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Manuscript: Evaluation of the GOSAT/GOSAT-2 XCO₂ proxy XCH₄ product by comparison with TCCON observations over China

Iteration: Minor revision

Dear Reviewer,

Thank you very much for your constructive comments and suggestions. We have carefully revised the manuscript in response to your comments, which have helped us improve its clarity and scientific discussion. We have supplemented the Abstract, Sect. 5.2, and Conclusions to further discuss the influence of regional and local methane emissions, atmospheric transport, and spatial sampling differences on satellite–TCCON comparisons, as well as the associated spatial representativeness uncertainties. We hope that the revised manuscript satisfactorily addresses your concerns.

Below, our responses are presented in black and the corresponding revisions made in the manuscript are highlighted in red. All page and line numbers cited in our responses refer to the clean version of the revised manuscript.

Response:

Regarding the comments, we recognize that differences among satellite products may arise not only from retrieval algorithms and instrument characteristics but also from differences in spatial sampling. The satellite observations within the $\pm 2.5^\circ$ matching domain cover areas with different emission and transport conditions. As the reviewer pointed out, both TCCON sites in China are affected by local and regional emission sources, which, together with variations in horizontal and vertical transport, result in inhomogeneous XCH₄ distributions and affect the representativeness of satellite–TCCON comparisons. In particular, the positive OCPD biases south of Xianghe may be associated with greater sampling of urban or methane-enhanced areas. We have therefore expanded Sect. 5.2 to discuss the influence of methane emissions, atmospheric transport, and spatial sampling on the validation results. We have also revised the Abstract and Conclusions to explicitly acknowledge these effects and their implications for the spatial representativeness of satellite–TCCON comparisons. The corresponding revisions are provided below:

Abstract:

“All products, except OCPD, overestimate XCH₄ at Hefei and underestimate XCH₄ at Xianghe, due to XCO₂ model errors and spatial differences associated with regional and local methane emissions affecting both sites.” (Page 1, Line 30 ~ 31)

Sect. 5.2:

“Compared with the other products, OCPD may include more observations over urban or potentially methane-enhanced areas to the south of the Xianghe site, where satellite footprints may capture higher XCH₄ concentrations than those measured at the TCCON site, contributing to its extensive positive biases.” (Page 21, Line 643 ~ 645)

“These spatial differences indicate that regional and local methane emissions may affect the representativeness of satellite–TCCON comparisons at both sites. As the satellite observations used in this study were not acquired in target mode over Hefei and Xianghe (Suto et al., 2021), the $\pm 2.5^\circ$ matching domain includes measurements from different locations that may be influenced by different emission and transport conditions. The uneven distribution of anthropogenic methane emissions

produces spatial variations in atmospheric CH₄ concentrations, particularly in urban and emission-intensive regions of northern China (Han et al., 2025). Methane emitted from urban and other emission-intensive areas is transported and dispersed by atmospheric circulation, with variations in wind fields, vertical mixing, and terrain affecting the location and extent of methane enhancements, thereby contributing to spatial differences in XCH₄ between satellite footprints and TCCON observations (Gao et al., 2026; Zheng et al., 2026).” (Page 21, Line 660 ~ 668)

Conclusions:

“The data presented indicate that the two TCCON sites in China are affected by local and regional emission sources which, together with variations in horizontal and vertical transport, result in inhomogeneous distributions of XCH₄ which in turn affect the representativeness of satellite–TCCON comparisons.” (Page 23, Line 697 ~ 700)

Response:

Regarding the suggestion that “careful data selection may be necessary, including filtering based on wind direction and speed and excluding enhanced area affected by downwind emission sources,” we recognize that such filtering could help reduce the influence of regional and local methane emissions on satellite–TCCON comparisons. However, methane transport involves three-dimensional atmospheric processes that cannot be fully characterized by surface wind conditions alone. In addition, cloud and aerosol conditions can affect the availability of valid satellite retrievals, resulting in uneven spatial sampling. Therefore, filtering based solely on surface wind direction and speed may not fully resolve the spatial representativeness differences between satellite and TCCON observations. We have added a discussion of these limitations to the Conclusions and emphasized the need to consider atmospheric transport, emission-related concentration gradients, and observation sampling in future validation studies. The effects of additional wind-based filtering on the current validation statistics have not been evaluated. The corresponding revisions are provided below:

Conclusions:

“In addition, regional and local methane emissions introduce spatial representativeness uncertainties into satellite–TCCON comparisons. Methane enhancements are influenced by three-dimensional atmospheric transport, while cloud and aerosol conditions can affect the availability of valid satellite retrievals, resulting in uneven spatial sampling. These effects cannot be fully accounted for by simple filtering based on surface wind direction and speed. Future validation studies should therefore consider the combined influence of atmospheric transport, emission-related concentration gradients, and observation sampling to better distinguish spatial representativeness errors from satellite retrieval biases.” (Page 23, Line 720 ~ 725)