Black: referee's comments red: authors' answers
First of all, we want to thank the referee for the detailed analysis of our paper.
For the details, please look into the paper with keeping track of changes.

Anonymous Referee #1

General comments: The paper describes a new ground-based FTIR measurement site in China, presents a study of greenhouse gases using a ground-based Fourier Transform Infrared Spectrometer of the Bruker IFS 125HR. The measured spectra are analyzed using the GFIT-2014 code and the retrieved Xgas are presented. The XCO2 retrieved from the ground-based FTIR are compared to XCO2 retrieved from OCO-2, XCH4 and XCO retrieved from the ground-based FTIR are compared to the XCH4 and XCO retrieved from TROPOMI satellite observations. However, the description of the paper lacks scientific significance and originality. Also ,the time series of target gases cover only one year period, so some discussion and conclusions are not representative.
The paper is aim to describe the new ground-based FTIR XCO_2, XCH_4 and XCO measurements at Xianghe, and to show that the data quality of our FTIR measurement is comply with the TCCON requirement. The site is located in a very polluted area in North China, with no TCCON site at the moment. These measurements are very useful for the climate and air pollution studies as well as related satellite validation.

Specific comments:
1. The aim of the study is to validate satellite data using the FTIR observations, but the paper doesn't describe how to evaluate the accuracy or precision of the FTIR observations.
In the revised version, we reword the title, abstract, introduction and conclusion to make the target of our paper more clear. In fact, the aim of the study is to describe the ground-based FTIR data at Xianghe, and to show that the data quality of our FTIR measurement is comply with the TCCON requirement.

The data quality at Xianghe is assessed by the instrument line shape, the quality of the spectra, the uncertainty of the metadata, the residual of the fitting, and the standard deviation of the retrievals. The setup of the instrument at Xianghe follows the guidance of the TCCON, and in this paper we prove that all these parameters meet the TCCON requirements. In addition, the spectra at Xianghe are analyzed by the standard retrieval code (GGG2014), where the systematic uncertainty (accuracy) of the retrieval is mainly from the spectroscopy. According to the comparison with aircraft or AirCore measurements (Wunch et al., 2015), the systematic correction factors are already implemented in the GGG2014 code to eliminate the systematic uncertainty of XCO_2, XCH_4 and XCO retrievals (mainly from the spectroscopy uncertainty). The random uncertainties (precision) of the XCO_2, XCH_4 and XCO retrievals at Xianghe are evaluated by their standard deviations (see Table 1 and Table 2 in the revised version), and their random uncertainties are all within the TCCON reported errors (Wunch et al., 2015).

2. The discussion about day to day variations of Xgas in section 3.3 only use 6-day data, for example in Fig. 10 and 11, so the conclusions about the day to day variation trend of Xgas and the emission source are not reliable and representative.
Thanks for the suggestions. More analyses are added in the revised to make the statement reliable and representative:

Figure 1 (a, b) shows the correlations between the XCO and XCO_2 daily means and between the XCO and XCH_4 daily means at Xianghe. XCO_2 is high in winter and low in summer, and XCH_4 is high in summer and autumn and low in winter. In order to reduce the impact from the seasonal variation, a linear regression model is used to fit the time series of the measurements

$$Y(t) = A_0 + \sum_{k=1}^{3}(A_{2k-1}\cos(2k\pi t) + A_{2k}\sin(2k\pi t)) + \Delta Y(t),$$

where $Y(t)$is the measurements of XCO_2, XCH_4 or XCO; A_0 the mean of the measurements (background), and A_1-A_6 are the amplitudes of the periodic variations during the year (seasonal variation); $\Delta Y(t)$ is the measurement without background and seasonal variations, representing the day-to-day variation. Note that, we assume there are no trends of these species due to a relatively short time coverage of about one year. Figure 1 (c, d) show the correlations between the ΔXCO and ΔXCO_2 daily means and between the ΔXCO and ΔXCH_4 daily means. The correlation coefficient (R) between XCO and XCO_2 increase from 0.50 to 0.66, and the R between XCO and XCH_4 increase from 0.67 to 0.82. The seasonal variation of ΔXCO_2 still can be observed, but the amplitude is much reduced. There is almost no seasonal variation of ΔXCH_4. Figure 2 shows the correlations in all seasons. It is found that a good correlation between ΔXCO and ΔXCH_4 is found for the whole year, with R values in the range of 0.72-0.87. There is a good correlation (R>=0.85) between ΔXCO and ΔXCO_2 in autumn and winter, and a slightly weak correlation (R=0.47) in spring and (R=0.57) in summer.

