National Aeronautics and Space Administration

Goddard Earth Science Data Information and Services Center (GES DISC)

README Document for

Orbiting Carbon Observatory Products

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1 Introduction

This README file applies to the Version 7 data products from the Orbiting Carbon Observatory (OCO) and contains basic information regarding the OCO products.

An early examination of the V6/V6r L2 production products revealed large (> 1%) residuals in the spectral fits in the two CO2 channels and significant XCO2 biases. The large residuals were traced to errors in the calibration tables used to produce the version 6 and 6R L1B production products. This required expedited replacement of V6/6r with V7/7r.

More extensive documentation (including all documents referenced in this README) is available from the OCO documentation page at the Goddard Earth Sciences Data and Information Services Center (GES DISC).

Brief overview of OCO-2 mission, retrieval concept, description of the content of the current and planned for public distribution OCO-2 data products, naming conventions, key data fields recommendations for data analysis, and tools to view and search the data products are provided in the User Guide.

OCO-2 employs a dedicated spacecraft with a single instrument. It was launched on July 2, 2014, into a near-polar orbit on an expendable launch vehicle. OCO-2 joined the A-Train formation of satellites on August 3, 2014. The OCO-2 instrument incorporates three high-resolution spectrometers that make coincident measurements of reflected sunlight in the near-infrared CO2 near 1.61 and 2.06 µm, and in molecular oxygen (O2) A-Band at 0.76 µm.

Concerning the spectral domain, high spectral resolving power ($\lambda/\delta\lambda > 20{,}000$) is needed to resolve the CO2 and O2 lines from the adjacent continuum to maximize the sensitivity to small (< 0.3%) variations in total column CO2.

In the spatial domain, the OCO-2 instrument have a narrow swath - it collects 8 soundings over its 0.8-degree wide swath every 0.333 seconds, yielding surface footprints with along-track dimensions < 2.25 km and cross-track dimensions that vary from 0.1 to 1.3 km at nadir.

1.1 Dataset Description

The full suite of OCO-2 products is given in Table 1. These are all data collections currently released by the OCO-2 Science Team.

Table 1

Product	Long Name	Level
OCO2_Att	OCO-2 spacecraft attitude data	0
OCO2_Eph	OCO-2 spacecraft ephemerides	0
OCO2_L1aIn_Sample	Collated, parsed, OCO-2 Science or Calibration Data	1A
OCO2_L1aIn_Pixel	Collated, parsed, OCO-2 Calibration Data	1A
OCO2_L1B_Science	Calibrated, geolocated OCO-2 science spectra	1B
OCO2_L1B_Calibration	Calibrated, geolocated OCO-2 calibration spectA	1B
OCO2_L2_IMAPDOAS	Geolocated retrieved values of XCO2 and fluorescence generated by the IMAP-DOAS algorithm	2
OCO2_L2_Diagnostic	Geolocated XCO2 retrieval results plus algorithm diagnostic information	2
OCO2_L2_Standard	Geolocated XCO2 retrieval results	2
OCO2_L2_Lite_FP	OCO-2 Level 2 bias-corrected XCO2 and other select fields from the full-physics retrieval aggregated as daily files	2
CO2_L2_Lite_SIF	OCO-2 Level 2 bias-corrected solar-induced fluorescence and other select fields from the IMAP-DOAS algorithm aggregated as daily files	2

1.2 Algorithm Background

In preparation to use the final CO2 retrievals from OCO-2, it would be most informative for users to read about the basics of the algorithm in the User Guide. In addition, the OCO-2 Science Team has also provided documentation on the Level 2 full physics retrieval.

For advanced users interested in working with the calibrated Level 1B spectra, for instance to test their own CO2 retrievals, there exist several important documents:

- The Level 1b Algorithm Theoretical Basis Document

- The companion L1B algorithm specification document
- Software Interface Specification for the L1B products

These, as well as documents for the Level 2 products, are organized on the GES DISC web site.

1.3 Data Disclaimer

After reading the very brief but essential quality statement , users are encouraged to visit for more details, in an increasing order of complexity, the L1B Algorithm Specification Document, the L1B ATBD, and the Data User Guide. We note that without familiarizing with the L1B ATBD, and in particular caveats on the instrument and collected radiances, it would be next to impossible to understand and properly use the OCO-2 data.

1.4 Mailing List

A mailing list is established for everyone interested in updates on a monthly basis. We will notify users if there is new documentation, important announcements about the dataset, etc. We encourage everyone who downloads OCO-2 data to sign up to the oco2_updates email list. To subscribe, send an email to **sympa at list.jpl.nasa.gov** with the subject:
subscribe oco2_updates

2 Data Organization

2.1 Three basic groups of OCO-2 data collections

Publicly available OCO-2 data are organized in Attitude and Ephemeris, Level 1, and Level 2 final retrieval of column CO2 (see Table 1).

