Black: referee's comments green: 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.

Referee #1

This paper uses the SFIT4 code to retrieve Carbon monoxide (CO), acetylene (C2H2), ethane (C2H6), formaldehyde (H2CO), and hydrogen cyanide (HCN) five species from the FTIR spectra for more than three years and discusses the correlation between them.

The paper is nicely organized and results summarized well (though some minor editorial work needed here and there) but I have a few concerns with the scientific significance and value of this research. Within the NDACC, these five species are conventional gases. There is no improvement or innovation in the inversion algorithm in this study. It seems that the selection of these five gases is that they are in the mid infrared band which is lack of scientific significance. Some key issues:

Thanks for the overall positive comments.

Regarding the species, we do have the scientific consideration to select these five species. Currently, there are 10 standard targets within the NDACC-IRWG community (InSb region: C2H6, HCN, CO, HCl, HF, N2O, CH4; MCT region: HNO3, ClONO2, O3). At Xianghe, we are able to retrieve C2H6, HCN, CO, HCl, HF, N2O, CH4, but not HNO3, ClONO2, O3 (no MCT detector). Among these 7 available target species, HCl, HF are mainly in the stratosphere, N2O and CH4 are long-lifetime greenhouse gases,C2H6, HCN, and CO are highly related to biomass burning, fossil fuel combustion, with a similar lifetime. Therefore, we investigate C2H6, HCN, and CO together. Moreover, although C2H2 and HCHO are not regular NDACC target species, many tests within NDACC community have been carried out in the last years (Duflot et al., 2013; Vigouroux et al., 2018). Previous studies have investigated the C2H2 and HCHO along with C2H6, HCN, and CO, and good correlations among them were observed due to their common sources and sinks (Vigouroux et al., 2012; Duflot et al., 2013; Viatte et al., 2014; Yamanouchi et al., 2021). We then tested the C2H2 and HCHO retrievals at Xianghe as well. Since all these five species have been retrieved successfully at Xianghe and good correlations found among them, we finally select these five species in this study.

Regarding the retrieval settings, the retrieval windows of these five species follow the NDACC-IWRG recommendation and previous studies. The retrieval windows work well at Xianghe, with good fitting residuals (Figure 3). So, we do not change them. However, apart from the retrieval windows, we apply the latest SFIT4 retrieval algorithm (v1.0) together with the updated WACCM model as the a priori profile, and used the latest ATM20 spectroscopy. All these settings are advanced and innovated, which have not been published in the whole NDACC community yet (tests are still ongoing; James Hannigan et al., personal communication). Based on the retrievals at Xianghe, we show that the a priori and spectroscopic settings can be improved compared to the current NDACC-IRWG settings.

Finally, regarding the innovation and scientific significant of this study, the five important trace gases are presented for the first time at Xianghe, North China. The time series and seasonal variation of the FTIR measurements are presented and discussed. We show good correlations among these species related to the local anthropogenic emissions. The HCN measurements reveal the boreal forest fire in Russia. These measurements can be further used for satellite validation and model verification.

1. In table2, what's the reason for different gases with different spectral resolutions, e.g., CO with 0.0035 cm-1 where H2CO, C2H6 with 0.0051 cm-1. How is the spectral band range determined? For TCCON, each inversion window is carefully selected, how is inversion window determined for these five species?

Thanks for the questions. The 125HR spectrometer allow a maximum optical path difference (MOPD) of 250 cm, corresponding to a spectral resolution of 0.0035 cm^{-1}. However, in reality, we do not always record solar spectra using the 250cm MOPD. The actual resolution has been tested at Maido Reunion Island for different spectral region (Senten et al., 2008). In our case, 0.0051 cm^{-1} and 0.0076 cm^{-1} are adopted for hh and ch, respectively. With a lower spectral resolution, we can reduce the measurement time and record more spectra. Nevertheless, the absorption lines of C_2H_2, C_2H_6, HCN, HCHO in hh, and ch spectra (0.0051cm^{-1} and 0.0076 cm^{-1}) at Xianghe can be well recognized and fitted. In the NDACC-IRWG HCHO harmonized work (Vigouroux et al., 2018), the spectral resolutions recorded by the NDACC community (21 FTIR site) are between 0.0035 and 0.0090 cm^{-1}. The uncertainty due to different spectral resolution is much less as compared to other estimated uncertainty.

Regarding the window choice, we have followed the NDACC-IRWG community recommendation (https://www.acom.ucar.edu/irwg/IRWG_Uniform_RP_Summary-3.pdf) and previous FTIR studies (Zhao et al., 2002; Vigouroux et al., 2012; Viatte et al., 2014; Zhou et al., 2018; Vigouroux et al., 2018). As the retrieval windows work well at Xianghe, with good fitting residuals (shown in Figure 3), we do not specifically change the retrieval windows here.

