Reviewer #2

We thank the reviewer for his/her constructive comments and suggestions to improve the quality and clarity of our manuscript. We have made major and careful modifications to the original manuscript according to all the comments and suggestions from the reviewers. The major modifications include:

(1) We have changed to using a fixed CO profile as the a priori for all the retrievals, and make changes to all relevant figures. The use of a fixed a priori make it easy to interpret and compare with models and detect anomalies such as wildfires emissions. Specifically, for our purpose of retrieving the diurnal changes of CO columns, the main topic of this study, a fixed a priori is preferred because any significant perturbation to the constant a priori, which does not change diurnally, may indicate information that is retrieved from the observed spectra;

(2) We removed the 0-1km results and replaced it with the bottom 3-layer, which ranges from the surface to 3km above sea level. In addition, we added North India as the 4^{th} representative region in the analysis, besides North China Plain, Mongolia, and East China Sea.

(3) We added diurnal cycle comparison of the retrieved CO columns and DOFS, boundary layer height from ERA5 reanalysis, and model simulations of CO columns from CAMS EAC4 reanalysis. All time in the revised manuscript has been changed to Beijing Time (UTC +8).

(4) A detailed comparison between our retrievals and IASI has been added, including spatial and temporal comparisons. We showed that the DOFS between GIIRS and IASI are comparable, and the vertical sensitivities, as quantified by the AK matrix, are also similar between GIIRS and IASI.

(5) We added in the Discussions section about the applicability of the algorithm in retrieving CO using GIIRS observation in the winter season, and used December observations as examples.

Item-by-item responses to the specific comments are provided below, in which the reviews' comments are in blue, our responses in **black**, and modifications of the original manuscript are indicated by highlight in yellow in the revised manuscript.

This study describes the CO retrieval algorithm for the geostationary GIIRS sounders on board FY-4B satellite. The paper is in general well explained and clear, particularly for the algorithm, however some information or clarification are missing.

Comments:

Ln 9: The year of when the sounder was launched should be indicated in the abstract to inform the reader.

We have added the information in the abstract: **"… using observations from GIIRS onboard FY-4B, which was launched in June 2021, …"**

Ln 10: how having hyperspectral measurements of CO provide diurnal observation of CO? I would think that having geostationary CO data allow observation of diurnal CO variability. Could you reformulate your sentence or give more precision?

We have rephrased this statement: "**With hyperspectral measurement collected from a geostationary orbit …**"

Ln 34. I would maybe say "(GEO) orbit can provide contiguous coverage with similar or higher spatial resolution than LEO and a revisit time of 1-2 hours […]" or a similar sentence. Because, GIIRS has the same spatial resolution than IASI (12km diameter at nadir).

We have changed the statement as you suggested: "… **with similar or higher spatial resolution …**"

Ln. 89: Figure A1. b and c, are these figures for the same day as Fig. A1.a?

Yes. We have added the date information in the figure caption: "… **on July 07, 2022**".

Fig. 1b. The values on Fig. 1B are a too small.

We have enlarged the font size of Fig. 1B. The number index (from 1 to 128) of the detector array pixel is unchanged since these index number is not key information.

Fig. 1c. It would be interesting to have, as well, the Jacobian by pressure (the ones used for the radiative transfer model). This would inform on the variability that GIIRS channels sensitivity have depending on atmospheric pressure. Additionally, there is no comment on this figure. What do you conclude with this figure in term of sensitivity for CO and H_2O with GIIRS?

We have added Figure S1 in the supplementary materials that shows an example of Jacobian as a function of pressure for three channels: strong CO absorption channel at 2165.625 cm^{-1}, median absorption channel at 2166.250 cm^{-1}, and weak absorption channel at 2166.875 cm^{-1}.

The added the following statement as conclusions from Fig. 1(c) and Fig. S1: "**In this micro-window, the absorption features from CO and the primary interference gas H_2O are mostly separated and can be distinguished. Examples of Jacobian as a function of pressure and absorption strength are shown in the supplementary Figure S1. The changing Jacobian values demonstrate the vertical sensitivity of the CO absorption lines at different pressure levels, which peaks at the surface layer in the daytime and at mid-troposphere in the nighttime.**"

Ln. 171. You computed 3-hourly CO profile climatology for each month, which month are you talking about? The period of study has not been introduced yet, except result for July 2022 introduced in the abstract.

