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OCO (Orbiting Carbon Observatory) Project OCO-2

Software Interface Specification for the SDOS Level 1B Product

Revision D
April 10, 2016

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Change Log

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1 Product Identification and Software Version

This document describes the specification of one of the data products generated by the OCO-2 Science Data Operations System (SDOS). This document applies to the following product and system version:

Product Name:	Level 1B Product
Short Name:	OCO2_L1B_Science, OCO2_L1B_Calibration
SDOS System Version:	B7.3.00 and later
GES DISC Version:	Version 7 and Version 7r
Product Description:	Geolocated, radiometrically calibrated data in a standard granularity (for both science and calibration observations)

SDOS System Bn.x.yy generates products either with predictive calibration parameters (Version n) or with parameters derived via analysis of past instrument performance (Version nr). Therefore, nr is considered of higher quality. Analyses mixing the two sets should be undertaken with a degree of caution. The product specifications for n and nr are identical and this document applies to both.

2 Background information

The OCO-2 SDOS converts telemetry downloaded from the Observatory into data products that provide comprehensive mission results as well as material for further research and investigation. The SDOS generates products from Level 0 through Level 2, some of which are available for distribution to both the scientific community and the general public. All products are available to users of the SDOS computing cluster.

2.1 NASA Data Levels

The following table provides the definitions of the data levels used in this document. These definitions are standard within the NASA community

Level	Description
Packet data	Telemetry data stream as received at the ground station, with science and engineering data embedded
Level 0	Instrument science data (e.g., raw voltages, counts) at full resolution, time ordered, with duplicates and transmission errors removed
Level 1A	NASA Level 0 data that have been located in space and may have been transformed (e.g., calibrated, rearranged) in a reversible manner and packaged with needed ancillary and auxiliary data (e.g., radiances with the calibration equations applied)
Level 1B	Irreversibly transformed (e.g., resampled, remapped, calibrated) values of the instrument measurements (e.g., radiances, magnetic field strength)
Level 2	Geophysical parameters, generally derived from NASA Level 1 data, and located in space and time commensurate with instrument location, pointing, and sampling

2.2 Product Pedigree and Destination

This product is generated within the nominal SDOS pipeline by the CalApp PGE using the following input data:

- Level 1A instrument product
- Geolocation product
- Ancillary Radiometric Product

This product is expected to be an input to the following PGE's within the nominal SDOS pipeline:

- L1bStat
- Level 2 A-Band Preprocessor
- Level 2 IMAP-DOAS Preprocessor
- Level 2 Sounding Selection PGE
- Level 2 Full-Physics
- Level 2 Diagnostic Product Generator

The Level 1A product is slightly different for data acquired in Science modes vs. Calibration modes. Both product types are described in this document.

2.3 Suggested Tools to Read Product

The following set of tools can be used to open and examine this HDF-5 product on Linux systems. Other tools may be available.

- h5dump
- hdfview

3 Reference Documents

1. OCO-2 SDOS Software Design Document (JPL D-71459)
2. OCO-2 SDOS Data Bible
3. OCO-2 Science Data Management and Archive Plan (JPL D-64039)

4 Product Description

4.1 Format and Size

This product is in HDF-5 format. For most nominal orbits, the Science products use 1.1 Gigabytes (potentially across multiple files) and the Calibration products use between 35 and 77 Megabytes.

4.2 Naming Convention

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

Field	Description	Format	Selection
<i>ProductId</i>	A mnemonic indicating a file type.	String	L1bSc - Level 1B Science product
			L1bCl - Level 1B Calibration product
<i>Mode</i>	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
<i>Orbit</i>	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	MS - Sample Lunar Calibration
			MP - Single-Pixel Lunar Calibration
			SB - Stand-by
<i>ModeCounter</i>	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, ...
<i>AcquisitionDate</i>	The date (UTC) the data were acquired.	yymmdd	

Field	Description	Format	Selection
<i>ShortBuildId</i>	The identification of the related software build	<i>Bstuu</i>	s = ID of major build cycle t = ID of scheduled build within a major build cycle uu = ID of incremental or patch build
<i>CalibType</i>	Indicates whether processing used predictive or retrospective calibration	Single character if retrospective; Not present if predictive	r = retrospective calibration used
<i>ProductionDateTime</i>	The date and time (UTC) that the file was produced.	yymmddhhmmss	

5 Specification Table – Science Modes

The HDF file structure consists of a large number of Data Elements with values. These Elements (a.k.a., 'fields') may be of various types (e.g., arrays, scalars) and are organized into Groups. Groups are utilized in various ways, such as to combine Elements/values generated by different PGE's.