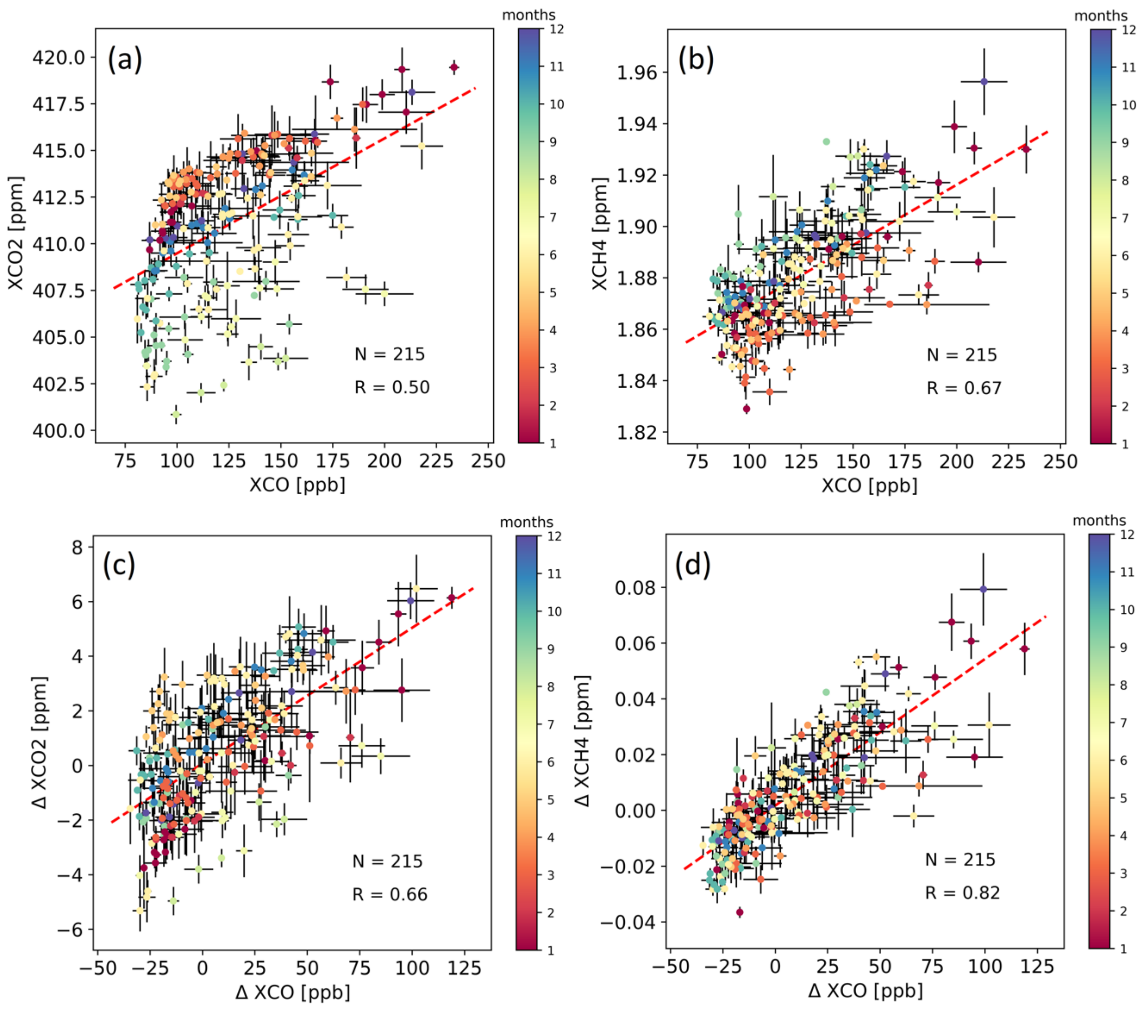

Figure 1. The correlation plots between the XCO and XCO_2 and XCH_4 daily means (a, b) and the correlation plots between the ΔXCO and ΔXCO_2, and ΔXCH_4 daily means (c, d) from

FTIR TCCON-type measurements at Xianghe. The dash red line is the linear fit. The N is the number of the measurement days, and R is the correlation coefficient. The error bar is the standard deviation of the measurements in each day. The data are colored with the measurement months.

