Atmos. Meas. Tech. Discuss.,
doi:10.5194/amt-2019-390-AC2, 2020

Atmospheric Measurement Techniques Discussions

Interactive comment on "On the performance of satellite-based observations of CO_2 in capturing the NOAA Carbon Tracker model and ground-based flask observations over Africa land mass" *by* Anteneh Getachew Mengistu and Gizaw Mengistu Tsidu

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Received and published: 4 April 2020

Authors Response to Anonymous Referee #2 comments and suggestions on manuscript entitled " On the performance of satellite-based observations of CO2 in capturing the NOAA Carbon Tracker model and ground-based flask observations over Africa land mass " by Anteneh Getachew Mengistu and Gizaw Mengistu Tsidu

General comments: The manuscript entitled, "On the performance of satellite-based

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Discussion paper

observations of CO2 in capturing the NOAA Carbon Tracker model and ground-based flask observations over Africa land mass" presents a scientifically interesting comparison of Carbon Tracker, GOSAT, OCO-2, and flask CO2 measurements. Despite Africa lacking ground-truth instruments such as TCCON, studies such as this one are useful for pointing out differences in the models and satellite observations. Response: We thank the anonymous referee for supporting the importance of the study.

General comments: In general, there is one major methodological issue and many clarifications and technical fixes needed, but I recommend publication once they are resolved. Response: We have carefully addressed the comments and suggestions raised by the referee and improved the quality of the manuscript.

General comments: - GOSAT and OCO-2's primary product is the column-averaged dry-air mole fraction of CO2 (XCO2), not a vertical profile of CO2. There are typically less than 2 degrees of freedom for vertical CO2 for any given retrieval. Thus, the entire comparison to flasks should come with a disclaimer that the NASA L2 retrievals for GOSAT and OCO-2 are not designed to be used in this way. The comparison is still interesting, but I am unsure about the scientific value.

Response: Here, we try to include information on the CO2 profile and estimate near-surface values of CO2 mixing ratio to compare the Level 2 data sets of GOSAT and OCO-2 with the flasks values. The XCO2 from the GOSAT and OCO-2 was the column averaged with profile information from top to surface and we have used the lower pressure levels from the satellite retrieval. This kind of comparison of in-situ CO2 measurements and XCO2 retrieved from satellite will provide information on how strong is the influence of the local CO2 flux. The scientific values of comparison of in-situ CO2 measurements with Satellite XCO2 was described in the study of Ye Yuan et.al. 2019 and our study is not for the first time in this sense. General comments: The authors often list characteristics of a certain region (e.g. high anthropogenic emissions, low vegetation levels) and then attribute the difference between CT and GOSAT/OCO-2 to these characteristics. The data is indicating correlation, not causation. Additional

research (e.g. a detailed modelling study) would need to be done to provide evidence that the XCO2 difference is *caused* by such characteristics. I note several instances of this below where it would be wise to soften the language.

Response: We agree with the referee's comment that additional studies are needed to identify and quantify the causes of the discrepancies observed. It is not the scope of this study to quantify all sources of the discrepancy. We have merely indicate some possible source of discrepancy based on physical connection, not just on correlation. Identification of causality chain is complex and may need modeling works in some cases and it is not our intension to do so.

General comments: For all the maps, I would strongly suggest not to use the default rainbow colormap for XCO2. Depending on the coding language you use, there are a number of much better colormaps available. For ordered information, such as XCO2, you should use a perceptually uniform colormap (such as viridis in Python). For diverging data, such as CT2016 – GOSAT, you should use a diverging colormap (such as RdBu in Python) and center the colorbar at 0. In many of your figures, you use a rainbow colormap with unequal positive and negative limits, which makes it incredibly difficult to determine where on the map the bias is above or below zero. https://matplotlib.org/tutorials/colors/colormaps.html Response: We understand the concern of the reviewer. It is always a difficult task in Matlab. We accept the anonymous referee suggestion to enhance the quality of the figures.