Description of column headers in the following tables:

Data Element	The name of the Data Element
Shape	See Appendix 1
Type	The data type of the values
Units	The SI units of the values, if any
Minimum value	The lowest possible value. In some cases, this is the lowest safe value (i.e., a 'red' limit)
Maximum value	The highest possible value. In some cases, this is the highest safe value (i.e., a 'red' limit)
Comments	Descriptive information about the Element
(no value = n/a)	

L1B_Science Product HDF specification

Group	Metadata					
Group description	Granule-level Metadata					
Data Element	Shape	Type	Units	Minimum value	Maximum value	Comments
<u>Standard Metadata</u>						
AcquisitionMode	Scalar	String				The instrument mode in which the data in the product were collected. Valid values are: 'Glint', 'Nadir', 'Target', 'Sample Dark Calibration', 'Sample Lamp Calibration', 'Sample Solar/limb Calibration', 'Single-Pixel Dark Calibration', 'Single-Pixel Lamp Calibration', 'Single-Pixel Solar/limb Calibration'
ActualFrames	Scalar	Int32				Actual number of frames reported in this product
ARPAncillaryDatasetDescriptor	Scalar	String				The name of the Ancillary Radiometric Product file used to calibrate this file
AscendingEquatorCrossingDate	Scalar	String				The date of the equator crossing of the spacecraft ground track in the ascending direction
AscendingEquatorCrossingLongitude	Scalar	Float32	Degrees	-180	180	The longitude of the equator crossing of the spacecraft ground track in the ascending direction

AscendingEquatorCrossingTime	Scalar	String				The time of the equator crossing of the spacecraft ground track in the ascending direction
AutomaticQualityFlag	Scalar	String				Not implemented - set to NULL
BadPixelMapVersionNum	Spectrum_Array	UInt32				Version number of corresponding Bad Pixel Map used to calibrate this data file
ColorSlicePositionO2	O2Slice_Array	Int16		1	1024	Absolute spectral position of each ABO2 color slice
ColorSlicePositionStrongCO2	StrongCO2Slice_Array	Int16		1	1024	Absolute spectral position of each SCO2 color slice
ColorSlicePositionWeakCO2	WeakCO2Slice_Array	Int16		1	1024	Absolute spectral position of each WCO2 color slice
DiffuserPosition	Scalar	Float32				The position of the solar diffuser at the beginning of the mode: 0 - Lamp or Closed position, 75 - Open for science, 150 - Solar Calibration position
EphemerisType	Scalar	String				The source of the spacecraft ephemeris data that were utilized to generate this data file
EquatorCrossingDate	Scalar	String				The date of the equator crossing of the spacecraft ground track in the descending direction
EquatorCrossingLongitude	Scalar	Float32	Degrees	-180	180	The longitude of the equator crossing of the spacecraft ground track in the descending direction
EquatorCrossingTime	Scalar	String				The time of the equator crossing of the spacecraft ground track in the descending direction

ExpectedFrames	Scalar	Int32				Nominal number of frames in this product
FirstSoundingId	Scalar	Int64				The ID of the first sounding in this file
InitialUnusedSpatialPixels	Spectrum_Array	Int16				Distance in spatial pixels of the start of first footprint from edge of FPA
L1BAlgorithmDescriptor	Scalar	String				Identification of the algorithm and version used to generate this product
LastSoundingId	Scalar	Int64				The ID of the last sounding in this file
MaxMS	Spectrum_Array	Float32	$\text{Ph sec}^{-1} \text{ m}^{-2} \text{ sr}^{-1} \text{ um}^{-1}$			The maximum measureable signal value to be used in radiance noise calculation
ModeCounter	Scalar	String				The Nth occurrence of this particular mode for this orbit, indicated by letter ('a', 'b', 'c', 'd', etc.)
OperationMode	Scalar	String				The two-letter abbreviation of the AcquisitionMode: GL, ND, TG, DS, LS, SS, BS, NP, GP, TP, DP, LP, SP, BP, XS, XP, MS, MP, SB
OrbitEccentricity	Scalar	Float32				The eccentricity of the spacecraft orbital path
OrbitInclination	Scalar	Float32	Degrees	0	180	The angle between the plane of the spacecraft orbital path and the Earth equatorial plane
OrbitParametersPointer	OrbitParamPtr_Array	String				The data files that provided the orbit parameters used to generate this product
OrbitPeriod	Scalar	Float32	Seconds			The time span between two consecutive descending node crossings

OrbitSemiMajorAxis	Scalar	Float32	Meters			The length of the semi-major axis of the spacecraft orbit
OrbitStartDate	Scalar	String				The date of the equator crossing of the spacecraft nadir track in the descending direction
OrbitStartLongitude	Scalar	Float32	Degrees	-180	180	The longitude of the equator crossing of the spacecraft ground track in the descending direction
OrbitStartTime	Scalar	String				The time of the equator crossing of the spacecraft ground track in the descending direction
ReportedSoundings	SoundingPosition_Array	Int8		0	1	Indicates the inclusion of each footprint in the data: 0 - not included, 1 - included
SciToFPAColorOffset	Spectrum_Array	Int16				The index of the first spectral pixel of arrays with FPAColor shape that appears in the first spectral element of arrays with SciColor shape
SpectralChannel	Spectrum_Array	String				A description of the spectral channels used for the measurements
Group	InstrumentHeader					
Group description	Instrument characteristics					
Data Element	Shape	Type	Units	Minimum value	Maximum value	Comments
ils_delta_lambda	Spectrum_Sounding_SciColor_DeltaLambda_Array	Float32	Microns			Wavelength offset from peak response for sampled data
ils_relative_response	Spectrum_Sounding_SciColor_DeltaLambda_Array	Float32				The relative response defined at ils_delta_lambda
full_width_half_maximum	Spectrum_Sounding_SciColor_Array	Float32	Microns			The spectral response width at full-width-half-maximum, per pixel

