Orbiting Carbon Observatory-3 (OCO-3) Data Quality Statement:
Level 2 Forward Processing
Data Release Early (vEarly)

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The Orbiting Carbon Observatory (OCO-3) has released the first version of the Level 2 (L2) forward processing data product, containing estimates of the column averaged carbon dioxide dry air mole fraction (X_{CO2}), other geophysical quantities retrieved from OCO-3 observations. This version of the L2 Product is release Early (vEarly) and begins with August 2019 data. The full OCO-3 L2 data set with complete reprocessing back to August 2019 will be complete and posted at the Goddard Earth Sciences Data and Information Services Center later in the year. Updated documentation including the L1B and L2 Algorithm Theoretical Basis Documents and L2 Data User's Guide will be made available along with the OCO-2 reprocessing release later in the summer 2020.

The vEarly version of the OCO-3 data is the first public release of Level 2 (L2) data products. The L2 algorithms used are the same as those that are used for the upcoming OCO-2 L2 data release, to aid in the use of the two datasets together.

Users should be aware of two known issues in the vEarly OCO-3 data, tied to known errors in the L1b data in radiometric calibration and geolocation.

Radiometric errors: The radiometric calibration is limited by the short duration of the data record, and is expected to improve as the data record length increases. The overall radiometric scaling is not yet well constrained (~10%), as OCO-3 cannot perform solar calibrations, and has not yet performed lunar calibration. Analysis of the lamp data suggests that early mission data (August through October 2019) have radiometric errors in the O_2 A-band of 2 to 5%. After that, the errors increase from about 6% in December to about 12% by March. In the L2 data, this error is seen primarily as a growing dP error in the XCO2 retrievals. The August 2019 data typically have dP errors of -3 hPa (retrieved – prior), while March 2020 values are larger, between -5 and -8 hPa, with the larger value for water glint. Users should be cautious about timeseries analysis, as comparison of the XCO2 data with TCCON suggest biases appear to be stable. This radiometric error will for the full record will be addressed in an updated release in late 2020. It is important to note that the improved radiometry was integrated into vEarly data starting on April 8 (solar day 5268). Users can expect to see a step change in dP as a result. The radiometry of the weak CO_2 and strong CO_2 bands also changes but by 1% to 2%.

Additional updates relative to pre-flight have been made to the signal to noise (SNR) coefficients in the later vEarly data. The inflight dark and lamp data were used to improve the estimate of the background noise, resulting in more consistent behavior across footprints, and this removed extreme outliers in both coefficients from the prelaunch fits.

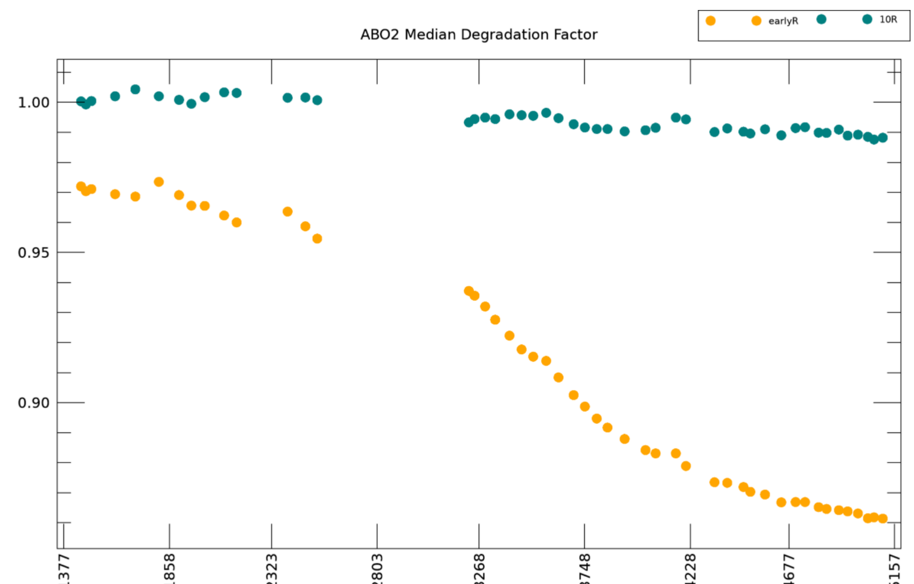

Figure 1: Timeseries of median gain degradation coefficients for the O_2-A Band. The organge circle indicate the values used in vEarly. The blue are an improved estimate, which was adopted after solar day 5268 for vEarly and which will be used in the B10 produced in late 2020.