2. The author use the optimal estimation method (OEM) for CO and use the Tikhonov L1 method for other four species? Can you give a discussion about the two method and the reason for choosing different method for different species?

Thanks for the comment. A discussion is added in the revised version. The OEM and Tikhonov regularizations are selected based on the a priori knowledge. For CO, we have surface in situ measurements at Xianghe, that agree well with WACCM model simulations. The reason is probably that there are many in situ at the surface and aircraft profile measurements around the world (e.g. NOAA networks; HIPPO campaign). The CO simulations generated from the WACCM model are more reliable as compared to the other 4 species. Therefore, we use the OEM method for CO and the a priori covariation matrix is directly derived from the WACCM model. However, for the other 4 species, we have no surface measurement at Xianghe and lack a priori knowledge. Therefore we apply the Tikhonov L1 method so that the retrievals are less affected by the a priori profile.

3. Since Xianghe FTIR measurements compliant with the NDACC-IRWG protocols and the algorithm is available in the published literature, just a brief description is needed here for completeness.

Done.

4. It seems strange that CO has no seasonal changes. Could you please compare it with CO total column retrieved by TCCON algorithm?

Added in the appendix A. The seasonal variation of TCCON XCO is hardly observed, which is similar to the NDACC CO measurements and TROPOMI overpass results.

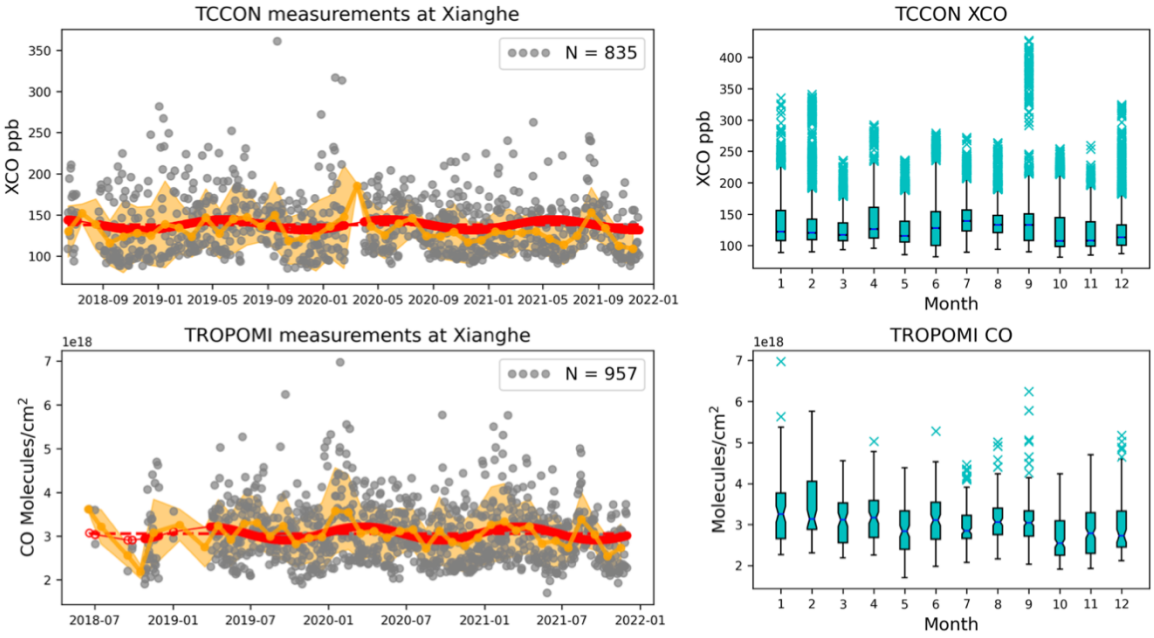

Figure A1. Left panels: time series of XCO and CO columns observed by TCCON at Xianghe (top) and TROPOMI overpass within 50 km around Xianghe (bottom) between June 2018 and November 2021. Grey dots are daily means with the total number indicated by N; the orange dotted line is the monthly mean together with the yellow shaded area as the monthly standard deviation; the red dashed line is the offset A_0; the red solid line is the fitted time series y(t). Right panels: the monthly box plot of the CO columns in each month. The bottom and upper boundaries of the box represent the 25% (Q1) and 75% (Q3) percentile of the data points around the median value, the errorbars extend no more than 1.5× IQR (IQR = Q3 - Q1) from the edges of the box, and the blue crosses are the outliers.

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