measurable_signal_max_observed	Spectrum_Array	Float32	Ph sec ^{-1} m ^{-2} sr ^{-1} um ^{-1}			Maximum radiance measurable by each spectrometer without detector saturation
snr_coef	Spectrum_Sounding_SciColor_SNRCoef_Array	Float64				Three coefficients of the noise model: photon component (proportional to the square root of signal), a constant background component and a bad sample flag where 0 - OK, 1 - ignore for retrievals
dispersion_coef_samp	Spectrum_Sounding_DispersionCoefficient_Array	Float64				Coefficients that express the relationship between the spectral element index and its associated wavelength
residual_estimate	Spectrum_Sounding_SciColor_ResidualCoefficient_Array	Float32				Empirical estimate of the systematic residuals that cannot be removed by calibration
GranuleDegradationFactor	Spectrum_Sounding_SciColor_Array	Float32				The average gain degradation factor of the granule that converts modified radiance based on the preflight gain to radiance
Group	FrameHeader					
Group description	Frame-level metadata					
Data Element	Shape	Type	Units	Minimum value	Maximum value	Comments
frame_id	Frame_Array	Int64				The mission-unique frame identifier
frame_time_string	Frame_Array	String				Time of telemetry frame (yyyy-mm-ddThh:mm:ss.mmmZ)
frame_time_tai93	Frame_Array	Float64	Seconds			Time of telemetry frame in seconds since Jan 1, 1993
frame_qual_flag	Frame_Array	UInt64				Bit flags indicating the quality of the data in each frame: 0 - good, non-zero - see Product Quality Flags table below

clocking_offset_start	Frame_Spectrum_Array	Int32		-127	128	The first pixel where the flight software applies a focal plane clocking correction - negative value indicates the clocking shift operates downward, positive value indicates clocking shift is upward
clocking_offset_interval	Frame_Spectrum_Array	Int16		0	256	The number of pixels between each successive pixel shift used to apply a clocking correction
Group	FrameTemperatures					
Group description	Selected instrument temperatures for each frame					
Data Element	Shape	Type	Units	Minimum value	Maximum value	Comments

temp_fpa	Frame_Spectrum_Array	Float32	Kelvins			FPA temperatures extracted for this frame time from the temperature data history
temp_optical_bench_grating_mz	Frame_Array	Float32	Kelvins			Temperature of the optical bench grating
temp_relay_sco2_mz	Frame_Array	Float32	Kelvins			Temperature of the relay
temp_telescope	Frame_Array	Float32	Kelvins			Temperature of the telescope
temp_shroud_py_tz1	Frame_Array	Float32	Kelvins			Temperature of the shroud
temp_afe_electronics_enclosure	Frame_Array	Float32	Kelvins			Temperature of the AFE electronics enclosure
temp_smooth_fpa_o2	Frame_Array	Float32	Kelvins			ABO2 FPA temperature after noise-reduction processing
temp_smooth_fpa_strong_co2	Frame_Array	Float32	Kelvins			SCO2 FPA temperature after noise-reduction processing
temp_smooth_fpa_weak_co2	Frame_Array	Float32	Kelvins			WCO2 FPA temperature after noise-reduction processing
temp_smooth_optical_bench_grating_mz	Frame_Array	Float32	Kelvins			Optics temperature for this frame after noise-reduction processing
Group	FrameGeometry					
Group description	Geometric information that applies to all measurements in frame					
Data Element	Shape	Type	Units	Minimum value	Maximum value	Comments
spacecraft_position	Frame_EuclidDim_Array	Float32	Meters			Interpolated spacecraft position at the frame time
spacecraft_velocity	Frame_EuclidDim_Array	Float32	Meters Second ^{-1}			Interpolated spacecraft velocity at the frame time

roll	Frame_Array	Float32	Degrees	-180	180	Interpolated spacecraft attitude at the frame time
pitch	Frame_Array	Float32	Degrees	-180	180	Interpolated spacecraft attitude at the frame time
yaw	Frame_Array	Float32	Degrees	-180	180	Interpolated spacecraft attitude at the frame time
spacecraft_lat	Frame_Array	Float32	Degrees	-90	90	Geodetic latitude of the spacecraft at the frame time
spacecraft_lon	Frame_Array	Float32	Degrees	-180	180	Longitude of the spacecraft at the frame time
spacecraft_alt	Frame_Array	Float32	Meters			Altitude of the spacecraft above the reference ellipsoid at the frame time
relative_velocity	Frame_Array	Float32	Meters Second ^{-1}			Velocity of the spacecraft along the LOS: positive indicates spacecraft moving toward target location
ground_track	Frame_Array	Float32	Degrees	0	360	Ground track orientation relative to local North
Group	FootprintGeometry					
Group description	Geometric information for individual footprints					
Data Element	Shape	Type	Units	Minimum value	Maximum value	Comments
footprint_time_tai93	Frame_Sounding_Spectrum_Array	Float64	Seconds			Data acquisition time for the center of footprint in seconds since Jan. 1, 1993
footprint_time_string	Frame_Sounding_Spectrum_Array	String				Data acquisition time for the center of footprint (yyyy-mm-ddThh:mm:ss.mmmZ)
footprint_o2_qual_flag	Frame_Sounding_Array	UInt16				Bit flags indicating the quality of the ABO2 data in footprint: 0 - Good, non-zero - see Product Quality Flags table below