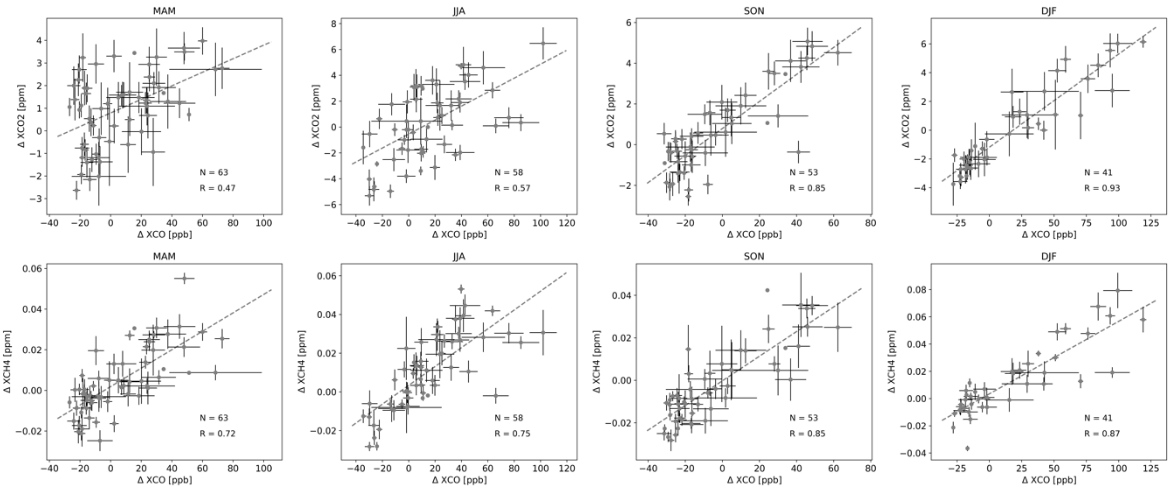

Figure 2. Upper panels: the correlation plots between the ΔXCO and ΔXCO_2 in four seasons (spring: March, April, May (MAM); summer: June, July, August (JJA); autumn: September, October, November (SON); winter: December, January, February (DJF)). Lower panels: the correlation plots between the ΔXCO and ΔXCH_4 in four seasons. The dash line is the linear fit. The N is the number of the measurement days, and R is the correlation coefficient. The error bar is the standard deviation of the measurements in each day.

In revised version, we add the Lagrangian particle dispersion model version 9.02 (FLEXPART) 10-days backward trajectories for all polluted and clean days. It is assumed that the random distribution of the ΔXCO is symmetric, and the lowest ΔXCO is -36 ppb. Therefore, each day with a ΔXCO>36 ppb is classified as a polluted day, vice versa. In total, we have 28 polluted days and 187 clean days. FTIR measurements show the ΔXCO, ΔXCO_2 and ΔXCH_4 are much larger in the polluted days than those in the clean days (see Table 1).

Table 1. The mean and standard deviation of ΔXCO, ΔXCO_2 and ΔXCH_4 at polluted and clean days.

	Polluted days	Clean days
ΔXCO [ppb]	-9.51±21.10	58.40±19.58
ΔXCO_2 [ppm]	-0.64±2.05	2.75±2.01
ΔXCH_4 [ppm]	-0.003±0.016	0.029±0.019

The FLEXPART is able to simulate a large range of atmospheric transport processes, taking mean flow, deep convection, and turbulence into account. The backward running of FLEXPART provides the release–receptor relationship, which is applied to study the source and transport of the observations from a measurement site. In this study, 20000 air particles are released at Xianghe between 10:00 – 14:00 (local time) for days when FTIR measurements are available in the vertical range of surface – 2 km, and a 4-D response function to emission inventory is calculated. The model was driven by the meteorological data from the European Centre for Medium Range Weather Forecast (ECMWF). The residence time of particles in output grid cells describes the sensitivity of the receptor to the source. Figure 3 shows the mean air sources for polluted and clean days. It is found that the air is mainly from the south and the local polluted region (North China) for the polluted days, and is mainly from the north and remote clean places (Inner Mongolia, Mongolia and Russia) for the clean days.

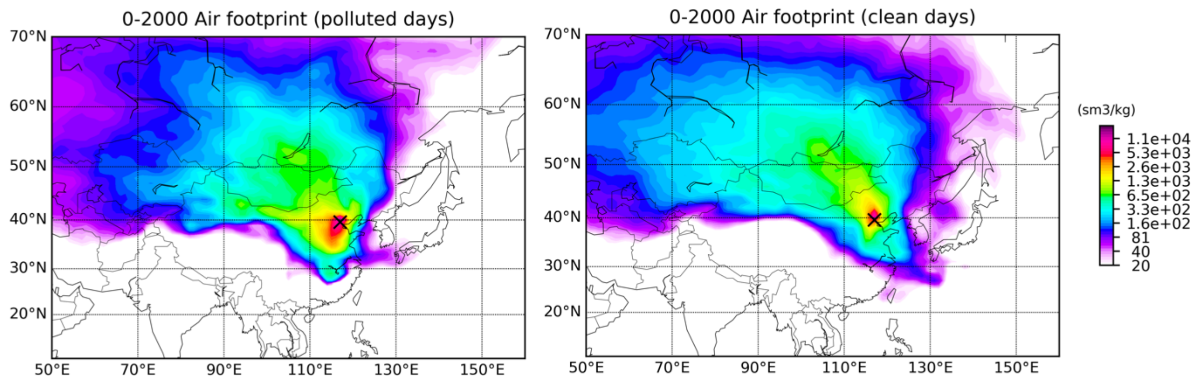

Figure 3. The mean emission response sensitivities of the air mass at Xianghe (the cross symbol) for polluted (left) and clean (right) days in the vertical range from surface to 2000 m a.s.l. simulated with a 10 day backward run with FLEXPART v9.02.

