Replies to Reviewers' comments

Ms. Ref. No. : amt-2021-222

Title: Neural Network Based Estimation of Regional Scale Anthropogenic CO_2 Emissions Using OCO-2 Dataset Over East and West

We sincerely thank the Editor of the journal for reviewing our research paper and providing the list of comments/suggestions raised by the learned reviewers which in turn helped us in improving the quality of an earlier version of the manuscript. As per the suggestions of the reviewers, we have gone through the entire paper giving suitable answers to their queries and revised the whole paper. We have updated the figures following the suggestions of the reviewers. The authors wish to thank the Editor of the journal for his encouragement and support in contacting the reviewers to complete the peer-review process in time. The authors are also grateful to the anonymous reviewers for their constructive and useful comments, suggestions and critics which in turn improved the scientific content of an earlier version of the manuscript. All responses to the reviewers' comments in the revised manuscript are highlighted in RED, so that they may be easily identified.

Kind regards,
Farhan Mustafa & Co-authors

Response to Anonymous Referee 1 Comments

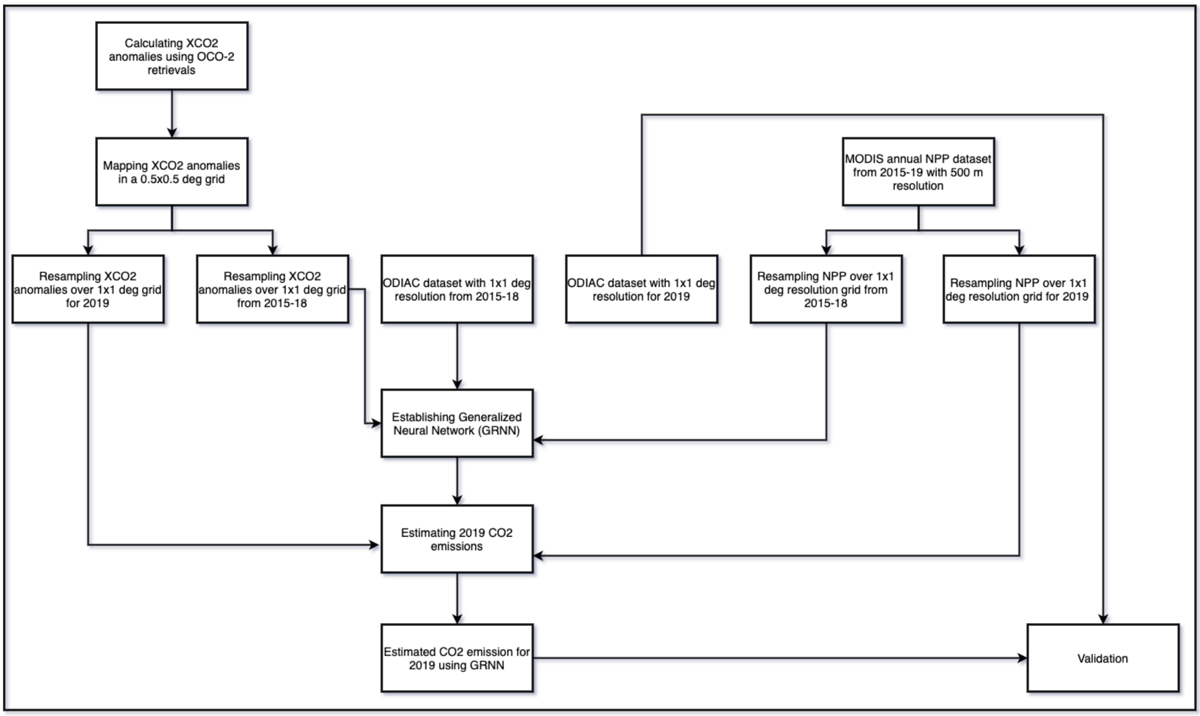
1. General Comments

Point 1: In this study, the authors proposed a method to estimate the regional scale anthropogenic CO2 emissions with OCO-2 XCO2 retrievals over East and West Asia. The topic fits well to the aims and scopes of AMT. Concerning critical requirement for quantitative estimates of carbon emissions and the rapid development of machine learning techniques, this study would be certainly interesting to the community. However, the current version of the manuscript, in my opinion, cannot be recommended for publication. I do have some major concerns that need to be responded if the authors consider to submit the revised manuscript. First of all, I see little scientific significance in this paper, actually after I read the paper by Yang et al. (2019) https://www.mdpi.com/1424-8220/19/5/1118, I surprisingly found out there are many similarities in both papers, even though the old one has been cited by the authors. For example, Section 2.2 is quite similar to Section 2.3 on Yang et al. (2019), including all equations and Figures 1 and 2. I am not saying that the methodology (algorithms, processing steps) should not be reused especially when its performance has been justified in previous studies. But the authors claimed in the manuscript that we proposed a method to estimate the regional scale anthropogenic CO2 emissions, which can be misleading to readers. The only differences between these two papers seem to be that Mustafa et al. used OCO-2 data and extended the study region to West Asia. Therefore, if possible, I would suggest the authors to highlight the differences in both estimation methods, if not, please completely revise the manuscript for readers to better understand the objective of this paper.

Response 1: We are thankful to the anonymous referee for his/her constructive comments. The comments are very helpful in improving the quality of the manuscript and we have carefully used them to revise the manuscript.