footprint_weak_co2_qual_flag	Frame_Sounding_Array	UInt16				Bit flags indicating the quality of the WCO2 data in footprint: 0 - Good, non-zero - see Product Quality Flags table below
footprint_strong_co2_qual_flag	Frame_Sounding_Array	UInt16				Bit flags indicating the quality of the SCO2 data in footprint: 0 - Good, non-zero - see Product Quality Flags table below
footprint_latitude_geoid	Frame_Sounding_Spectrum_Array	Float32	Degrees	-90	90	Geodetic latitude of the footprint based on standard geoid
footprint_longitude_geoid	Frame_Sounding_Spectrum_Array	Float32	Degrees	-180	180	Longitude of the footprint based on standard geoid
footprint_latitude	Frame_Sounding_Spectrum_Array	Float32	Degrees	-90	90	Geodetic latitude of the footprint center based on Earth topography
footprint_longitude	Frame_Sounding_Spectrum_Array	Float32	Degrees	-180	180	Longitude of the footprint center based on Earth topography
footprint_altitude	Frame_Sounding_Spectrum_Array	Float32	Meters			Altitude of the footprint center based on Earth topography
footprint_altitude_uncert	Frame_Sounding_Spectrum_Array	Float32	Meters			Uncertainty of the source Earth topography data
footprint_slope	Frame_Sounding_Spectrum_Array	Float32	Degrees	0	180	Slope of a plane fit to points within the footprint
footprint_plane_fit_quality	Frame_Sounding_Spectrum_Array	Float32	Meters			Goodness of fit - standard deviation of the points to which the plane is fitted, with the expected values taken as the orthogonal projection of the points onto the plane
footprint_aspect	Frame_Sounding_Spectrum_Array	Float32	Degrees	0	360	Orientation of the surface slope relative to the ground track

footprint_surface_roughness	Frame_Sounding_Spectrum_Array	Float32	Meters			Standard deviation of the altitude within the footprint
footprint_solar_azimuth	Frame_Sounding_Spectrum_Array	Float32	Degrees	0	360	Angle between the solar direction as defined from the footprint location to the sun, and the footprint location local north direction measured clockwise from the local North
footprint_solar_zenith	Frame_Sounding_Spectrum_Array	Float32	Degrees	0	180	Angle between the solar direction as defined from the footprint location to the sun, and the footprint location local zenith direction
footprint_azimuth	Frame_Sounding_Spectrum_Array	Float32	Degrees	0	360	Angle between the LOS as defined from the footprint location to the spacecraft, and the footprint location local north direction measured clockwise from the local North
footprint_zenith	Frame_Sounding_Spectrum_Array	Float32	Degrees	0	180	Angle between the LOS as defined from the footprint location to the spacecraft, and the footprint location local zenith direction
footprint_vertex_longitude	Frame_Sounding_Spectrum_Vertex_Array	Float32	Degrees	-180	180	Longitude of the footprint vertices using Earth topography
footprint_vertex_latitude	Frame_Sounding_Spectrum_Vertex_Array	Float32	Degrees	-90	90	Geodetic latitude of the footprint vertices using Earth topography
footprint_vertex_altitude	Frame_Sounding_Spectrum_Vertex_Array	Float32	Meters			Altitude of the footprint vertices using Earth topography
footprint_stokes_coefficients	Frame_Sounding_Spectrum_StokesCoefficient_Array	Float32				Weighting factors applied to the Stokes parameters calculated by the radiative transfer code to compute the radiance
footprint_land_fraction	Frame_Sounding_Spectrum_Array	Float32	Percent	0	100	Percentage of land surface type within the footprint