Geolocation errors: The geolocation errors for this release are typically less than a footprint for the nadir data. For the snapshot area maps, where the pointing mechanism is at a wide range of positions, we find errors that range from 1km to 4km and are generally larger when the elevation actuator of the pointing mirror assembly is farther off nadir. We are continuing investigations to find the fundamental cause of this error. In addition, it appears that there is some time variation in the errors. Users are cautioned to carefully review the data for areas with highly variable topography, as the geolocation error results in error of the surface pressure and therefore XCO2.

Validation Status: The fundamental means for tying the OCO-3 X_{CO2} to the World Meteorological Organization's CO_2 standard is by comparison with ground-based observations from the Total Carbon Column Observation Network (TCCON). A description of the process of validating OCO-2 data against TCCON is described in Wunch et al., 2017 using an earlier OCO-2 data version. The OCO-2 validation plan was first described prior to launch in an analysis using TCCON and X_{CO2} estimates retrieved using the OCO-2 retrieval algorithm on data from the Japanese GOSAT satellite (Wunch et al, 2011b). To derive quality filtering and bias correction, we follow the methods described in O'Dell et al., (2018). We compare the retrieved XCO_2 to an independent estimate of XCO_2, a so-called truth proxy. For OCO-3 vEarly, we use a different truth proxy data set for each of the three observational modes: TCCON for nadir observations over land, a small area approximation for glint observations over water, and a small area approximation using a subset of SAMs for area map and target mode observations.

For nadir observations over land (NL) we use TCCON data from 17 stations as the truth proxy data set. We use the GGG2014 data set covering the time period between August and October 2019 and spanning from 55°N to 45°S in latitude. We use similar coincidence criteria as O'Dell et al., (2018) to match airmasses observed by TCCON and OCO-3. In total, we count ~80K coincident soundings between OCO-3 and TCCON that are used in our training data set.

For glint water (GW) measurements, we use a small area approximation (SAA) as truth proxy (for more details see O'Dell et al., (2018)). The SAA makes use of the low spatial variability of XCO_2 over small regions (up to 100km) and short time spans (~10s). Here, we define continuous glint segments of up to 70km length along-track as small areas. Between August and October 2019 we find ~3000 small areas over water which we use as a truth proxy data set for glint mode observations.

For area map and target mode observations, we treat a subset of area map observations over scenes also regularly observed by ECOSTRESS, solar-induced fluorescence (SIF) scenes, and desert scenes as small areas. In contrast to observations over fossil fuel targets, XCO_2 concentrations over ecological scenes of the size of 80km x 80km can be assumed as nearly constant within a ~2 minute interval (approximate length of one area map observation). The median value of XCO_2 over such a scene is assumed to be the *true* XCO_2 and variations of single soundings from this truth are used to identify spurious and systematic biases in the retrieval algorithm. Currently, remaining uncertainties in the knowledge of the pointing of OCO-3 may introduce biases in the XCO_2 retrievals, especially in regions with large topographic variations. These topography related biases are more prominent in the data for large PMA elevation angles which are typically reached during area map and target mode observations. Therefore, we only include area maps in our training data set with low topographic variations (less than 200m over the entire scene). In total, 47 area maps over ECOSTRESS, SIF, and deserts contribute to the SAA truth proxy for area map and target mode observations.

A first comparison between co-located TCCON and filtered and bias corrected NL XCO_2, indicating a bias of 0.18ppm and a root mean squared error (RMSE) of 1.07ppm. Only overpasses with at least 25 good OCO-3 and TCCON soundings within +/- 2h of the mean OCO-3 overpass time are considered. Coverage over water is more sparse than over land between August and October 2019. The land-ocean bias is ~ 0.25ppm between 15°N and 55°S and ~ 1.5ppm north of 15°N. This contrast is currently under investigation, but might be driven by the time of year and strong biospheric CO_2 uptake in the northern hemisphere. In addition, we do not apply a global scaling factor to OCO-3 glint observations over water in vEarly.