We understand the concerns of the learned referee about the similarities between our manuscript and the article authored by (Yang et al., 2019). We extended the study following the suggestion given in the conclusion of the article written by Yang et al. (2019). However, following the suggestion of the respected reviewer, the manuscript has been revised completely and substaintial changes have been made in the revised version of the manuscript.

- The prediction model has been changed/improved. A new dataset, MODIS net primary productivity (NPP) has been added to train the model and then predict the anthropogenic CO2 emission. The new flowchart of the model, updated in the revised manusctipt as, "Figure 1" is given in the following:



- More detail has been added to the section 2.2 of the revised manuscript at

L196-203 as, "OCO-2 XCO_2 dataset was downloaded from the Earthdata platform (https://earthdata.nasa.gov/) and to ensure the reliability of the data, screening and filtering of the dataset was carried out following the instructions given in the OCO-2 Data User Guide (DUG). Each sounding that is processed using the ACOS L2FP retrieval algorithm is assigned either a "good" (=0) or "bad" (=1) quality flag based on screening criteria derived from comparisons with TCCON and modelled CO_2 fields. It is generally advised that users should use the "good" quality soundings for regional and local scale studies because the soundings flagged as "bad" quality might include biases that compromise their utility for the application. In this study, the OCO-2 XCO_2 retrievals were included if: (i) they were flagged good (flag=0) and (ii) the standard deviation of the good soundings for the day was less than 2 ppm."

L245-256 as, "During the process of photosynthesis, the living plants convert the CO_2 into sugar molecules they use for food. In the process of making food, they also release the oxygen we breathe. Plant productivity plays a crucial role in the global carbon cycle by absorbing the CO_2 released by anthropogenic activities. The net primary productivity (NPP) shows how much CO_2 is absorbed by the plants during photosynthesis minus how much CO_2 is released during respiration. A negative value of NPP means that CO_2 is released into the atmosphere and a positive value represents the absorption of atmospheric CO_2. To improve the model results, an NPP dataset (MOD17A3HGF) provided by MODIS has also been used in this study. It provides information about annual NPP and is distributed by NASA's Land Processes Distributed Active Archive Center (LP DAAC). The NPP dataset with a spatial resolution of 500 meters (m) was downloaded from the LP DAAC website (https://lpdaac.usgs.gov/products/mod17a3hgfv006/). The annual NPP is derived from the sum of all 8-day Net Photosynthesis (PSN) products (MOD17A2H) from the given year. The MODIS NPP dataset was reprojected and resampled to the spatial resolution of 1°×1° Longitude/Latitude for each year and used along with the ODIAC and OCO-2 datasets to train the GRNN model and as well predicting the CO_2 emission."

- The sentence including, “we proposed a new method has been revised” and the author Yang et al., (2019) is given proper credit at various places of the manuscript. Such as,

At L105-107 as, “In this study, we have improved the model initially developed by (Yang et al., 2019) to estimate the regional scale anthropogenic CO_2 emissions using OCO-2 XCO_2 retrievals over East and West Asia. MODIS NPP, OCO-2 and ODIAC CO_2 datasets were obtained for a period of five years from January 2015 to December 2019.”

