The Total Carbon Column Observing Network's GGG2020 Data Version

Response to Anonymous Referee #2

Joshua L. Laughner on behalf of all coauthors

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Thank you to the reviewer for taking the time to evaluate our manuscript, and for their positive endorsement of its value. We have done our best to address the comments made. Below, comments from the reviewer are in red, our responses are in blue, and quotes of the manuscript are in black. Unless otherwise stated, line, figure, table, and section numbers used in comments and responses refer to the *original* manuscript while such cross-references in quotes of the new version of the paper refer to the *revised* version.

One note on the organization. The processing chain is complex and there are many steps. The first section of the paper gives a bit of an overview, and then notes the subprograms and where they are discussed in the paper. I do agree with another review that suggests the paper sections should be ordered to reflect the processing chain more directly. Start with the section on interferograms (now 5), and then move to gsetup (now section 4), and then the spectroscopy and continuum fitting (now sections 3 and 6). Finish with post processing, as the paper now has.

Agreed, we have adopted the suggested order as well as moved the section on miscellaneous changes to the data format to follow sect. 2. We have also added a new figure with a flowchart of the components of GGG and the data delivery (new Fig. 1).

The introduction section steps through the process of gathering measurement data and transforming into the desired gas columns. I was expecting it to set the stage for the subprogram discussion that starts at about line 60. I would suggest a modification in the paragraph that starts on line 23 with "TCCON instruments measure solar spectra in the near-infrared (NIR) wavelengths;". I suggest you say TCCON instruments measure interferograms with direct sun measurements in the near-infrared (NIR wavelengths). There are transformed into spectra.... Or something to that effect, so the idea of interferograms is introduced here. The transformation to spectra and the issues such as detector non-linearity and phase correction are important and improvements there are having a significant positive impact on the dataset.

Changed this sentence to:

> "TCCON instruments **record interferograms of direct-sun measurements** in the near-infrared (NIR) wavelengths. **These interferograms are transformed into spectra from which** the final column average mole fractions

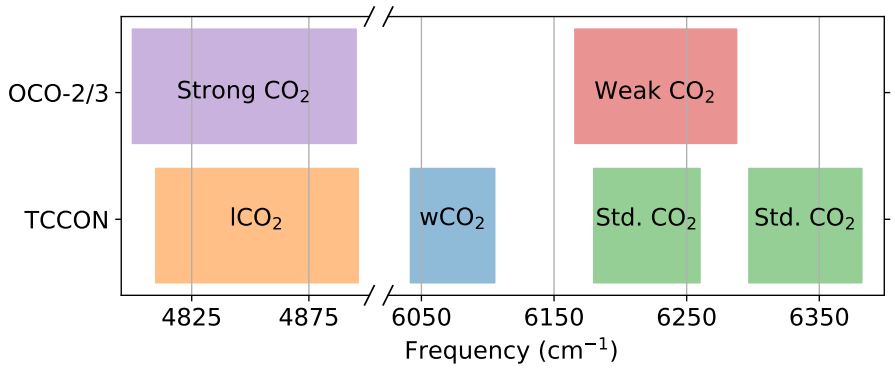

Figure R1: The new figure added to compare the TCCON and OCO-2/3 CO2 windows.

(henceforth denoted as "X_{gas}", e.g. "X_{CO_2}") are derived using the retrieval software GGG."

Line 55 - I would replace "for all retrievals except those listed in §7.3.2" with "for the discussion of changing O2 mole fraction in §7.3.2"

We changed this to:

"GGG2020 assumes that $f_{O_2} = 0.2095$ for **all** X_{gas} **products** except those listed in §8.3.2 **with a variable O_2 mole fraction implemented.**"

Lines 82 and 83 - how do the windows discussed here relate to the measurement windows of OCO-2 and other satellite instruments. Seems that if they are the same, this could provide some insights into how the intercomparions of TCCON and satellite data are influenced by window selection.

We have added a new figure that shows this visually and a new sentence referencing it:

"Figure 2 shows how these two windows (plus the windows for the standard TCCON X_{CO_2} product) align with the strong and weak CO_2 windows used by OCO -2 and -3.""

Line 111 - perhaps add a pointer to the section where the solar continuum is addressed (section 6)?

We have added a final line to this section:

"The solar continuum is handled separately from the linelist in GGG. This is discussed in §7."

Line 117 in section 3.2 - what are the implications of the choice of lineshape? Now HITRAN is not a database that includes the info you need? Is that a change of strategy?

Correct, HITRAN (or at least the standard 160 character product) does not contain all the data we need. However, this is not a full-fledged change in strategy, as we have always developed a custom linelist that draws from multiple sources. We have added a paragraph to the non-Voigt section that says this:

> "This does mean that the standard 160-character wide HITRAN linelist product does not include all of the parameters required for these gases. It has always been true that GGG has used a customized version of the HITRAN linelist. Therefore, this need for additional parameters represents an increase in the complexity of our linelist strategy, but a continuation of the same approach to use the best spectroscopic information from various sources."

Line 198 - Are the changes you have made to the line intensities similar to the uncertainties reported by spectroscopists? Do experts in this area think this is a reasonable scaling?

HITRAN uncertainties are conservative, so if they're asking if our changes are within the uncertainties reported by the HITRAN codes, then we believe so. Uncertainties reported by individual groups tend to be more optimistic, so we expect our changes are within the group-to-group differences, but perhaps outside the individual groups' reported uncertainties.

Line 275 - is igram meant to be interferogram?

Yes, changed.

Line 300 - I'm curious to know what the level of disagreement is that remains? Is it hard to summarize with a single statistic, and that is what you have just stated "does not completely resolve the problem", or can you be more quantitative?

The challenging part here is that the underlying problem—inconsistencies in the phase correction of the interferogram—can be present without causing the more readily observable bias in XCO2 between the forward and reverse scans. In our development, lowering the PCT eliminated that forward/reverse bias in XCO2, but did so by moving the challenging part of the phase correction to a part of the interferogram where it is much less likely to impact the Xgas values. So by "does not completely resolve the problem," we meant that the impact on the Xgas values (that the user cares about) has been mitigated, but the underlying physical problem remains and could have other impacts not yet identified. We have modified this sentence to say this more plainly:

> "...which improves the consistency between forward and reverse scans. **This eliminates the observed bias in X_{CO_2} between forward and reverse scans, but is not a fully general solution to the underlying problem.** We hope to develop a future version..."

Line 344 - is there information about the order of the polynomials in the final data product? How does a user know of this has been set properly or if channel fringing is an issue in a particular instrument?

This information is stored in the detailed netCDF files delivered by TCCON partners to Caltech. We review diagnostics for channel fringing as part of our routine quality control

process before releasing the data, and can check the polynomial order if we have reason to suspect that these are incorrect. Users of the public data do not have access to the detailed information (the sheer volume of variables in the private files make them much more difficult to use); if they have concerns about the data, they are encouraged to contact us with questions. We have added a paragraph to §6.1:

> "Diagnostics to detect channel fringes are reviewed as part the quality control process before TCCON data is made public. Any channel fringes detected will be removed by adjusting the fitting before the data is released to the public archive, though this is extremely uncommon."

Line 516 - figure 11 presents data as a function of Xluft. Did you examine other variables, like time or modulation efficiency, and decide that Xluft was the best variable to use?

We did look at other variables, but have not yet found a better predictor of bias. Xluft is particularly useful because it acts as a metric for several error terms (e.g. ILS, nonlinearity, pointing), so for Fig. 11 it is the best variable for the x-axis.