Dear Editor, and referees,

We appreciate the time and effort that you dedicated to providing feedbacks on our manuscript. We have addressed the comments and incorporated suggestions made by Reviewers 1 and 2. Please see below, in blue, for a point-by-point response.

Best regards,

Minqiang Zhou and all co-authors

Referee #2:

In this contribution, the authors presented the first ground-based FTIR GHG observation data collected on Qinghai-Tibetan Plateau from a 20-day campaign and the inter- comparisons with in-situ measurements and satellite GHG products. This study fills an important gap in GHG observations over the Tibetan Plateau. The paper is well-structured and summarizes the key findings. While the core contribution is solid, the manuscript would benefit from revisions to improve clarity and strengthen certain aspects of the analysis.

Major comments

1. Calibration: The study employs standard GGG2020 retrieval procedures and X/O2 normalization. However, it remains unclear whether additional calibrations were implemented to account for the unique high-altitude environment at QOMS. The manuscript should address whether Instrument Line Shape (ILS) characterization was performed under high-altitude conditions. Since GGG2020 a priori profiles are based on GEOS-FPIT, which may not fully capture local thermodynamic conditions on the plateau, it would strengthen the analysis to discuss whether alternative data sources (e.g., radiosonde data or ERA5 reanalysis) were considered, and how sensitive the retrievals, particularly XCH4, are to such profile inputs in this setting.

Thanks for the comments.
Regarding the ILS characterization, unfortunately we did not have the lab resources at QOMS and could not perform the ILS measurements during the campaign. Instead, we did the ILS measurements before and after the campaign at IAP/CAS Beijing (Table 1). As the modulation efficiency and phase error keep almost unchanged before and after the campaign, indicating that the EM27/SUN instrument was well protected during the long-distance transportation. The observed ILS parameters have been used by the GGG2020 code. Since the ILS is mainly determined by the alignment of the instrument and not dependent on the surface pressure, the ILS parameters should be stable during this campaign.

Table A1. The modulation efficiency and phase error of the EM27/SUN instruement line shape.

Date	Modulation efficiency	Phase error
In 2019 from Bruker company	0.9792	0.0026
23 March 2022; before campaign	0.9773	0.0033
04 August 2022; after campaign	0.9771	0.0035
03 July 2023; one year after campaign	0.9762	0.0036

Regarding the a priori inputs, we have no measurements, such as radiosonde data.

Following your suggestion, we have done a comprehensive uncertainty analysis of the FTIR retrievals. We test ERA5 data by using the temperature and humidity profiles from ERA5 reanalysis data. In addition, to estimate the uncertainty from the gas a priori profile, in the revised version, we manually add 2% random noise on the TCCON prior. More detail information could be found in Table A2.

2. Uncertainty: While the manuscript acknowledges limitations in GEOS-FPIT a priori profiles (Lines 156-162), a quantitative assessment of their impact is lacking. Given this study's contribution to satellite validation, it is recommended to include a comprehensive uncertainty analysis of the FTIR retrievals. Specifically, a decomposition of systematic and random error components — including contributions from spectroscopy, observation geometry, a priori dependence, and instrumental effects— would significantly enhance the robustness of the results and align with AMT community standards.

Thanks for the suggestion. In the revised version, we have added the uncertainty estimation (Table A2) in the appendix I. The uncertainties of the EM27/SUN CO2, CH4, CO and N2O measurements at QOMS are estimated by perturbing the inputs using the GGG2020 code. In this study, we include contributions from instrumental effects (ILS), observation geometry (pointing offset), temperature profile, spectroscopy (line intensity), a priori dependence, and measurement noise.

Table A2. List of sources, values used for the uncertainty analysis, and CO2, CH4, CO and N2O column retrieval uncertainties for all measurements at QOMS site using the GGG2020 code. (ME: modulation efficiency amplitude; SNR: signal-to-noise ratio). The third column provides the partitioning of the error values between random (ran) and systematic (sys) contributions. Note that an uncertainty less than 0.01% is indicated as '-'.

Error source	Uncertainty value	sys/ran contribution [%]	CO_2 column uncertainty (sys/ran) [%]	CH_4 column uncertainty (sys/ran) [%]	CO column uncertainty (sys/ran) [%]	N_2O column uncertainty (sys/ran) [%]
Prior	2%	50/50	0.01/0.01	0.02/0.02	0.04/0.04	0.08/0.08
ILS (ME and phase error)	1% and 0.01rad	50/50	0.1/0.1	0.1/0.1	0.1/0.1	0.1/0.1
Pointing offset	0.1°	10/90	-/0.1	-/0.1	-/0.1	-/0.2
Temperature profile	2 K	50/50	0.03/0.03	0.15/0.15	0.80/0.80	0.07/0.07
Spectroscopy	2%	100/0	2.0/-	2.0/-	2.0/-	2.0/-
Measurement noise	1/SNR	0/100	-/0.1	-/0.1	-/0.3	-/1.2
Total			2.0/0.2	2.0/0.2	2.0/0.9	2.0/1.2