At L381-388 as, “(Yang et al., 2019) estimated the CO_2 emissions by a similar machine learning approach using GOSAT XCO_2 retrievals over China and differences between the estimated and the ODIAC actual CO_2 emissions were between -5×10^9 kg to 5×10^9 kg. Moreover, the predicted results from the referenced study exhibited overall less CO_2 emissions relative to the ODIAC emissions contradicting our results. Our study showed better results and it might be due to several reasons; (i) we improved the prediction model with the addition of NPP dataset (Figure 4e), (ii) we utilized the higher resolution XCO2 retrievals provided by OCO-2, and (iii) we incorporated the OCO-2 XCO_2 retrievals processed using the latest version of the retrieval algorithm. The newer version of the ACOS L2FP retrieval algorithm has improved the quantity as well as the quality of the satellite-based observations (Taylor et al., 2021).”

- Figure 1 (given above) has been changed as the model has been changed with the addition of new dataset.
- Figure 2 is a general structure of GRNN, however, the figure has been properly cited.

Point 2: Although this study directly used the XCO2 product, it would be important for readers to know essential information of the retrieval algorithm, as the authors claimed in Section 3.2 that compared to previous studies, this study obtained a better result due to the improvements in the XCO2 retrieval algorithm. Therefore, in Section 2.1.1, please add more relevant details

Response 2: We are thankful to the reviewer for valuable suggestion. The updates in the XCO2 retrieval algorithm have summarized in the revised version of the manuscript at:

Table 1: Evolution of ACOS L2FP retrieval algorithm (Taylor et al., 2021).

		ACOS v7	ACOS v8/9	ACOS v10
1	Spectroscopy	ABSCO v4.2	ABSCO v5.0	ABSCO v5.1
2	Meteorology prior source	ECMWF	GEOS5 FP-IT	No changes
3	Aerosol prior source	MERRA monthly climatology	No changes	GEOS5 FP-IT with tightened prior uncertainty
4	Retrieved aerosol types	Water + ice + 2 MERRA types	+ stratospheric aerosol	No changes
5	AOD prior value (per type)	0.0375	0.0125	No changes
6	CO_2 prior source	TCCON ggg2014	No changes	TCCON ggg2020
7	Land surface model	Lambertian	BRDF	No changes

At L150-164 as, "The quality and the quantity of the XCO_2 product have been improved with the developments in the ACOS FP retrieval algorithm. The evolution of the ACOS L2FP retrieval algorithm from v7 to v10 is summarized in Table 1.

No major changes were made in the ACOS v9 L2FP retrieval algorithm relative to v8 except for sampling of meteorological prior. The trace gas absorption coefficient tables (ABSCO) were updated in various versions of the ACOS L2FP retrieval algorithms. The source of the prior meteorology was changed from the European Center for Medium-range Weather Forecast (ECMWF) in ACOS v7 to the NASA Goddard Modeling and Assimilation Office (GMAO) Goddard Earth Observing System (GEOS) Forward Processing – Instrument Team (FP-IT) products for v8/9. The aerosol prior source was changed from the GMAO Modern-Era Retrospective analysis for Research and Applications (MERRA) product in v7-9 to GEOS5 FP-IT in v10. Moreover, an additional stratospheric aerosol layer was introduced in ACOS v8-10. The prior value of aerosol optical depth for each retrieved aerosol type was lowered from 0.0375 in v7 to 0.0125 in v8-10. The CO_2 prior developed by the TCCON team using the ggg2014 algorithm remained same throughout various versions of the algorithm. Another major change was switching the land surface model from a purely Lambertian land surface model to Bi-Directional Reflectance Distribution Function (BRDF) model (Taylor et al., 2021)."

Point 3: Information about training, testing, validation of the GRNN should be given, e.g., what are input parameters, only OCO-2 data? How did you organize the training, testing, and validation datasets?

Response 3: We are thankful to the learned reviewer for valuable suggestion. The required information has been added to the revised version of the manuscript:

At L196-203 as, "OCO-2 XCO_2 dataset was downloaded from the Earthdata platform (https://earthdata.nasa.gov/) and to ensure the reliability of the data, screening and filtering of the dataset was carried out following the instructions given in the OCO-2 Data User Guide (DUG). Each sounding that is processed using the ACOS L2FP retrieval algorithm is assigned either a "good" (=0) or "bad" (=1) quality flag based on screening criteria derived from comparisons with TCCON and modelled CO_2 fields. It is generally advised that users should use the "good" quality soundings for regional and local scale studies because the soundings flagged as "bad" quality might include biases that compromise their utility for the application. In this study, the OCO-2 XCO_2 retrievals were included if: (i) they were flagged good (flag=0) and (ii) the standard deviation of the good soundings for the day was less than 2 ppm."