General comments: When discussing the distance between a given GOSAT/OCO-2 measurement and CT, could you please elaborate on what exactly this means? Each GOSAT/OCO-2 measurement should fall within a CT grid cell, so dx seems meaningless to me. Response: we averaged satellite values in a 3 X 3 degree window centering the grid cell of CT as described on page 6 line 5. Hence, we use a rectangle the maximum distance of the observation from the satellites can have a value $\sqrt{}$(ãĂŰ1.5ãĂŮˆ2 ãĂŰ+1.5ãĂŮˆ2)=2.1 degree which is indicated on the color bar of Fig. 2.

General comments: The mean bias for the entirety of Africa is mentioned numerous times, including in the abstract. However, your analysis shows that there are large regional patterns. Thus, there is little scientific value in, for example, stating that GOSAT XCO2 is 0.28 ppm higher than CT. Additionally, no uncertainties are given for any statistics in this paper. This should be resolved before publication. For example, 0.28 +/- 1.5 ppm is much less meaningful than 0.28 +/- 0.2 ppm. Response: We have indicated the standard deviation of the mean bias in table 1 on page 10. However, We agreed that it was also good to indicate as +/- from the mean bias as suggested. And now we updated in the main text including the abstract.

General comments: For OCO-2, are you using land nadir data, land glint data, or both? For GOSAT, you are presumably including the medium gain data, but please state so. Response: We use both nadir data and land glint data in the analysis as they are both can normally be used for scientific analysis (see Wunch et., al.). It is explicitly stated on page 5 of line 20 in the revised manuscript.

Specific comments: P2 L30: Citation for this? The land surface characteristics could affect retrievals, but I'm unaware of the impact of anthropogenic sources on satellite XCO2 biases. Response: accepted and citation is added on page 3 of line 2.

Specific comments: P3 L9: This makes it sound as if models are intrinsically more accurate than the satellite measurements. If this were true, why would we even need satellite measurements? In general, however, the paper does a good job at saying the models and obs. "agree" or "disagree" rather than one is "wrong" or "right." Response: The statement on page 3 of lines 7 -11 now on page 3 from lines 13-17 shows the regional uncertainties in GOSAT retrieval varied from one region to others. The GOSAT retrievals did a good job over the US while it has large regional variation over China which suggests the need for consistency check on the satellite retrievals. Our study shows that there are certain limitations and strengths of both models and satellite data.

Specific comments: P4 L10: SCIAMACY measured CO2 and CH4 before GOSAT.

Response: We mentioned GOSAT as the world's first spacecraft dedicated fully to measure the concentrations of carbon dioxide and methane. This statement is rephrased in this sense on page 4 line 7. SCIAMACY on ENVISAYT is providing good data on CO2 in recent times but it was not CO2 dedicated satellite mission.

Specific comments: P4 L19: GOSAT ACOS B3.5 is now 5.5 years out of date. B7.3, which represents a significant update to the retrieval, has been available for over 3 years now. It is too much to ask of the authors to repeat their analysis with the newer version, but it must be noted that the version used is very outdated. See the official Data Users Guide for details on the latest product: https://docserver.gesdisc.eosdis.nasa.gov/public/project/OCO/ACOS_v7.3_DataUsersGuideRevF.pdf
Response: We have specified the data version which can indicate when the datasets were retrieved.

Specific comments: P4 L26: Please cite some OCO-2 papers in this section (e.g. Crisp et al., 2008, Response: accepted and change is made on page 4 of line 15.

Specific comments: P5 L16: If CT is a 3-hourly product, the maximum d(time) would be 1.5 hours. Response: we agree that the maximum d(time) in CT is 1.5 hour . But instead of 1.5 hrs sampling interval, we used 3 hr to get more coincident measurements.

Specific comments: P7 L10: Citation needed regarding Southern Africa's characterization. Response: accepted and change is effected on page 7 line 25.

Specific comments: P7 L11: How do you know that this is the reason for the bias dipole? Response: The distribution map shows that there is dipole distribution which is higher XCO2 north of the equator than south of the equator. The Southern Africa region is characterized by weak anthropogenic CO2 emission and high CO2 uptake by the vegetation than Northern Africa (see also Ciais et al., 2011).

Specific comments: P7 L19: How would low number statistics result in a high bias?

It's certainly possible, but no explanation or mechanism is provided. Response: That is likely because the satellite retrievals have noise which can be smoothed out when a large number of datasets are averaged.

Specific comments: P7 L19: Citation needed regarding rainfall. Response: accepted and change is made on page 8 line 7.