Minor comments

1. Timing: The campaign was conducted in May, but it remains unclear whether this timing was chosen based on specific meteorological conditions and seasonal patterns of greenhouse gas concentrations in the QTP region, or if it was mainly due to logistical constraints such as resource availability and research team schedules. This raises questions about the representativeness of the May observations - to what extent can the findings represent annual or seasonal variations in greenhouse gas concentrations? Could the authors comment on whether the GHG levels during this period are climatologically representative based on past in situ or model records, or whether they might

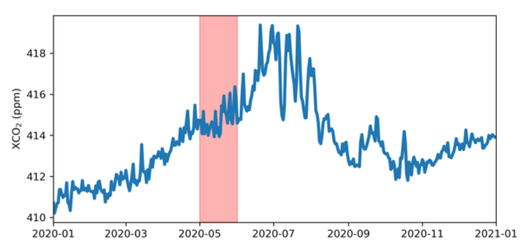
reflect transient synoptic conditions? Are there any plans to conduct additional observations during other seasons to provide a more complete temporal coverage?

Thanks for the comment.

This GHG campaign is part of the Earth Summit Mission-2022, so the timing is mainly determined by the resource availability and research team schedules. As a key task of the Earth Summit Mission: a team climbed up to the top of Mt. Qomolangma to install several meteorological stations and brought back the ice core of the mountain. The best time to climb the Mt. Qomolangma is in spring (between April and May). The mountain is virtually unclimbable in summer due to the deadly monsoon season which generally brings mist to the area. In winter, this region is extremely cold.

Using the CAMS global greenhouse gas reanalysis (EGG4) model (https://ads.atmosphere.copernicus.eu/datasets/cams-global-ghg-reanalysis-egg4?tab=overview), we plot the XCO2 and XCH4 mole fractions at QOMS in 2020. Based on the CAMS model, the XCO2 at QOMS keeps increasing in May and it starts decreasing in August. The XCH4 at QOMS in May is relatively low, and the XCH4 values become large in July-September.

In August 2024, we have installed one EM27/SUN at Nagqu, Tibet. Currently, the FTIR at Nagqu is continuously operating and we plan to keep the measurements at least for another year.



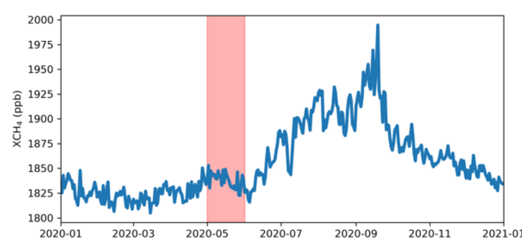


Figure A1. The time series of XCO2 (left) and XCH4 (right) from the CAMS greenhouse gas model simulations in 2020.

2.OCO-2 Distance (Line 132): The spatial representativeness of QOMS FTIR measurements, particularly when comparing with OCO-2 data at distances up to 500 km, requires further discussion. Has the spatial variability of XCO2/CH4 over the Tibetan Plateau been evaluated through regional modeling or high-resolution simulations? A discussion of potential spatial representativeness error would be helpful here.

Thanks for the suggestion.

We now use the CAMS model simulations in May 2020 to estimate the spatial variability of XCO2 between the QOMS and OCO-2 footprints in this study.

The mean and std of the differences in CAMS XCO2 between the QOMS and OCO-2 footprint around 29.2°N, 84.5°E (~250 km away) are 0.02 ppm and 0.27 ppm, respectively. The mean and std of the differences in CAMS XCO2 between the QOMS and OCO-2 footprint around 30.2°N, 82.4°E (~480 km away) are 0.10 ppm and 0.34 ppm, respectively.

In the revised version, we have add the texts:

"As the footprint of OCO-2 is not exactly over the QOMS site, we the CAMS model simulations in May 2020 to estimate the spatial variability of XCO_2 between the QOMS and OCO-2 footprints in this study. The mean and std of the differences in CAMS XCO_2 between the QOMS and OCO-2 footprint around 29.2°N, 84.5°E (~250 km) are 0.02 ppm and 0.27 ppm, respectively. The mean and std of the differences in CAMS XCO_2 between the QOMS and OCO-2 footprint around 30.2°N, 82.4°E (~480 km) are 0.10 ppm and 0.34 ppm, respectively. According to the CAMS model simulations, the XCO_2 spatial variability in this region is relatively small."