footprint_polarization_angle	Frame_Sounding_Spectrum_Array	Float32	Degrees	0	360	The angle between the accepted polarization axis of the instrument and the instrument reference plane for polarization, defined as the plane formed by the LOS and the ray from the footprint location to the local zenith
Group	SoundingGeometry					
Group description	Geometric information for each sounding					
Data Element	Shape	Type	Units	Minimum value	Maximum value	Comments
sounding_id	Frame_Sounding_Array	Int64				Unique identifier for each sounding
sounding_time_string	Frame_Sounding_Array	String				Data acquisition time for the sounding based upon the three footprint times (yyyy-mm-ddThh:mm:ss.mmmZ)
sounding_time_tai93	Frame_Sounding_Array	Float64	Seconds			Data acquisition time for the sounding based upon the three footprint times in seconds since Jan. 1, 1993
sounding_overlap	Frame_Sounding_Array	Float32	Percent	0	100	Area of intersection of all three band footprints relative to average area of all three band footprints
sounding_overlap_o2_weak_co2	Frame_Sounding_Array	Float32	Percent	0	100	Area of intersection of the footprints of ABO2 and WCO2 relative to the average area of the two footprint
sounding_overlap_weak_co2_strong_co2	Frame_Sounding_Array	Float32	Percent	0	100	Area of intersection of the footprints of WCO2 and SCO2 relative to the average area of the two footprints
sounding_overlap_strong_co2_o2	Frame_Sounding_Array	Float32	Percent	0	100	Area of intersection of the footprints of ABO2 and SCO2 relative to the average area of the two footprints
sounding_slant_path_diff_o2_weak_co2	Frame_Sounding_Array	Float32	Meters			Difference in slant path between ABO2 and WCO2 footprints
sounding_slant_path_diff_weak_co2_strong_co2	Frame_Sounding_Array	Float32	Meters			Difference in slant path between WCO2 and SCO2 footprints
sounding_slant_path_diff_strong_co2_o2	Frame_Sounding_Array	Float32	Meters			Difference in slant path between SCO2 and ABO2 footprints

sounding_center_offset_o2_weak_co2	Frame_Sounding_Array	Float32	Meters			Distance between the ABO2 band footprint center and the WCO2 band footprint center
sounding_center_offset_weak_co2_strong_co2	Frame_Sounding_Array	Float32	Meters			Distance between the WCO2 band footprint center and the SCO2 band footprint center
sounding_center_offset_strong_co2_o2	Frame_Sounding_Array	Float32	Meters			Distance between the SCO2 band footprint center and the ABO2 band footprint center
sounding_qual_flag	Frame_Sounding_Array	UInt64				Bit flags indicating the quality of the data in sounding: 0 - Good, non-zero - see Product Quality Flags table below
sounding_latitude_geoid	Frame_Sounding_Array	Float32	Degrees	-90	90	Geodetic latitude of the sounding based on standard geoid
sounding_longitude_geoid	Frame_Sounding_Array	Float32	Degrees	-180	180	Longitude of the sounding based on standard geoid
sounding_latitude	Frame_Sounding_Array	Float32	Degrees	-90	90	Geodetic latitude of the sounding based on Earth topography
sounding_longitude	Frame_Sounding_Array	Float32	Degrees	-180	180	Longitude of the sounding based on Earth topography
sounding_altitude	Frame_Sounding_Array	Float32	Meters			Altitude of the sounding based on Earth topography
sounding_altitude_uncert	Frame_Sounding_Array	Float32	Meters			Uncertainty of the source Earth topography data
sounding_slope	Frame_Sounding_Array	Float32	Degrees	0	180	Slope of a plane fit to points within the sounding

sounding_plane_fit_quality	Frame_Sounding_Array	Float32	Meters			Goodness-of-fit of surface slope: the standard deviation of the points, to which the plane is fitted, with the expected values taken as the orthogonal projection of the points onto the plane
sounding_aspect	Frame_Sounding_Array	Float32	Degrees	0	360	Orientation of the surface slope relative to the local North
sounding_surface_roughness	Frame_Sounding_Array	Float32	Meters			Standard deviation of the altitude within the sounding
sounding_solar_distance	Frame_Sounding_Array	Float64	Meters			Distance between sounding location and the Sun
sounding_solar_azimuth	Frame_Sounding_Array	Float32	Degrees	0	360	Angle between the solar direction as defined from the sounding location to the sun, and the sounding location local north direction measured clockwise from the local North
sounding_solar_zenith	Frame_Sounding_Array	Float32	Degrees	0	180	Angle between the solar direction as defined from the sounding location to the sun, and the sounding location local zenith direction
sounding_azimuth	Frame_Sounding_Array	Float32	Degrees	0	360	Angle between the LOS as defined from the sounding location to the spacecraft, and the sounding location local north direction measured clockwise from the local North
sounding_zenith	Frame_Sounding_Array	Float32	Degrees	0	180	Angle between the LOS as defined from the sounding location to the spacecraft, and the sounding location local zenith direction
sounding_solar_relative_velocity	Frame_Sounding_Array	Float32	Meters Second ^{-1}			Velocity of the sun along the sounding location/Sun vector: negative indicates Sun moving toward sounding location
sounding_land_water_indicator	Frame_Sounding_Array	Int8		0	3	Surface type at the sounding location: 0 - Land, 1 - Water, 2 - unused, 3 - Mixed land water
sounding_land_fraction	Frame_Sounding_Array	Float32	Percent	0	100	Percentage of land surface type within the sounding
sounding_relative_velocity	Frame_Sounding_Array	Float32	Meters Second ^{-1}			Velocity of the spacecraft along the LOS: positive indicates spacecraft moving toward sounding location