Summary: Overall, OCO-3 vEarly XCO_2 shows a reasonable performance for all three modes at this early stage. With continued measurements of OCO-3 and ongoing effort to improve our knowledge of the instrument pointing and softening early mission glint point offset restrictions, we will revisit the derivation of quality filters and bias correction at a later point. A more detailed validation and evaluation study of OCO-3 XCO_2 against TCCON, model data, COCCON, and cross comparisons against OCO-2 will be extensively discussed in Kiel et al. (in prep.).

There is much more documentation that will help with utilizing the OCO-3 L2 data, all of which is available at the GES DISC OCO-3/OCO-2 documentation page (https://disc.gsfc.nasa.gov/information/documents?title=OCO-2%20Documents). Note that OCO-2 and OCO-3 have combined documents. For example, the L2 ATBD will describe the common algorithm as well as mission specific features and the small number of differences in the data fields.

References

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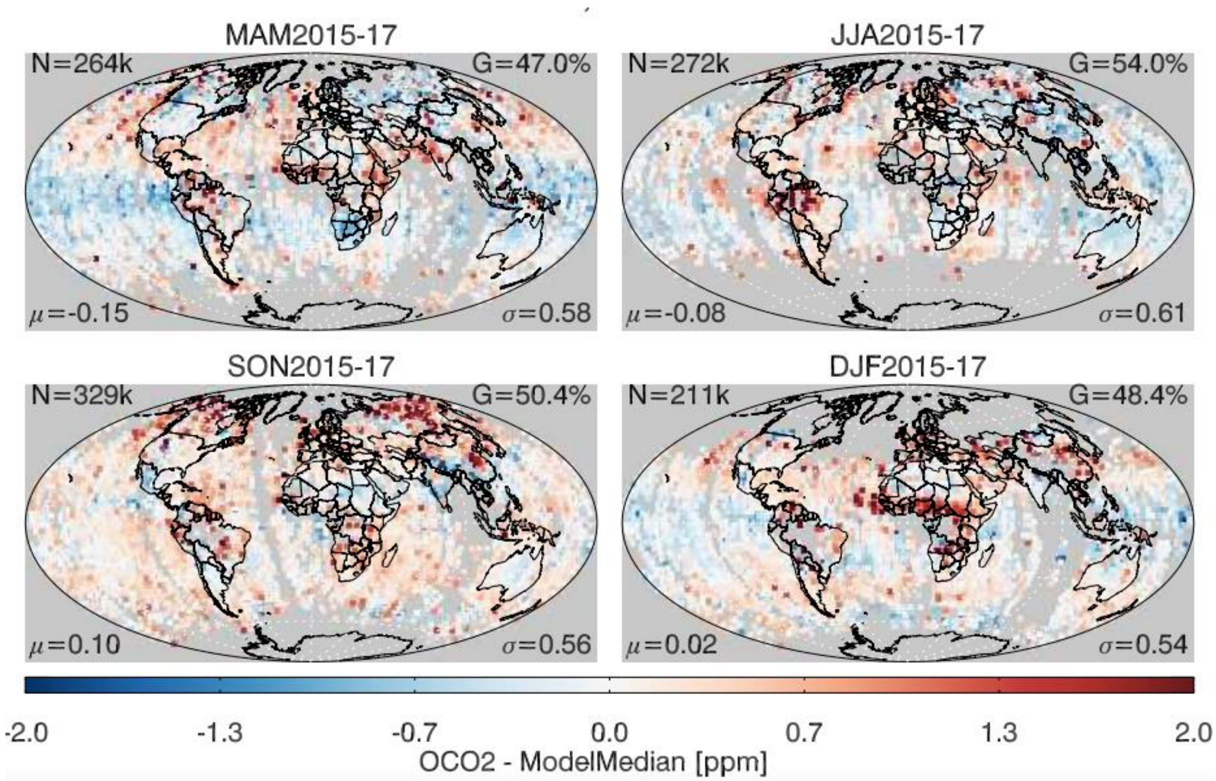

Figure 1. Difference between OCO-2 V10 data from 2015 – 2017 and an aggregation (median) of model results. These preliminary comparisons suggest that differences between the data and model have been reduced for V10 over the same comparisons for V9 data.

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