is not very informative beyond showing the location of all Tanager observations. Could authors at least color observations according to their goal (targeting CO2/CH4 emitting regions; non-trace gas hyperspectral applications)? This would help to better compare top and bottom panels of Figure 13, and possibly help identify where CO2/CH4 emissions were targeted without detecting any plume. Regarding non-detection, I wonder if it is possible to at least report the number of observed targets that were expected to show emission plumes and that did not show any over the first months of commissioning?

We have revised figure 13 (now figure 6) to differentiate between our priority CH4 tasking deck and all Tanager scenes acquired through August 15, 2025 (including those acquired for other hyperspectral applications). This provides readers with an indication of where we have focused on potential high emission regions. Additionally, we have added some zoomed in views for representative regions that illustrate the overlap between Tanager scenes and where emission sources have been detected to date. While this offers some qualitative intuition about the distribution of plume detections vs observed areas, we note that there is considerable uncertainty in the distribution of super-emitters globally and we do not have a prior model of the likelihood of their occurrence within a given grid cell. In future, we do plan to publish some quantitative analysis regarding detection rates and completeness once we have acquired a larger number of observations and in particular more samples of key regions to constrain temporal variability.

Regarding Figure 14, I find this plume observation quite surprising. My understanding is that panel B shows a zoom of panel A, where the background imagery within the red frame is the actual surface imagery at the time of the plume observation. If this is indeed the case, the methane plume shown in panel B appears to be partially located above the cloud…. Did

Tanager observe a methane plume being emitted and/or transported above clouds? If so, this would be quite a surprising find that calls for further explanation. Otherwise, can the authors please explain why the plume mask is overlapping cloudy pixels? How are cloudy pixels managed in the Carbon Mapper L2 processing pipeline? Could the plume seemingly appear above the clouds because of small co-location errors between Tanager RGB and SWIR channels? Could the plume be explained by retrieval artefacts caused by the high cloud density? Please elaborate on this surprising case.

In figure 14 (now figure 7), the plume does not actually overlay the cloud. The extent of the plume color map in panel B is an artifact of smoothing to aid visual visualization for non-expert users of our public data portal. To address the concern raised here we have added the actual plume mask (panel C) used to calculate an IME and emission rate. Additionally, three other Tanager observations of the same source on different dates including those with cloud free conditions indicate this is a persistent emitting source and our emission rate estimates are consistent across that time series. We have added a new panel to the figure showing that time series.

Regarding Figure 15, I am quite uncomfortable with the current framing used to compare the Kayrros Sentinel-5P/TROPOMI plume detection dataset – or any Sentinel-5P/TROPOMI plume detection dataset for that matter – against Tanager detection capabilities. ...So, the authors should reformulate the comparison as to not imply that these emissions should have been detected in TROPOMI.

We thank the referee for flagging this issue and have removed that reference.

Additional comments and concerns on the quality of other figures.

I list my comments for every relevant figure below:
- Figure 1: A colormap or legend to interpret the meaning of colors (see other comments above) should be provided.

Figure 1 has been removed as part of trimming material.

- Figure 4: No labels for x- and y-axis! Please provide these elements including physical units.

Figure 4 (now Figure SI-3) has been amended to provide labels and units.

- Figure 5: Purely decorative, please remove (the whole Section 2.3 could actually be removed, see next significant concern on structure and content).

Figure 5 has been removed. We feel that technical information on the Tanager smallsat bus is important reference information but have moved an abbreviated section to the SI supplement.

- Figure 7: Please consider a merge with Table 3, lots of redundancies between these two.

We feel that figure 7 helps convey the unique nodding imaging mode that differentiates Tanager from most other imaging spectrometer (mostly pure pushbroom) operations.

- Figure 8: Purely illustrative, the angles written on the figure are not defined anywhere. Please remove and just provide a plain-English definition of glint geometry.

We have removed figure 8 and provided a plain English definition.

- Figure 10: Please provide a colorbar with label and units.

Figure 10 has been moved to figure SI-4.

- Figure 11: Please provide a colorbar with a label for the left panel.

In Figure 11 (now figure 4), the left panel shows an RGB image slice overlaid on the hyperspectral image cube, a standard representation for VSWIR imaging spectrometers. Those layers are false colors and we feel that adding a color scale will not be instructive.

- Figure 13: Please see comment above about adding extra information.

Now figure 6, see above response.

- Figure 14: Please provide a colorbar and units and a scalebar for panel A.

Color bar added.

- Figure 15: Please provide a colorbar, longitude of the observed locations and an indication of the significance of the letter labels of the plumes and the map-pin in the right panel.

Now Figure 8. Color bar added. Reformatted image to remove extraneous labels including the map-pin. The latitude references are solely intended to indicate the high latitude location of the scenes. It's unclear that adding longitude provides useful context in this case.