sounding_polarization_angle	Frame_Sounding_Array	Float32	Degrees	0	360	The angle between the accepted polarization axis of the instrument and the instrument reference plane for polarization, defined as the plane formed by the LOS and the ray from the sounding location to the local zenith
Group						
FrameConfiguration						
Group description Configuration information provided for every frame						
Data Element	Shape	Type	Units	Minimum value	Maximum value	Comments
color_slice_position_o2	Frame_O2Slice_Array	Int16		1	1024	Absolute spectral position, in pixels, of each color slice in ABO2 band
color_slice_position_strong_co2	Frame_StrongCO2Slice_Array	Int16		1	1024	Absolute spectral position, in pixels, of each color slice in SCO2 band
color_slice_position_weak_co2	Frame_WeakCO2Slice_Array	Int16		1	1024	Absolute spectral position, in pixels, of each color slice in WCO2 band
footprint_spatial_end_position	Frame_SoundingPosition_Spectrum_Array	UInt8		1	220	Position of end of each footprint, in pixels, relative to initial_unused_pixels
footprint_spatial_start_position	Frame_SoundingPosition_Spectrum_Array	UInt8		1	220	Position of start of each footprint, in pixels, relative to initial_unused_pixels
initial_unused_pixels	Frame_Spectrum_Array	Int16		8	796	Distance in pixels of the start of first footprint from edge of FPA
Group						
SoundingMeasurements						
Group description Radiance measurements for each sounding						
Data Element	Shape	Type	Units	Minimum value	Maximum value	Comments
radiance_o2	Frame_Sounding_SciColor_Array	Float32	$\text{Ph sec}^{-1} \text{ m}^{-2} \text{ sr}^{-1} \text{ um}^{-1}$			Calibrated spectra for ABO2
radiance_weak_co2	Frame_Sounding_SciColor_Array	Float32	$\text{Ph sec}^{-1} \text{ m}^{-2} \text{ sr}^{-1} \text{ um}^{-1}$			Calibrated spectra for WCO2
radiance_strong_co2	Frame_Sounding_SciColor_Array	Float32	$\text{Ph sec}^{-1} \text{ m}^{-2} \text{ sr}^{-1} \text{ um}^{-1}$			Calibrated spectra for SCO2

snr_o2_l1b	Frame_Sounding_Array	Float32				The mean signal-to-noise ratio of the good samples in ABO2 falling between the 98th and 99th percentile for signal level
snr_weak_co2_l1b	Frame_Sounding_Array	Float32				The mean signal-to-noise ratio of the good samples in WCO2 falling between the 98th and 99th percentile for signal level
snr_strong_co2_l1b	Frame_Sounding_Array	Float32				The mean signal-to-noise ratio of the good samples in SCO2 falling between the 98th and 99th percentile for signal level
Group	SliceMeasurements					
Group description	Radiance measurements for each color slice					
Data Element	Shape	Type	Units	Minimum value	Maximum value	Comments
radiance_slice_o2	Frame_O2Slice_SpatialRow_Array	Float32	Ph sec ^{-1} m ^{-2} sr ^{-1} um ^{-1}			Radiance values for all ABO2 color slice pixels
radiance_slice_weak_co2	Frame_WeakCO2Slice_SpatialRow_Array	Float32	Ph sec ^{-1} m ^{-2} sr ^{-1} um ^{-1}			Radiance values for all WCO2 color slice pixels
radiance_slice_strong_co2	Frame_StrongCO2Slice_SpatialRow_Array	Float32	Ph sec ^{-1} m ^{-2} sr ^{-1} um ^{-1}			Radiance values for all SCO2 color slice pixels
Group	RadianceClockingCorrection					
Group description	Results of clocking analysis and correction					
Data Element	Shape	Type	Units	Minimum value	Maximum value	Comments
declocking_color_indicator	Spectrum_SciColor_Array	Int8				Declocking color selection over all science colors: 0 - the color is not selected, non-zero - the color is selected for declocking and the value is the aggregated color slice group index in the declocking processing
clocking_shift_color_indicator	Spectrum_SciColor_Array	Int8				Indicator of clocking-related spatial shift at the color: 0 - no shift, 1 - shift occurred
radiance_jump_ratio_o2	Frame_Sounding_DeclockingGroupO2_JumpColorO2_Array	Float32				Ratio of the mean ABO2 radiances after a jump to that of before the jump within a footprint from a color slice group
radiance_jump_ratio_weak_co2	Frame_Sounding_DeclockingGroupStrongCO2_JumpColorWeakCO2_Array	Float32				Ratio of the mean WCO2 radiances after a jump to that of before the jump within a footprint from a color slice group