3. Comparison to 6 sites (Line 164): The rationale for comparing QOMS to six mid- latitude urban/suburban TCCON sites is unclear. They are mostly urban or suburb sites while QOMS is far from anthropogenic sources. It could be imagined that the Xgas at QOMS is lower. Given QOMS is a remote high-altitude site, a more meaningful comparison may be with other background or mountain sites such as Izaña, which are more comparable in atmospheric conditions and anthropogenic influence.

Thanks for the suggestion. In the revised version, the measurements at Izaña are added in the Table 1, and related texts are modified in the paper.

4. 3 weeks (Line 196): The correlations between XCO2 and XCH4 are different in the three weeks. Are they driven by different weather/chemical conditions? It would help to link these changes in correlation patterns with meteorological conditions, e.g., changes in wind direction or boundary layer dynamics.

Thanks for the suggestions.

We now add the FLEXPART backward simulations to better understand the sources of the airmass coming from during this campaign. The main settings of the FLEXPART model are listed in Table A2. Figure A4 shows the backward sensitivities on 7, 16 and 21 May 2022. It is noted that the enhancement of the measurements on 16 May 2022 is mainly due to the transport. Compared to 7 and 21, on 16 May, there is a significantly greater airmass at QOMS from North India, with higher gas concentrations.

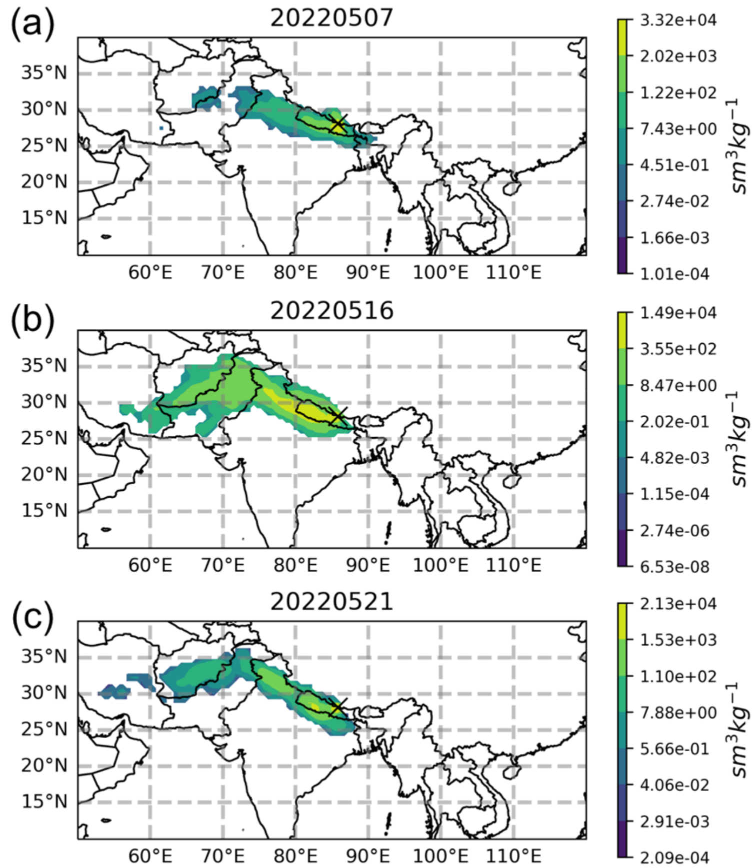


Figure A4. The spatial distribution of air backward sensitivities at QOMS between 04:00-05:00 (UTC) on 7, 16, 21 May 2022. The QOMS site is marked with a cross symbol.

5. in-situ VS TC (Line 230): The CH4 surface mole fraction is **averagely** 97 ppb larger than the XCH4, but Figure 5b appears to show contradictory patterns where surface measurements are lower than XCH4 in 7 of 12 days. Could the "97 ppb higher" represent the real difference? This discrepancy between the daily mean bias and daily value distribution may suggest that outliers or skewed distributions contributed disproportionately. A histogram or scatter plot of daily differences might clarify this.

In Figure 5, the EM27/SUN measurements are shown in the right y-axis, which has a different range as compare to the left y-axis. In general, the EM27 reports lower XCO2 and XCH4 than surface measurements all through the campaign period. To avoid confusion, we now add some texts in the caption of the Fig.5.

"Similar to Figure 4, but adding the EM27/SUN FTIR XCO2 and XCH4 hourly means and stds (right y-axis) between 13 and 24 May 2022."

Technical comments

Line 2: and contribute to ... → contributing to/and contributions to

Line 8: end → and
Line 17: Qomolongma→ Qomolangma
Line 227: mesurements → measurements

Line 328: OCO-3 → OCO-2
Line 366: CH4mole → CH4 mole
It is recommended to write out full form at first mention, e.g. “std”.

Thanks, and all these have been corrected.