2.2 File Naming Convention

The file naming for OCO-2 products products consists from the following elements that are described in Table 2.

oco2_[*ProductId*][*Mode*]_[*Orbit*][*ModeCounter*]_[*AcquisitionDate*]_[*ShortBuildId*]_[*ProductionDateTime*].h5

Table 2

Field	Description	Format	Selection
ProductId	A mnemonic indicating a file type.	String	L1bSc - Level 1B Science product
			L1bCl - Level 1B Calibration product
Mode	The acquisition Mode associated with the data.	Two character string	GL - Sample Glint
			ND - Sample Nadir
			TG - Sample Target
			DS - Sample Dark Calibration
			LS - Sample Lamp Calibration
			SS - Sample Solar Calibration
			BS - Sample Limb Calibration
			NP - Single-Pixel Nadir
			GP - Single-Pixel Glint
			TP - Single-Pixel Target
			DP - Single-Pixel Dark Calibration
			LP - Single-Pixel Lamp Calibration
			SP - Single-Pixel Solar Calibration
			BP - Single-Pixel Limb Calibration
			XS - Sample Transition
			XP - Single-Pixel Transition
			MS - Sample Lunar Calibration

Field	Description	Format	Selection
			MP - Single-Pixel Lunar Calibration
			SB - Stand-by
Orbit	The Orbit on which the associated data were acquired. If the Orbit number is less than 10,000, zeros are prepended to the number to ensure that the field is five digits long.	nnnnn	Actual Orbit number for data acquired du
ModeCounter	This field indicates how many times an acquisition Mode occurs in an Orbit. If a mode occurs only once, ModeCounter is set to "a".	Single character	a, b, c, …
AcquisitionDate	The date (UTC) the data were acquired.	yymmdd	
ShortBuildId	The identification of the related software build	B*stuu*	s = ID of major build cycle t = ID of scheduled build within a major build cycle uu = ID of incremental or patch build
ProductionDateTime	The date and time (UTC) that the file was produced.	yymmddhhmmss	

Examples:

oco2_Attde_02413_141214_B6000_141215232732.h5

oco2_Ephem_02413_141214_B6000_141215232732.h5

oco2_L1aInDS_02413a_141214_B6000_141215233629.h5

oco2_L1aInSB_02413a_141214_B6000_141215233629.h5

oco2_L1aInSB_02413b_141214_B6000_141215233629.h5

oco2_L1bClDS_02413a_141214_B6000_141216004409.h5

oco2_L1bScND_02412a_141214_B6000_141216030251.h5

2.3 File Format and Structure

All OCO-2 products from **Table 1** are in plain HDF5 format. The latter allows conspicuous grouping of datasets that are related by some criteria under folders. The latter can be easily viewed by means of the executable utility "h5dump" with option "-n". Below, a liberally truncated sample is given:
h5dump –n oco2_L1bScND_02412a_141214_B6000_141216030251.h5

```
group      /Dimensions
 group      /Dimensions/AncFile
……
dataset    /FootprintGeometry/footprint_latitude
……
 dataset    /FrameConfiguration/color_slice_position_o2
……
 dataset    /FrameTemperatures/temp_smooth_fpa_o2
……
dataset    /Metadata/AcquisitionMode
……
dataset    /SoundingGeometry/sounding_latitude
……
 group      /SoundingMeasurements
 dataset    /SoundingMeasurements/radiance_o2
 dataset    /SoundingMeasurements/radiance_strong_co2
 dataset    /SoundingMeasurements/radiance_weak_co2
```

Full description of groups and datasets within groups can be found in the documentation of the corresponding data type.

2.4 Key Science Data Fields

There is a very large number of variables in every OCO-2 HDF5 file, and every data type would have its key data fields. For instance, in the calibrated L1B spectra (product mnemonic "L1bSc" in the file name) the key group of variables can be assumed to be "/SoundingMeasurements" (see above). In Level 2 Full Standard Retrieval, "L2Std" in the file name, the key variables are

under /RetrievalResults, but users should pay as much attention to quality fields under /PreprocessingResults and /SpectralParameters. For a description of key variable, users should first refer to the Data User Guide.

2.5 Science Area

NASA successfully launched its first spacecraft dedicated to studying atmospheric carbon dioxide at 2:56 a.m. PDT (5:56 a.m. PDT) on Wednesday, July 2, 2014. Orbiting Carbon Observatory-2 (OCO-2) is NASA's first dedicated Earth remote sensing satellite to study atmospheric carbon dioxide from space. OCO-2 is an exploratory science mission designed to collect space-based global measurements of atmospheric CO_2 with the precision, resolution, and coverage needed to characterize sources and sinks (fluxes) on regional scales (≥1000km). OCO-2 will also be able to quantify CO_2 variability over the seasonal cycles year after year. This mission will also validate a space-based measurement approach and analysis concept that could be used for future systematic CO_2 monitoring missions.