radiance_jump_ratio_strong_co2	Frame_Sounding_DeclockingGroupWeakCO2_JumpColorStrongCO2_Array	Float32				Ratio of the mean SCO2 radiances after a jump to that of before the jump within a footprint from a color slice group
max_declocking_factor_o2	Frame_Sounding_Array	Float32				Maximum clocking correction factor of the ABO2 footprint
max_declocking_factor_weak_co2	Frame_Sounding_Array	Float32				Maximum clocking correction factor of the WCO2 footprint
max_declocking_factor_strong_co2	Frame_Sounding_Array	Float32				Maximum clocking correction factor of the SCO2 footprint
Group	SpikeEOF					
Group description	Results of spectral spike identification and removal					
Data Element	Shape	Type	Units	Minimum value	Maximum value	Comments
spike_eof_bad_colors_o2	Frame_Sounding_Array	Int16				Number of bad colors in ABO2 spectrum
spike_eof_bad_colors_weak_co2	Frame_Sounding_Array	Int16				Number of bad colors in WCO2 spectrum
spike_eof_bad_colors_strong_co2	Frame_Sounding_Array	Int16				Number of bad colors in SCO2 spectrum
spike_eof_weighted_residual_o2	Frame_Sounding_SciColor_Array	Int8				Weighted residual of EOF-based spectral reconstruction for ABO2: (measured-model)/noise
spike_eof_weighted_residual_weak_co2	Frame_Sounding_SciColor_Array	Int8				Weighted residual of EOF-based spectral reconstruction for WCO2: (measured-model)/noise
spike_eof_weighted_residual_strong_co2	Frame_Sounding_SciColor_Array	Int8				Weighted residual of EOF-based spectral reconstruction for SCO2: (measured-model)/noise

Product Quality Flags

frame_qual_flag	Bit	footprint_*_qual_flag	Bit	sounding_qual_flag	Bit
QAScienceCompleteO2 0=All O2 band science data (sample/hi-res pixels) present	0	CompleteSpectra 0=all spectral values present in footprint, 1=some spectral values missing from footprint	0	0 = The PGE successfully calculated the sounding position.	0
QAOHKCompleteO2 0=All O2 band OHK data is present	1	Spare	1	0 = Reported sounding time valid	1
QAScienceCompleteWeakCO2 0=All Weak CO2 band science data (sample/hi-res pixels) present	2	CompleteFootprintInput 0=All input values used to calculate footprint descriptive information (footprint_time, footprint_spatial_start_position, and footprint_spatial_end_position) were present	2	0 = Ephemeris data associated with sounding valid	2
QAOHKCompleteWeak CO2 0=All WeakCO2 band OHK data is present	3	CompleteFootprintOutput 0=All footprint descriptive information (footprint_time, footprint_spatial_start_position, and footprint_spatial_end_position) could be calculated	3	0 = Attitude data associated with sounding valid	3
QAScienceCompleteStrongCO2 0=All Strong CO2 band science data (sample/hi-res pixels) present	4	Spare	4-7	1=Aperture blocked by Cal Door while in Science mode	4
QAOHKCompleteStrongCO2 0=All Strong CO2 band OHK data is present	5	0 = The PGE successfully calculated the footprint position.	8	Spare	5-15
QAIInstHKComplete 0 = All instrument housekeeping data is present	6	0 = Reported footprint time valid	9	0 = The PGE successfully calculated the ABO2 sample radiances for the current sounding.	16
QAIInstHKMostRecent 0 = Most recent instrument housekeeping data was generated within an acceptable time period of the science data. The acceptable gap is reported in the AllowedIHKGap metadata field.	7	0 = Ephemeris data associated with footprint invalid	10	0 = The PGE successfully calculated the WCO2 sample radiances for the current sounding.	17
CompleteFrame 0=All input data for this frame are	8	0 = Attitude data associated with footprint invalid	11	0 = The PGE successfully calculated	18

frame_qual_flag	Bit	footprint_*_qual_flag	Bit	sounding_qual_flag	Bit
available, 1=At least one data element is missing				the SCO2 sample radiances for the current sounding.	
CompleteHeader 0=All header data for this frame are available, 1=At least one data element in the header is missing.	9	Spare	12-15	0 = Frame-level engineering data valid	19
AlgorithmicError 0=PGE successfully calculated all output elements in this frame, 1=Algorithmic errors detected in the frame	10			0 = ABO2 engineering data valid	20
0 = Successfully calculated all ABO2 FPA temperatures	11			0 = WCO2 engineering data valid	21
0 = Successfully calculated all WCO2 FPA temperatures	12			0 = SCO2 engineering data valid	22
0 = Successfully calculated all SCO2 FPA temperatures	13			0 = ABO2 summed offset and multiplier valid	23
0 = Data from all bands acquired simultaneously 1 = Data from one band offset in time from the other bands (Pixel-resolution data only). The offset is provided in the FrameTimeOffset Metadata field.	14			0 = WCO2 summed offset and multiplier valid	24
Calibration Door (Diffuser) position 1=Aperture blocked by Cal Door while in Science mode	15			0 = SCO2 summed offset and multiplier valid	25
0 = All frame geometry calculated successfully 1 = Some frame geometry fields not calculated successfully.	16			0 = ABO2 footprint position valid	26
0 = Valid frame time received 1 = Invalid frame time received or no frame time received	17			0 = WCO2 footprint position valid	27
0 = Valid ephemeris data received 1 = Invalid ephemeris data received	18			0 = SCO2 footprint position valid	28

frame_qual_flag	Bit	footprint_*_qual_flag	Bit	sounding_qual_flag	Bit
0 = Valid attitude data received 1 = Invalid attitude data received	19			0 = Radiance for all colors is less than or equal to measureable_signal_max_observed for ABO2	29
Spare	20-63			0 = Radiance for all colors is less than or equal to measureable_signal_max_observed for WCO2	30
				0 = Radiance for all colors is less than or equal to measureable_signal_max_observed for SCO2	31
				Spare	32-47
				Reserved for higher-level processing	48-63

