Reviewer 2

General comments:

Feng et al. investigate methane production and loss as drivers of global methane growth from 2018-2024 using GOSAT observations in two inversion frameworks (jointly optimizing OH and prescribing climatological OH). This is an interesting and relevant study that builds on previous work by showing the influence of the two treatments of OH on source attribution up to more recent years. I would like to see some additional detail and clarification addressing the comments below before I recommend publication.

We thank the reviewer for the insightful and constructive comments. We have addressed them in detail below.

Specific comments:

Line 116: I suggest that the authors report the implied global methane lifetime against tropospheric OH for both inversions (and for the prior) and compare to observationally-constrained estimates and/or other studies.

The methane lifetime against tropospheric OH implied by the inversion with fixed OH fields ranges from 11.30 to 11.63 years during 2019–2024, compared with 10.83 to 11.54 years in the control inversion. These values fall within the range reported in previous studies, although substantial uncertainty remains in the global OH abundance and its long-term variability. Recent studies have suggested both increasing OH concentrations (Zhu et al., 2026) and potential overestimation of OH in chemical transport models, highlighting the continuing uncertainty in methane sink estimates.

We have added the comparison:

Currently estimates of OH remain highly uncertain. Some studies have suggested increasing atmospheric OH concentrations (e.g, Zhu, Y., Shen, L., Liu, G. *et al.* Atmospheric CH_4 plateau sustained by NO_x emission rise and southward shift. *Nature* **657**, 674–679 (2026). https://doi.org/10.1038/s41586-026-10983-w). Other recent studies have suggested that the OH concentrations may be overestimated in chemical transport models (e.g., Toward Realistic Prognostic Modeling of the Methane Chemical Loss, *J. Geophys. Res.*, *131*, e2025JD045079, doi:10.1029/2025JD045079.). These findings highlight the substantial uncertainty that remains in the magnitude and long-term evolution of the global methane sink.

Lines 131-133: What is the justification for the 40% fixed uncertainty and the a priori spatial correlation length of 300 km? Has this been tested?

We thank the reviewer for this comment. We acknowledge that the prior error covariance, including the assumed 40% uncertainty and 300 km spatial correlation length, cannot be specified precisely because of limited knowledge of prior flux errors.

To assess the impact of these assumptions, we performed a series of sensitivity experiments. The manuscript has been revised to clarify this point:

“Sensitivity tests (not shown) demonstrate that our results are largely insensitive to the assumed prior error covariance. Adjusting the a priori uncertainties by ±20% changes the annual global emission estimate by less than 1%. Similarly, increasing the spatial correlation length from 300 km to 360 km changes the global annual emission by less than 5 Tg yr^{-1}. The impact on the interannual variability of the a posteriori global methane emissions and sinks, which is the primary focus of this study, is also small, generally below 5 Tg yr^{-1}.”

These results indicate that the major conclusions of the study are robust to reasonable variations in the assumed prior uncertainty and correlation length.

Lines 167-168 say that “On a global scale, the Inv-OH methane loss due to OH is due mainly to changes from the northern extratropics (Figure 2d), with only a small change originating from the tropics since 2020 (Figure 2c).” This seems inconsistent with Figure 2c which shows the tropics have the greatest magnitude of the sink, and with lines 163-165: “For Clim-OH and Inv-OH, we find that the tropics (Figure 2c) account for about 60-70% of the global chemical sinks (Figure 2a)…” Are you distinguishing between the absolute magnitude of the sink vs the interannual changes in the sink?

We thank the reviewer for pointing out this ambiguity. We agree that the tropics account for the largest fraction of the absolute global methane sink (approximately 60–70%, Figure 2c), as noted in Lines 163–165. However, the statement in Lines 167–168 refers to the contribution of different regions to the interannual variability of the methane sink rather than to its absolute magnitude.

We have clarified the text as follows:

“For interannual variations, the Inv-OH experiment shows that global and regional methane loss by OH fluctuates from year to year, whereas the Clim-OH experiment produces a more gradual increase driven primarily by rising atmospheric methane concentrations. Although the tropics account for the largest share of the absolute methane sink (Figure 2c), changes in the global methane sink since 2020 are driven mainly by variations in the northern extratropical sink (Figure 2d), with a comparatively smaller contribution from tropical OH changes.”

Line 237: Consider citing additional studies on South America/Amazon drought (e.g., Espinoza et al. 2024, Geirinhas et al. 2023)

Good suggestion. We have added the reference.

Line 242: Scaling factor needs a reference (e.g. Nisbet et al. 2023)

Reference added.

Lines 251-252 say there is a "modest increase in 2024" for OH, but line 257 says there is a "pronounced decrease observed in 2024 (Figure 1b)" when referring to OH concentrations. Figure 1b shows that OH decreases in 2024, so there is an inconsistency in these two sentences.

We thank the reviewer for identifying this inconsistency. The statement in Line 251 was incorrectly worded. Figure 1b shows that the inferred global mean OH concentration decreases in 2024. We have revised the text to ensure consistency throughout the manuscript.

Figure 7c shows the same analysis but for Inv-OH, for which we infer a posteriori changes in OH and methane emissions. We find substantial changes in OH throughout the study period, with a peak value in 2020, followed by a decline through 2024.