At L238-242 as, "The space-based soundings are irregularly distributed and have spatiotemporal gaps because a large amount of the satellite observations is removed after screening for clouds and other artifacts. To deal with the spatiotemporal gaps, kriging interpolation was used and a mapping dataset was generated with the spatial resolution of 0.5°×0.5° Longitude/Latitude and temporal resolution of 16 days. Finally, the mean against each grid cell was calculated for each year from 2015 to 2019."

2. Specific Comments

Line 46: Seriously, I don't think your own paper is proper for this statement "Satellites provide the most effective way to monitor atmospheric CO2 with great spatiotemporal resolutions". Satellite remote sensing has been utilized to measure greenhouse gases for over 20 years, and it is widely known that this technology can provide high-resolution CO2 observations..

Response : We are thankful to the reviewer for constructive comment. The citation of the paper has been removed.

Line 48: The references for satellite CO2 measurements can be largely improved. For instance, there have been a number of new studies available for TanSAT CO2 retrievals, which cannot be simply overlooked, e.g., Bao et al. (2020); Yang et al. (2018); Hong et al. (2021). In addition, it would be nicer to have journal papers instead of a conference abstract.

Response : We are thankful to the reviewer valuable suggestion. The references have been improved following the given suggestion.

Section 2.1.1: What is the spatial resolution of OCO-2? How good is the data quality of the employed XCO2 retrieval product?

Response : The required information has been added in the revised manuscript:

At L141-142 as, "The spatial resolution of OCO-2 is 2.25 km x 1.29 km."

At L151-152 as, "The latest OCO-2 XCO_2 product has single sounding precision of ~0.8 ppm over land and ~0.5 ppm over water, and RMS biases of 0.5-0.7 ppm over both land and water (ODell et al., 2021)."

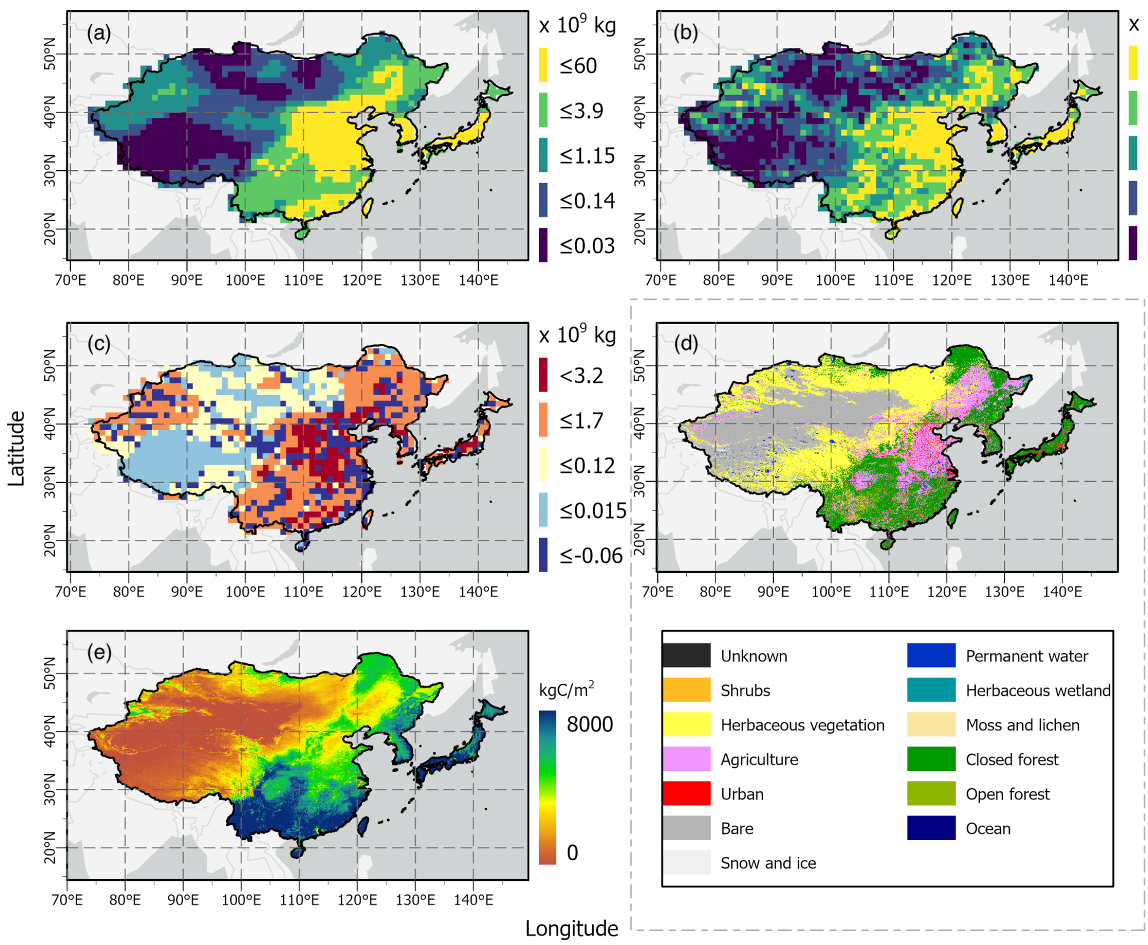
Section 2.1.2: Where do you acquire ODIAC dataset? Is it publicly available? Please specify it.