- Figure 16: Please provide a colorbar and scalebars.

Now figure 9. Color bar added.

- Figure 17: Please provide a colorbar.

Now figure 10. Colorbar added.

- Figure 23: Please provide a colorbar.

Now figure 16. This is a grayscale image of a CH4 retrieval intended to convey consistent plume morphology.

- Figure 27: This is purely illustrative, please replace with a figure that supports conclusions (see comment above)

Deleted as part of trimming.

Significant comment and concerns on content

As explained above, I think that this manuscript is an overwhelming read. It provides a lot of information on the Carbon Mapper emission monitoring system but lacks focus around the main and significant scientific novel(es presented in it. I cannot currently recommend the publication of the manuscript without large cuts or transfers to supplements). Besides, similar themes are inexplicably scattered in different corners of the manuscript (see above for completeness study in Sect. 2.1 and 4.3), so I strongly suggest that these cuts come with structure changes. I provide suggestions of cuts and structure change below.

We have endeavored to streamline and shorten the manuscript as suggested. As described above we have removed much of section 2.1 and all of section 4.3. Those topics will be addressed in a future manuscript. Additionally, we have transferred much of the detailed material to SI section.

Cut suggestions:
- Section 2.2, key design parameters driving Tanager detection performance can be quickly summarized in text, and all the non-essential technological details cut from the main text (and moved to supplements if necessary).

Most of this section has been moved to SI section.

- Section 2.3 is a Planet Labs product summary unrelated to the scientific content of this manuscript. It can or even has to) be cut out, and [URL2] can be provided when succinctly describing the Tanager satellite for example.

Shortened to key technical parameters and moved to SI section.

- Section 2.5.1 provides (to my knowledge) new information on the L1 calibration of the Tanager satellite instruments. However, these methodological elements are not directly related to the new scientific content of this manuscript. I suggest cutting

Section 2.5.1 and adding it to the currently provided ATBD documents on Carbon Mapper website and/or move it to the supplements.

We have moved most of this material to SI section as suggested.

- Section 2.5.2 can be heavily summarized focusing on the matched filter and IME methods, and providing a digest explanation of the other steps, namely cloud removal, plume detection, masking, manual verification and publication. References to the already available ATBDs [URL1] can be provided for readers interested in the methodological details.

We have heavily summarized this material in the main body and moved details to SI section as suggested.

I strongly suggest authors to consider a clearer structure centered around the main new scientific materials presented in this manuscript. As an example (already provided above), Sections 2.1 and 4.3 are very related and could be presented at the same place in the manuscript.

We have incorporated this feedback in our responses above.

Significant comment on writing style and tone

I would recommend the authors to revise the text of the listed sections aiming at (1) providing more neutrally phrased information; and (2) synthesizing information redundancy caused by repetitions.

We have carefully reviewed and endeavored to address the comments regarding writing style and tone throughout the manuscript.

Other significant comments, related to the literature review

GHGSat

GHGSat is a Canadian company operating – among others – a constellation of high-resolution (25x25 m2) methane sensitive satellites, providing high-resolution observations of methane plumes that allow to (1) quantify emission rates; and (2) pinpoint where emissions come from. GHGSat has been reporting on their methods in scien(fic literature (e.g. Jervis et al., 2021; McLean et al. 2024) and their observations have been used in different scientific publications (e.g. Varon et al., 2018, 2019, 2020; Maasakkers et al., 2022 or Schuit et al., 2023). Their observations are in nature comparable to Carbon Mapper's, however GHGSat is not mentioned in the literature review currently provided in the manuscript. Can authors report on GHGSat in their literature review?

We thank the referee for flagging this oversight. We have added a new section that offers a broader review of point source imaging satellites where we elaborate more fully on GHGSat and other relevant sensors to provide better context for where Carbon Mapper and the Tanager satellites contribute to the broader ecosystem of satellites.

TROPOMI detection threshold

Lower emission rate TROPOMI plume detections have been reported in the literature than the > 50 t/hr threshold reported by Lauvaux et al. (2022, 2021 is written in the text, please correct). For example, Schuit et al. (2023) provide a methane plume detection threshold of ~8 t/hr. I suggest authors revise the reported TROPOMI methane plume detection threshold or report a range including both references.

We thank the referee for flagging this and have added the Schuit et al number and citation.

Thermal infrared observations

AIRS is not the only instrument that can provide mid-tropospheric columns of CO2 and/or CH4. The thermal infrared sounder IASI has been providing similar products since 2006 (e.g. Crevoisier et al., 2009a, Crevoisiser et al., 2009b). I suggest authors to either include a complete review of GHG-sensitive thermal infrared products or, considering that thermal infrared observations are quite unrelated to high resolution SWIR-based observations of anthropogenic GHG emissions, to remove the thermal infrared discussion from the literature review.

We agree and have eliminated the reference to thermal IR sounders.