3. The FTIR measurements need to be very precise and accurate to be useful for satellite validation or model studies, a proper demonstration over a longer period of time is therefore needed for the site. However, the data cover only one year period.

Although only about one-year (June 2018 – July 2019) FTIR measurements are presented in the manuscript (in fact, the measurements are continually operating now), these measurements are still very useful for satellite validation or model studies as the following reasons:

1) We have 215 days' measurements of 15435 retrievals with good data quality between June 2018 and July 2019. As ground-based TCCON-type FTIR spectra are only recorded under the condition of the solar and clear sky, the amount of the measurement days and spectra at Xianghe are very good. As an example, at Bremen (a TCCON site), there are 235 days' measurements of 9473 retrievals during 4 years (2015-2018).
2) As the good time coverage mentioned above, the seasonal variations of XCO_2 and XCH_4 are well recognized by our FTIR measurements. The variations are compared to other TCCON sites with a similar latitude. Figure 9 shows that the phase of the seasonal variation of XCO_2 at Xianghe is close to other sites, but with a slightly larger amplitude of the seasonal variation. However, the phase of the seasonal variation of XCH_4 at Xianghe is very different from other sites, which is very interested to model studies. In addition, There is no clear seasonal variation in XCO at Xianghe, but with a much large XCO value together with a large variation. The XCO behavior is quite different compared to other sites. The time series of the FTIR measurements can be applied to study the sources and sinks of CO_2, CH_4 and CO in this region. For example, the reaction with OH is the main sink of atmospheric CH_4 (Rasmussen, et al., 1981). As the OH concentration is high in summer, there is a minimum in XCH_4 at Pasadena, Lamont and Karlsruhe. The maximum XCH_4 value in summer at Xianghe indicates that there is a strong CH_4 source in summer.
3) For satellite validation, the number of co-located FTIR measurements and OCO-2 XCO_2 measurements is 28 days, and the numbers of co-located FTIR measurements and TROPOMI XCH_4 and XCO measurements are 96 and 70 days, respectively. The number of co-located data pairs are comparable with other validation studies. Wunch

et al., (2017) used the TCCON measurements to validate the OCO-2 satellite XCO_2 data for over 2 years. The number of co-located TCCON and OCO-2 data (sum of glint and nadir) pairs is less than 28 at Eureka, Sodankyla, Bialystok, Bremen, Rikubestu, Manaus. For TROPOMI validation, the FTIR measurements at Xianghe is more useful, as the TROPOMI was launched on 13 October 2017. The near real time is only available after June 2018. The FTIR measurements at Xianghe can provide very useful information in a polluted area of North China. Even for the offline reprocess data between November 2017 and June 2019, the co-located TROPOMI and FTIR data at Xianghe is much more than that at some TCCON sites (Eureka, Bremen, Paris, JPL, Darwin, Reunion). For the details, please refer to Lambert et al., (2019). In addition, Fig 12, 13, 14 show that co-located FTIR and satellite data pairs are distributed evenly in all seasons.

4. In Line 25 Page 11, "The retrieved TROPOMI CO data is in the unit of total column density (molecules/cm2), so we converted them to to XCO (ppb) values for comparison with FTIR XCO measurements", there should be a short description of the method and cite a reference.
OK, added in the revised version.

5. In Line 12 Page 12, "Regular HCl cell measurements show that the ME loss is within 2% and the PE remains within 0.02 rad", the conclusion is not consistent with the ME results in Fig. 2.
Corrected. "Regular HCl cell measurements show that the ME loss is within 5% and the PE remains within 0.02 rad".

6. There are no unit for the mean and std value in the Fig. 12, Fig .13 and Fig. 14.
The units for the mean and std are the same as shown in the y axis. Added in the revised version.

7. In Line 14 Page 1, "The rapid economic growth of China has contributed to 30% of the global total carbon dioxide (CO_2) emissions from fossil fuel consumption and cement production (Jackson et al., 2017)", the exact contribution is about 28.5% according to the results in Jackson et al., 2017.
Corrected

Reference:
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