3 Data Contents

3.1 Dimensions

Some sense of dimensions can be acquired from the group /Dimensions. Although all dimensions are described in that group, admittedly it is not an easy task to relate that dimensions with the data fields they belong to. Still, the value of this group is that each dimension is given a short description.

3.2 Attributes

All Metadata attributes in OCO-2 files are under the group "/Metadata". It contains a large number of Metadata objects. The easiest way to print a filtered list is e.g.:

h5dump –n oco2_L1bScND_02412a_141214_B6000_141216030251.h5|grep Metadata

An example of important object there is “/Metadata/BuildId”, that identifies the algorithm version used in the processing.

4 Options for Reading the Data

4.1 Command Line Utilities

The HDF Group lists a number of HDF5 command line tools on their website:

https://www.hdfgroup.org/hdf-tools/

Among them, the one that is the most useful for previewing HDF5 content is **h5dump**. It is the “must-have” utility for quick previews of the HDF5 files structure and contents. For instance use to print the algorithm version:

h5dump -d "/Metadata/BuildId" oco2_L1bScND_02412a_141214_B5000_141216030251.h5

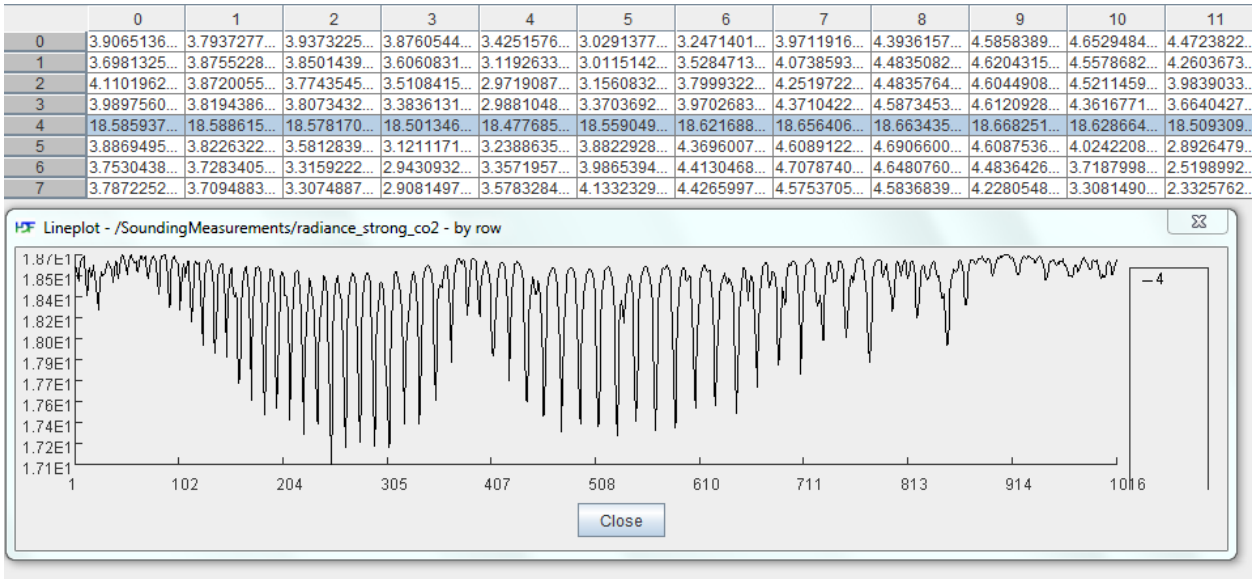
4.2 Tools for simple visualization and file content view

It should be noted that OCO-2 is a sounder with a very narrow swath, as opposed to imagers like MODIS. Simple L1B swath images, while technically possible, will make little sense for superficial viewing. Just go give a flavor, in L1B swaths, every pixel contains 1016 spectral “colors”.

4.2.1 HDFView

Users involved with sensor data debugging and spectroscopy may find **HDFView** very useful. Among the strengths of the tool is that OCO-2 files content can be viewed in a very friendly fashion – all groups are presented as folders where user can easily drill down the file hierarchy.

Quick line plots, as cross sections in the spectral or spatial domain, are very easy to view. Numerical data sets can be viewed as spreadsheets, and as images (multi-dimensional datasets). Simple data manipulations are also possible.



