The manuscript by Tsuruta et al., titled "Global CH4 Fluxes Derived from JAXA/GOSAT Lower Tropospheric Partial Column Data and the CTE-CH4 Atmospheric Inverse Model," explores, for the first time, the potential of the new lower tropospheric partial column, comparing it to several other inversion setups. In general, the authors propose useful concepts for the effective use of partial columns to constrain surface CH4 emissions, which is the second most important greenhouse gas (GHG). The authors highlight the following main findings: 1) "the advantages of JAXA/GOSAT lower tropospheric partial column retrievals in estimating global and regional CH4 budgets", 2) "lower tropospheric partial column data possibly reduce global emission uncertainty," and 3) "highlighted the importance of transport model resolution in estimation of total and partial column data, indicating the need for high resolution transport models in satellite-driven inversions". The overall structure of the article is well-organized and balanced. The methods and techniques employed are appropriate. The manuscript is scientifically sound, references previous literature appropriately. At the same time, it also highlights critical issues that must be addressed to ensure the accuracy and reliability of its results before the manuscript publication.

Major comments

1. Unfortunately, the main results are inadequately supported in the manuscript text:

    1.1. The test results are too evident and speculoos: InvSURF consistently outperforms in nearly all comparisons, including those with ground-based observations, demonstrating its superior performance in a broad range of cases. In contrast, InvGTOT proves to be more effective when compared to TCCON, as shown in Table 1. While the text emphasizes the benefits of InvGLT and InvGLT_land, these advantages appear to be overstated and are not substantiated by the observed results. The claimed improvements from InvGLT and InvGLT_land are not as pronounced or significant as suggested, and the data do not provide clear evidence to support the substantial benefits that the text implies.

    1.2. The reduction in emission uncertainty is not adequately supported by the data or analysis presented. The discussion lacks sufficient evidence to substantiate the claimed improvements in uncertainty reduction. Furthermore, the sentence on lines 323-326: “Within the GOSAT inversions, the number of assimilated data were higher in InvGTOT than InvGLT (Fig. A8), and the observational uncertainty and rejection thresholds were the same in both inversions. This indicates that the lower uncertainty in InvGLT was not simply due to the number of assimilated observations” introduces significant confusion, as it directly contradicts the fundamental principles of satellite inversion. Rayner and O'Brien (GRL, 2001) proved that a large number of satellite observations, even with moderate precision, can effectively constrain the global greenhouse gas (GHG) budget, a concept that has been further explored and validated in a variety of studies. The assertion that lower uncertainty in InvGLT is not attributable to the number of assimilated observations appears to be inconsistent with well-established principles of satellite data assimilation. Moreover, there are several critical questions that remain unaddressed and must be clarified for a more thorough understanding of the results. For instance, why is the maximum uncertainty reduction rate observed over ocean grids (Figure 6)? Additionally, why is there no significant difference in the uncertainty reduction between InvGLT and InvGLT_land? Given that InvGLT_land should involve a significantly different number of assimilated points due to the exclusion of oceanic regions, one would expect to observe clear discrepancies in the uncertainty reduction rates between these two inversion types. These unanswered questions call for further clarification and analysis to better support the conclusions regarding emission uncertainty reduction.

1.3 The effect of higher horizontal resolution on atmospheric models is well-documented and extensively discussed in the literature, as estimated in numerous studies (e.g., Houweling et al., ACP, 2004; Patra et al., ACP, 2011). These studies suggest that increased resolution leads to more accurate representation of atmospheric processes, with finer grids providing a more detailed and reliable depiction of the distribution of greenhouse gases, including methane. However, in this particular context, Figure A2 presents a particularly puzzling result that warrants further explanation. The figure demonstrates a clear discrepancy in the impact of grid resolution on the modeled data, as the difference calculated using the course 2° × 3° grid (Fig. A2d) is unexpectedly much smaller than the difference calculated using the finer 1° × 1° grid (Fig. A2a). This inconsistency in the figure requires clarification, as it challenges the well-established understanding that higher resolution typically enhances model accuracy. It also raises important questions about the potential influence of other factors, such as the observational data or the specific methodological approach used to process the results.

2. This study fails to account for averaging kernels, which are crucial for accurately comparing observed and modeled xCH4 values due to the inherent variability in the sensitivity of GOSAT instruments to vertical profiles of CH4. Averaging kernels represent instrumental sensitivity at different altitudes, and they play a key role in converting the observed column-integrated measurements into more precise information about the distribution of CH4 in the atmosphere. Without properly accounting for averaging kernels,

the comparison between the observed and modeled data could be misleading, as it would fail to fully capture the nuances of the instrument's sensitivity. Given that averaging kernels are now available in the latest version of the JAXA/GOSAT partial column product (v3.0), I strongly urge that all calculations in this study be revisited using the updated product. This would ensure that the analysis accounts for the improved accuracy and sensitivity provided by these kernels, which are crucial for obtaining more reliable results in satellite-based inverse modeling of methane emissions.

3. The definitions of parameters such as pXCH4_LT, pXCH4_LTmodel, and other partial column parameters utilized in this study are overly complex and may hinder the reader's understanding of the conceptual framework being presented. These definitions are essential for interpreting the study's methodology, but their complexity could lead to confusion for those not intimately familiar with the technical details. To improve clarity and facilitate a better understanding of the work, I strongly recommend the inclusion of a schematic plot that visually illustrates the concept of these parameters. A schematic diagram would provide a clear, step-by-step representation of how these parameters are defined and calculated, thereby enhancing the transparency of the study. This addition would greatly aid readers in comprehending the methodology and the relationships between the different variables involved.

Minor comments:

P2, L18: from Table 2. In https://www.esrl.noaa.gov/gmd/aggi/aggi.html, Global Radiative Forcing (W m^{-2}) is 0.561 in 2022 and 0.565 in 2023. Please clarify.

P3, L50: please consider correction: "before performing satellite inversions" -> "before performing satellite-based inversions"

P5, L134: Looks confusing, please revise: "Vertical interpolation was not applied, leading to potential biases."

L181: "the stratospheric partial column of $XCH_{4\,TCCON}^{tropo}$" the tropo index confusing in this context.

P10, Table 1: "Bias, root mean squared error (RSME) and Pearson's correlation against observations at surface ground-based stations assimilated in InvSURF, ATom aircraft measurements, and TCCON data." It seems other inversion cases should be added in the table description.

P11, Figure 3: It seems that the figure subtitles should be above panels.