Response : We are thankful to the reviewer valuable suggestion. The detail has been added in the revised manuscript:

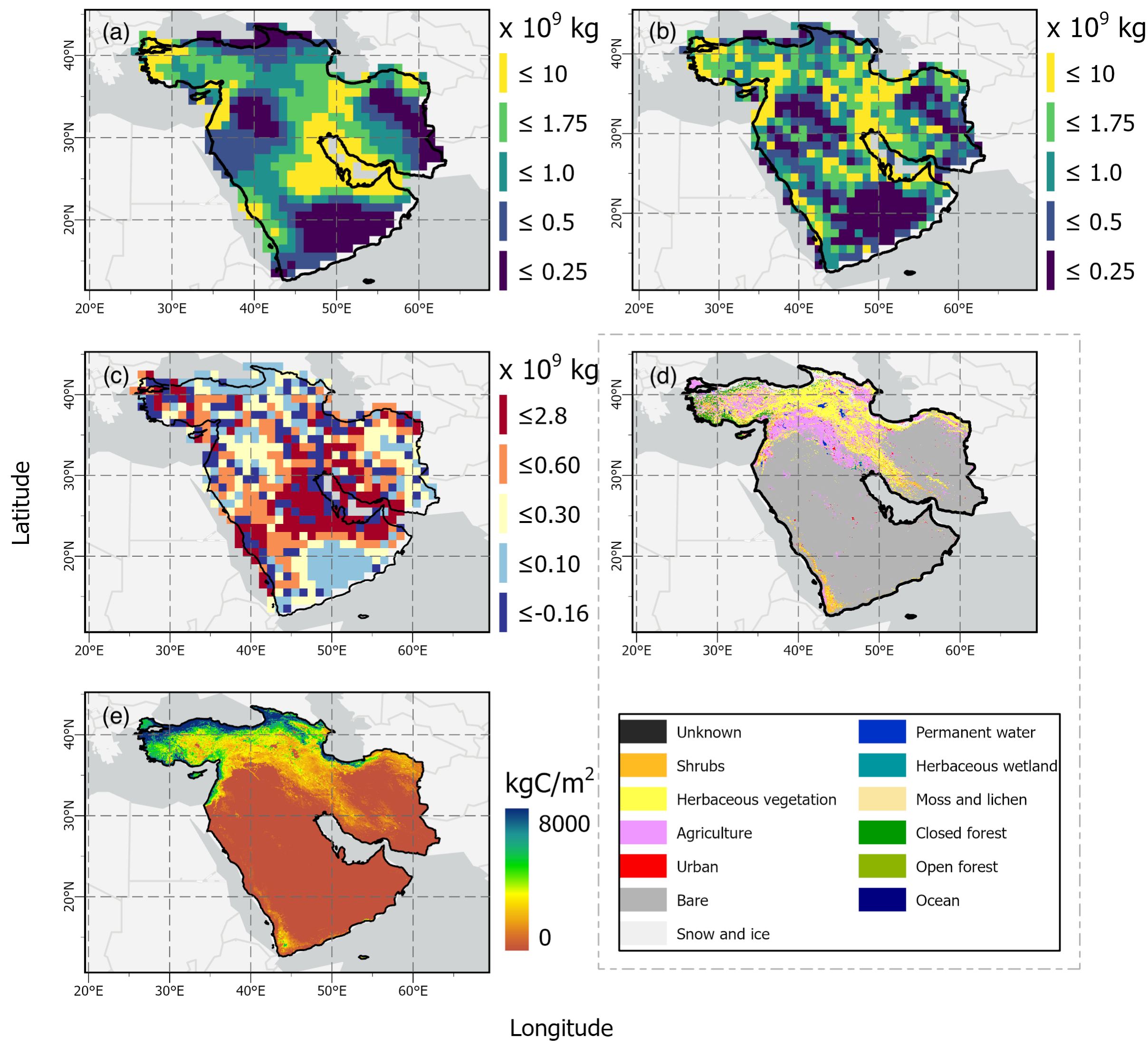
At L189-190 as, "In this study, we used the 2020 version of ODIAC emission dataset that is freely available and can be downloaded from http://db.cger.nies.go.jp/dataset/ODIAC/."