	0	1	2	3	4	5	6	7	8	9	10	11
0	3.9065136...	3.7937277...	3.9373225...	3.8760544...	3.4251576...	3.0291377...	3.2471401...	3.9711916...	4.3936157...	4.5858389...	4.6529484...	4.4723822..
1	3.6981325...	3.8755228...	3.8501439...	3.6060831...	3.1192633...	3.0115142...	3.5284713...	4.0738593...	4.4835082...	4.6204315...	4.5578682...	4.2603673..
2	4.1101962...	3.8720055...	3.7743545...	3.5108415...	2.9719087...	3.1560832...	3.7999322...	4.2519722...	4.4835764...	4.6044908...	4.5211459...	3.9839033..
3	3.9897560...	3.8194386...	3.8073432...	3.3836131...	2.9881048...	3.3703692...	3.9702683...	4.3710422...	4.5873453...	4.6120928...	4.3616771...	3.6640427..
4	18.585937...	18.588615...	18.578170...	18.501346...	18.477685...	18.559049...	18.621688...	18.656406...	18.663435...	18.668251...	18.628664...	18.509309..
5	3.8869495...	3.8226322...	3.5812839...	3.1211171...	3.2388635...	3.8822928...	4.3696007...	4.6089122...	4.6906600...	4.6087536...	4.0242208...	2.8926479..
6	3.7530438...	3.7283405...	3.3159222...	2.9430932...	3.3571957...	3.9865394...	4.4130468...	4.7078740...	4.6480760...	4.4836426...	3.7187998...	2.5198992..
7	3.7872252...	3.7094883...	3.3074887...	2.9081497...	3.5783284...	4.1332329...	4.4265997...	4.5753705...	4.5836839...	4.2280548...	3.3081490...	2.3325762..

Figure 1. Screen snapshot of HDFView spreadsheet of the 8 OCO-2 footprints, and plot of OCO-2 strong CO2 band (centered at 2.06 μm) spectrum from footprint 4 ($\log_{10}$ is taken).

For download and more information, follow this link:

http://www.hdfgroup.org/hdf-java-html/hdfview/index.html

4.2.2 Commercial

IDL and **MatLAB**, are two major commercial data languages, coming with their libraries that fully support all HDF formats.

Although created for the ACOS Task, the recipes listed at the GES DISC website will give some guidance on how to open and read HDF5 files, and even build some gridding code:

https://docserver.gesdisc.eosdis.nasa.gov/public/project/OCO/acos-data-handling-recipes.html

Since HDF5 files created under the ACOS Task (using GOSAT/TANSO-FTS radiances), and OCO-2, have very similar structure, the recipes are providing simple examples of basic HDF5 functions.

4.2.3 Science Team provided

More example recipes can be found in the OCO-2 User Guide. These are more complex recipes using IDL and Python.

5 Data Services

5.1 Mirador

GES DISC provides basic temporal and advanced (event) searches through its search and download engine, **Mirador:**

http://mirador.gsfc.nasa.gov/

Mirador offers various download options that suit users with different preferences and different levels of technical abilities. Users can start from a point where they don't know anything about these particular data, its location, size, format, etc.., and quickly find what they need by just providing relevant keywords, like "OCO", or "CO2".

5.2 On-line access

Note that authenticated data access has been mandated in 2016. Instruction for registration and data download strategies are provided here:

https://disc.gsfc.nasa.gov/data-access

Since all data are on-line, users can do global recursive downloads wget. The top data directory is:

https://oco2.gesdisc.eosdis.nasa.gov/data/OCO2_DATA/

5.3 OPeNDAP

OPeNDAP stands for “Open-source Project for a Network Data Access Protocol”. OPeNDAP is a framework that simplifies all aspects of scientific data networking. It provides simple means for parameter and spatial subset. In the case of OCO-2 Level 1 and 2 data, the simple spatial subset can be materialized by array indexes, not geographical coordinates. In the most simplistic case, OPeNDAP can be used to convert data from HDF5 to NetCDF3, ASCII, and plain binary. The data directory hierarchy, as served by OPeNDAP, can be viewed in any browser:

https://oco2.gesdisc.eosdis.nasa.gov/opendap/

In this case OPeNDAP will be convenient to preview file contents and in particular variables names, dimensions sizes, and quick print of reasonably small variables to the screen.

5.4 Summary Access

All data access methods for all OCO-2 data types can viewed at the GES DISC:

https://disc.gsfc.nasa.gov/datasets?project=OCO

6 More Information

- Detailed Science Team documentation on all OCO-2 products can be found at:

https://disc.gsfc.nasa.gov/information/documents?title=OCO-2 Documents

- GES DISC is also summarizing essential information for every OCO-2 product in product pages that can be accessed from:

https://disc.gsfc.nasa.gov/datasets?project=OCO

- OCO-2 Science Team at JPL is maintaining an excellent website, where the richest information, from the sensor/spacecraft operations, to science perspectives of CO2 observations, is residing:

http://oco.jpl.nasa.gov/

For further assistance, please use this contact information:

Email: gsfc-help-disc at lists.nasa.gov

Voice: 301-614-5224

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8 References

Exhaustive list of references can be found in the User Guide.