In the original manuscript, the climatology was constructed for July only, and we have only retrieved data in July. In the revised manuscript, we have changed to using a fixed CO profile as the a priori, instead of a time-varying a priori CO profile. The fixed CO a priori profile is derived from CO simulations from CAMS EAC4 reanalysis. All 3-hourly simulation results in 2021 are used. The details are described in Section 3.2.

As a response to your question in the end about whether we have applied the retrieval algorithm to another month, we have tested the retrieval algorithm using observations in December 2022, when the temperatures of the surface and the atmosphere reach to the lowest point in a year. Figures S9, S10, S11 are the results added. Please see our detailed response to your comment below.

Ln. 174. Should be "2080 cm^{-1} to 2120 cm^{-1}".

It has been changed: **"In the spectral window from 2143 cm^{-1} to 2181.25 cm^{-1}"**

Ln. 194. "The number of pressure grids in the forward RT model should be large enough to reduce the error [...]". A reference is missing here regarding this remark.

The reference Clough et al. (2016) has been added for this statement.

Ln 262: To be consistent, I would write the title as " Averaging kernel (AK) matrix and Degree of Freedom for Signal (DOFS)"

It has been changed as suggested.

Ln. 276. How much data are removed after the quality filter? Similarly, how much data are removed before and after labeled clear sky for the period of your study, before the post-screening is done?

For the cloud screening, in Section 2.3, we added:

"For each measurement cycle, there are 12×27 FORs and each FOR collects 16×8 observations using the infrared plane array detector. In total, there are 41472 observations. For each day with 12 measurement cycle, the total observation is about 500K. After cloud screening and excluding data with viewing zenith angle larger than 70°, the average daily observation number for clear sky is about 90K in July of 2022."

For the post-screening, in Section 4.3, we added:

"In the post-processing, multiple filters are applied to ensure good retrieval quality. First, retrievals that fail to converge after 10 iterations are excluded. Second, retrievals with the

goodness of fit, quantified by reduced χ^2, less than 1.5 are excluded. Lastly, Retrievals with root-mean-square-error of fitting BT residual that are more than one standard deviation away from the mean, which is about 0.7K for July 2022, are excluded. After data screening, the total number of observations, which is 2,812,071, is reduced to 2,045,228 in July 2022."

Ln. 289. Could you precise why you added a Gaussian white noise? Is the added noise mentioned Ln 291 referring to the Gaussian white noise. If yes, then Ln 291 should appear just after the white noise is mentioned Ln. 289.

The Gaussian white noise is noise with mean of zero and, in this study, a standard deviation of NedR×1.5. This type of noise is usually assumed for the measurement spectra assuming they are not biased (mean=0) but has a random noise level that following Gaussian distribution. We have rephrased the statement to be **"… Gaussian white noise with mean of zero and a standard deviation equal to NedR×1.5**."

Also, the sentence referring to the noise has been moved forward to be right after the description of the white noise.

Ln. 293. You could introduce a map to visualize the regions of interest.

We have labelled the four regions of interest in Figure A1(a) with explanations in the figure caption.

Ln. 304. How can you conclude that from Figure 2?

In the revised manuscript, we have added the diurnal change of DOFS. This sentence has been rephrased to be: **"The complexity of the diurnal TC change as demonstrated by various land use types in East Asia affects the diurnal changes of DOFS from the CO retrievals by FY-4B/GIIRS, as shown in Figure 3(b)**"

Ln. 314.: The results of Figure 3 are only for North China Plain, but have you done it also for the two other regions? Mongolia has a more complex diurnal TC change than North China Plain but the surface pressure/topography is also different between the two regions. Would the results of Figure 3 be the same for Mongolia region or not?

In the revised manuscript, we have updated the figure and show the correlation between TC and DOFS and the retrieval accuracy from the synthetic experiments in two different figures: Figure 3 and Figure 4 in the revised manuscript, and Fig. S2, Fig. S3 and Fig. S4 in the supplementary materials. We have also added North India as the fourth region of interest. In addition, the correlation plot between TC and DOFS based on all the retrievals in July of 2022 for the four selected regions are also shown in Figure 9. Indeed, we see that Mongolia has a wider range of TC changes. As a result, its correlation with DOFS are different from the other three regions.