Line 216: Both tons and Mt are not SI base or SI-accepted units. Please check information at https://www.bipm.org/documents/20126/41483022/SI-Brochure-9-EN.pdf/2d2b50bf-f2b4-9661-f402-5f9d66e4b507?version=1.9&download=true.

Response : We have changed the units in figures as well as in the main text from tons to the SI unit kg.



(a)
(b)
(c)
(d)
(e)
x 10^9 kg
≤60
≤3.9
≤1.15
≤0.14
≤0.03
<3.2
≤1.7
≤0.12
≤0.015
≤-0.06
kgC/m²
8000
0
Unknown
Shrubs
Herbaceous vegetation
Agriculture
Urban
Bare
Snow and ice
Permanent water
Herbaceous wetland
Moss and lichen
Closed forest
Open forest
Ocean
20°N
30°N
40°N
50°N
70°E
80°E
90°E
100°E
110°E
120°E
130°E
140°E
Latitude
Longitude



Line 217: What are the improvements in the XCO2 retrieval algorithm? Again, does this sentence just prove that this study USED the method proposed in (Yang et al., 2019), but with a different dataset?

Response : The improvements in the manuscripts have been described above, also in the revised version of the manuscript. This sentence has been changed completely in the revised manscript:

At L384-389 as: "Our study showed better results and it might be due to several reasons; (i) we improved the prediction model with the addition of NPP dataset, (ii) we utilized the higher resolution XCO2 retrievals provided by OCO-2, and (iii) we incorporated the OCO-2 XCO_2 retrievals processed using the latest version of the retrieval algorithm. The newer version of the ACOS L2FP retrieval algorithm has improved the quantity as well as the quality of the satellite-based observations (Taylor et al., 2021)."

Page 9 13: Many references do not have the standard format, journal names are missing in many cases.

Response : There was an issue in the referencing softwate that missed the journal names in the references. However, all the citations and references have been reformatted correctly.

Figure 3: Please correct the subfigure index in the caption.
Response : The mistake has been corrected.

References

ODell, C., Eldering, A., Gunson, M., Crisp, D., Fisher, B., Kiel, M., Kuai, L., Laughner, J., Merrelli, A., Nelson, R., Osterman, G., Payne, V., Rosenberg, R., Taylor, T., Wennberg, P., Kulawik, S., Lindqvist, H., Miller, S., and Nassar, R.: Improvements in XCO2 accuracy from OCO-2 with the latest ACOS v10 product, in: EGU General Assembly Conference Abstracts, EGU21-10484, 2021.

Taylor, T. E., O'Dell, C. W., Crisp, D., Kuze, A., Lindqvist, H., Wennberg, P. O., Chatterjee, A., Gunson, M., Eldering, A., Fisher, B., Kiel, M., Nelson, R. R., Merrelli, A., Osterman, G., Chevallier, F., Palmer, P. I., Feng, L., Deutscher, N. M., Dubey, M. K., Feist, D. G., Garcia, O. E., Griffith, D., Hase, F., Iraci, L. T., Kivi, R., Liu, C., De Mazière, M., Morino, I., Notholt, J., Oh, Y.-S., Ohyama, H., Pollard, D. F., Rettinger, M., Roehl, C. M., Schneider, M., Sha, M. K., Shiomi, K., Strong, K., Sussmann, R., Té, Y., Velazco, V. A., Vrekoussis, M., Warneke, T., and Wunch, D.: An eleven year record of XCO2 estimates derived from GOSAT measurements using the NASA ACOS version 9 retrieval algorithm, Atmosphere – Atmospheric Chemistry and Physics, https://doi.org/10.5194/essd-2021-247, 2021.

Yang, S., Lei, L., Zeng, Z., He, Z., and Zhong, H.: An Assessment of Anthropogenic CO_2 Emissions by Satellite-Based Observations in China, Sensors, 19, 1118, https://doi.org/10.3390/s19051118, 2019.