Specific comments: P8 L1: These plots are very difficult to interpret because of the large number of data points. I would strongly suggest to instead plot heatmaps of the XCO2 difference vs. the spatial difference. And, as noted above, it is not clear what the distance metric actually represents. Response: accepted.

Specific comments: P9 L5: The higher GOSAT/OCO-2 uncertainty in these regions is likely driven by low signal to noise in the strong CO2 band over dark forests. P10 L6: Could use a general citation here. Response: This part is removed and partly considered on the introduction section as recommend by the other referee.

Specific comments: P12 L15: If the CO2 sink is growing after the rainy season, why would GOSAT not see it? Response: This discrepancy is over the African equatorial region which largely covered by dense forests since GOSAT may have large uncertainty over the dark forest region. However, further studies are needed to answer specifically why the discrepancy occurs.

Specific comments: P14 L1: Same as above: why would there be a difference? You seem to imply that the difference must be because of local sources and transport, yet this is speculation. I would simply soften the language from "likely" to "possibly." Response: accepted.

Specific comments: P17 L4: The cirrus cloud hypothesis should be removed unless you can show that there are more cirrus clouds over that specific region which could potentially be biasing the satellite results. Response: accepted and the statement is removed.

Specific comments: P17 L11: By what mechanism would a cold bias impact the CT XCO2? Would suggest removing unless you can provide a reasonable hypothesis. Response: accepted and it is now removed.

Specific comments: P17 L18: How would low vegetation levels and local sources result in a low correlation between the two products? Would suggest removing unless you can provide a reasonable hypothesis. Response: On a vegetation-free area, the XCO2 has weak to no seasonal patterns. Furthermore, the presence of a point CO2 emission source may not be captured by the coarse model simulation.

Specific comments: P19 L17: Good. Here, a correlation is discussed (higher OCO-2 where there's more vegetation) without asserting causation. Another hypothesis could be cloud contamination in the satellite retrievals. P23 L9: What plantation is this referring to? Please elaborate or remove this statement. Response: accepted and the statement was removed.

Specific comments: P25 L11: What intensive fire is this referring to? Please elaborate or remove this statement. Response: The statement is further elaborated on page 26 line 7.

Specific comments: P29 L2: This is a disappointingly brief discussion on reasons why the model could have issues. This paper should emphasize that neither models nor satellites are perfect, and that all that can be done in a poorly constrained place such as Africa is a comparison and discussion of potential reasons for the differences. For example, clouds, aerosols, and dark surfaces can result in biased XCO2 from satellites, while poor parameterizations and insufficient input data can hinder models. Response: Although we are clear on how both observations and model go wrong, we made further statements regarding potential problems in both cases in the manuscript by highlighting reviewer's inputs at various places in the revised manuscript.

Specific comments: P29 L4: Should thank both the appropriate Japanese agencies for GOSAT and NASA JPL for the GOSAT ACOS and OCO-2 retrievals. Technical

comments: There are numerous spelling and grammar issues that should not be the responsibility of a reviewer to fix. I would suggest that the authors spend some time resolving these issues. Response: Changes are made according to the recommendations.

Specific comments: Overall: XCO2 is never defined. Response: accepted and it is defined on page 1 line 4 (abstract) and page 3 line 1. Specific comments: P3 L25: “combines observed in situ carbon dioxide”; P7 L15: Likely a typo. GOSAT in comparison to GOSAT. Response: Changed to “GOSAT ....in comparison to CT” on page 8 line 3.

Specific comments: P10 L2: Oddly worded. Just say Africa has significant land mass in both hemispheres. Response: This paragraph have been moved to introduction and modified on page 3 line 19.

Specific comments: P27 L17: Oddly worded. Perhaps, “is important to identify differences between GOSAT and CT. Response: Accepted and change is made on page 28 line 11.

Specific comments: ” Figure comments: - As stated above, please use appropriate colormaps and colorbar ranges for diverging data. - For time series, please use years and months instead of “months since.” Response: accepted.

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Please also note the supplement to this comment:
https://www.atmos-meas-tech-discuss.net/amt-2019-390/amt-2019-390-AC2-supplement.pdf

Interactive comment on Atmos. Meas. Tech. Discuss., doi:10.5194/amt-2019-390, 2019.