Ln. 315. It is confusing, the "truth" is based on the ECMWF EAC4 results but it is also used as CO a priori profile in your retrieval algorithm, so what is the difference between the comparison of (1) and (2)? How can you compare the retrievals to ECMWF

EAC4, if you already used this CO profile as a priori profile in your retrieval algorithm (see Ln. 291)?

In the revised manuscript, we have adopted a different strategy for the a priori CO profile. We have used a fixed a priori CO profile and re-made the comparison. Now the "truth" CO columns from the model simulations and the static CO a priori profile are independent of each other. From our comparison results shown in Figure 4 for North China Plain, and Figure S2-4 shows the results for Mongolia, East China Sea, and North India, respectively, we found that the accuracy of the retrieval relies heavily on the DOFS which shows large difference between daytime and nighttime.

Ln. 470-479: Talking about wildfires, during the month of July 2022, several wildfires occurred in Siberia. The transport and mixing of CO in the Northern Hemisphere might have bring CO concentrations from the Siberian fires to the regions of your study. Have you looked at that? The ECMWF EAC4 and ER5 simulation/reanalysis used in your algorithm do not include 2022 and so might not be representative of CO concentrations for the month of July 2022. It is difficult to determine if your retrievals are well representative of July 2022 consequently. It could be then interesting to have evaluation of your L2 retrievals to in situ data.

Yes, the wildfire emissions have been detected by GIIRS CO retrievals around the Siberia in the north eastern corner of our study area. In Figure 13, we compare the map of CO columns from GIIRS and IASI in the daytime and nighttime on July 07, 2022. Due to different cloud screening process, the available data points around the wildfire region may be different. Nonetheless, we can see the high CO levels in the Siberia around 60°N and 135°E that has been well captured by GIIRS and IASI. We have added the following statements in the revised manuscript: "**We can see the spatial distribution of CO columns in the daytime is characterized by two source regions, the North China Plain as a source of anthropogenic emissions and the Siberia region as a source of natural wildfire emissions. This wildfire over Siberia on July 07, 2022 is further confirmed using MODIS optical images and fire counts (not shown here). In the nighttime, the emissions from North China Plain persist. However, the wildfire regions are not covered. The scatter plots comparing the collocating observations show good agreements between the two datasets**" in Section 6.4, and "**In addition, elevated CO column values can be detected around the Siberia region which is close to the north eastern region of our study area. The high CO values are related to the wildfire emissions over the region which intensifies in the summer season**" in Section 6.3.

The model simulations from CAMS EAC4 assimilates observations from MOPPIT and IASI for CO simulations, so the wildfire emissions should in theory be assimilated in the model. However, since the most updated data are not available, a comparison is not feasible. Similarly, the most updated in situ data are not available at this moment. Therefore, we rely on the collocating IASI retrieval, as an independent data source, to compare with our retrievals.

The wildfire emissions of CO can also be seen from the averaged diurnal maps in Figure 11 and Figure 12. The high values around the region close to Siberia are mostly affected by the CO emissions from the Siberia wildfires in July.

Appendix A: Figure A1.a is not used in the study. Considering the wildfires in July 2022, was there fire CO emissions included in CAMS model?

Yes, it has assimilated wildfire emissions. However, the most updated simulations are not available at this moment. We used the same period data in 2021. In the revised manuscript, we have changed the a priori to be a fixed CO profile with a large variability in the retrieval algorithm. Through comparison with IASI, we found our results are consistent in capturing unexpected natural events such as wildfire emissions. Please also see our response to your last comment.

This study was only done for a summer month, but have you look at other season? The diurnal cycle might be associated to meteorological conditions and emissions patterns different by season. Additionally, having hourly data and comparing North China with Mongolia and East China Sea, I was wondering if you looked at the difference in CO concentration between these regions during the daytime. I would expect to observe highest concentration for North China than Mongolia during the morning time corresponding to rush hours, however this would depend on synoptic disturbances.

In the revised manuscript, we added Section 7.1 in the Discussion section and Fig. S9, Fig. S10, and Fig. S11 to discuss the preliminary results from applying the algorithm to a month in the winter season (December 2022) when the temperature of the surface and the atmosphere become with low compare to July. The results show that the spectral fitting residual increases by a factor of 2, leading to larger retrieval uncertainty and less available retrievals after applying the quality control filters. However, we see the lower latitude land the ocean region, the temperature is still high and can be a good study area using GIIRS CO retrievals in winter. For details, please see our discussions in Section 7.2