We have amended Line 257:

This pattern reflects the post-COVID recovery and stabilization of OH concentrations from 2020 to 2023, followed by a decrease in 2024 (Figure 1b).

Lines 288-292: The discussion highlights the need for improved observational constraints on methane, and so should also mention TROPOMI, which provides much denser coverage than GOSAT. Several recent global methane inversions have used TROPOMI XCH4 for constraining emissions and OH.

We agree that TROPOMI has become an important source of information for methane inversions because its dense spatial coverage provides much stronger observational constraints than GOSAT alone. We have therefore expanded the discussion and added references to recent studies that use TROPOMI XCH4 observations to constrain methane emissions and OH.

At the same time, differences among retrieval versions and residual inconsistencies between TROPOMI and GOSAT products remain an area of active investigation and can influence inversion results. We therefore view the joint use of multiple satellite data sets as an important next step.

To address this reviewer comment, we have added the following sentence to the manuscript:

"TROPOMI provides much denser spatial coverage than GOSAT and has been used extensively in recent methane inversion studies (Hachmeister et al., 2024). Future work will explore the joint assimilation of TROPOMI and GOSAT observations to further improve constraints on methane emissions and OH, while accounting for potential systematic differences between the two data sets."

Figure 3b: The differences in methane loss to OH between adjacent latitude bands are very stark, especially between the northern tropics and northern extratropics. Are the results (including for emission estimates) sensitive to the choice of latitude bands?

We acknowledge that the sharp contrasts between adjacent latitude bands reflect the limited spatial degrees of freedom used to optimize OH. The latitudinal scaling approach was adopted because the indirect observational constraints on OH are not sufficiently strong to robustly estimate OH adjustments at much finer spatial resolutions.

To assess the sensitivity of our results to this assumption, we performed an additional experiment in which the OH scaling factors were optimized across narrower 15° latitude bands. The resulting OH adjustment patterns exhibit greater spatial detail and smaller contrasts between latitude bands (See responses to Reviewer 1). However, the inferred global methane emissions, methane sink, and their interannual variability remain broadly consistent with those obtained using the 25° latitude-band configuration. These results indicate that the principal conclusions of this study are not strongly sensitive to the choice of latitude-band width. In addition, in the revised paper, we report the new inversion with10 scaling factors for OH concentrations at 15° latitude bands as the control run, and have added a discussion of these results and the implications in the revised manuscript.

How does the inversion separate OH and emission contributions (i.e., distinguish between the two signals), since OH can alias with emission adjustments?

We acknowledge that methane emissions and OH are intrinsically coupled in atmospheric methane inversions because changes in either quantity can affect atmospheric methane concentrations. To reduce this aliasing, our inversion exploits the distinct spatial and temporal signatures associated with emissions and OH. Methane emissions primarily influence concentration gradients between source regions and downwind/background regions, whereas OH variations affect methane more broadly through changes in its atmospheric loss rate. The observational constraints therefore provide information on both the magnitude and spatial distribution of methane concentrations, helping to distinguish between source and sink changes.

We also note that the optimized OH field has a relatively small number of degrees of freedom, with scaling factors estimated for broad latitude bands, whereas methane emissions are optimized at much finer spatial resolution. This framework helps reduce the potential for OH changes to compensate for regional emission errors.

Finally, the limited posterior correlations between the optimized OH scaling factors and methane emissions suggest that the inversion can distinguish these two contributions with reasonable confidence. Our findings are also consistent with recent studies demonstrating that satellite methane observations contain useful information for constraining tropospheric OH (e.g. Penn et al., 2025). We have added text to clarify this point in the revised manuscript.

We have added the following text in the manuscript:

“Although methane emissions and OH both influence atmospheric methane concentrations, they produce different spatial and temporal signatures. Emissions primarily affect concentration gradients associated with source regions, whereas OH changes modify the large-scale methane loss rate. By jointly assimilating satellite observations and optimizing OH only at broad latitudinal scales, the inversion can exploit these distinct patterns to separately constrain methane emissions and OH.”

Technical corrections:

- **Line 75: Missing a period after 2024**
- **Lines 189 and 218: Is this “significant” statistically significant? Consider using a different word if not.**

  Change to ‘substantial’
- **Line 205: 2024 typo**
- **Line 223: Typo “zero a priori bias is assumed to be zero”**
- **Line 248: Sentence repeats “due to” multiple times**
- **Figure 7 caption: NOAA data is in green, not cyan**

We have corrected all typos.

References:

Hachmeister, J., Schneising, O., Buchwitz, M., Burrows, J. P., Notholt, J., and Buschmann, M.: Zonal variability of methane trends derived from satellite data, Atmos. Chem. Phys., 24, 577–595, https://doi.org/10.5194/acp-24-577-2024, 2024.

Penn, E., Jacob, D. J., Chen, Z., East, J. D., Sulprizio, M. P., Bruhwiler, L., Maasakkers, J. D., Nesser, H., Qu, Z., Zhang, Y., and Worden, J.: What can we learn about tropospheric OH from satellite observations of methane?, Atmos. Chem. Phys., 25, 2947–2965, https://doi.org/10.5194/acp-25-2947-2025, 2025.