6 Specification Table – Calibration Modes

L1B Calibration Product HDF specification

Group	Metadata					
Group description	Granule-level Metadata					
Data Element	Shape	Type	Units	Minimum value	Maximum value	Comments
Standard Metadata	See OCO-2 Standard Metadata specification table below					
AcquisitionMode	Scalar	String				The instrument mode in which the data in the product were collected. Valid values are: 'Glint', 'Nadir', 'Target', 'Sample Dark Calibration', 'Sample Lamp Calibration', 'Sample Solar/limb Calibration', 'Single-Pixel Dark Calibration', 'Single-Pixel Lamp Calibration', 'Single-Pixel Solar/limb Calibration'
ActualFrames	Scalar	Int32				Actual number of frames reported in this product
ARPAncillaryDatasetDescriptor	Scalar	String				The name of the Ancillary Radiometric Product file used to calibrate this file
AscendingEquatorCrossingDate	Scalar	String				The date of the equator crossing of the spacecraft ground track in the ascending direction
AscendingEquatorCrossingLongitude	Scalar	Float32	Degrees	-180	180	The longitude of the equator crossing of the spacecraft ground track in the ascending direction
AscendingEquatorCrossingTime	Scalar	String				The time of the equator crossing of the spacecraft ground track in the ascending direction
AutomaticQualityFlag	Scalar	String				Not implemented - set to NULL
BadPixelMapVersionNum	Spectrum_Array	UInt32				Version number of corresponding Bad Pixel Map used to calibrate this data file

ColorSlicePositionO2	O2Slice_Array	Int16		1	1024	Absolute spectral position of each ABO2 color slice
ColorSlicePositionStrongCO2	StrongCO2Slice_Array	Int16		1	1024	Absolute spectral position of each SCO2 color slice
ColorSlicePositionWeakCO2	WeakCO2Slice_Array	Int16		1	1024	Absolute spectral position of each WCO2 color slice
DiffuserPosition	Scalar	Float32				The position of the solar diffuser at the beginning of the mode: 0 - Lamp or Closed position, 75 - Open for science, 150 - Solar Calibration position
EphemerisType	Scalar	String				The source of the spacecraft ephemeris data that were utilized to generate this data file
EquatorCrossingDate	Scalar	String				The date of the equator crossing of the spacecraft ground track in the descending direction
EquatorCrossingLongitude	Scalar	Float32	Degrees	-180	180	The longitude of the equator crossing of the spacecraft ground track in the descending direction
EquatorCrossingTime	Scalar	String				The time of the equator crossing of the spacecraft ground track in the descending direction
ExpectedFrames	Scalar	Int32				Nominal number of frames in this product
FirstSoundingId	Scalar	Int64				The ID of the first sounding in this file
InitialUnusedSpatialPixels	Spectrum_Array	Int16				Distance in spatial pixels of the start of first footprint from edge of FPA
L1BAlgorithmDescriptor	Scalar	String				Identification of the algorithm and version used to generate this product

LastSoundingId	Scalar	Int64				The ID of the last sounding in this file
ModeCounter	Scalar	String				The Nth occurrence of this particular mode for this orbit, indicated by letter ('a', 'b', 'c', 'd', etc.)
MaxMS	Spectrum_Array	Float32	$\text{Ph sec}^{-1} \text{ m}^{-2} \text{ sr}^{-1} \text{ um}^{-1}$			The maximum measurable signal value to be used in radiance noise calculation
OperationMode	Scalar	String				The two-letter abbreviation of the AcquisitionMode: GL, ND, TG, DS, LS, SS, BS, NP, GP, TP, DP, LP, SP, BP, XS, XP, MS, MP, SB
OrbitEccentricity	Scalar	Float32				The eccentricity of the spacecraft orbital path
OrbitInclination	Scalar	Float32	Degrees	0	180	The angle between the plane of the spacecraft orbital path and the Earth equatorial plane
OrbitParametersPointer	OrbitParamPtr_Array	String				The data files that provided the orbit parameters used to generate this product
OrbitPeriod	Scalar	Float32	Seconds			The time span between two consecutive descending node crossings
OrbitSemiMajorAxis	Scalar	Float32	Meters			The length of the semi-major axis of the spacecraft orbit
OrbitStartDate	Scalar	String				The date of the equator crossing of the spacecraft nadir track in the descending direction
OrbitStartLongitude	Scalar	Float32	Degrees	-180	180	The longitude of the equator crossing of the spacecraft ground track in the descending direction
OrbitStartTime	Scalar	String				The time of the equator crossing of the spacecraft ground track in the descending direction

ReportedSoundings	SoundingPosition_Array	Int8		0	1	Indicates the inclusion of each footprint in the data: 0 - not included, 1 - included
SciToFPAColorOffset	Spectrum_Array	Int16				The index of the first spectral pixel of arrays with FPAColor shape that appears in the first spectral element of arrays with SciColor shape
SpectralChannel	Spectrum_Array	String				A description of the spectral channels used for the measurements
Group	InstrumentHeader					
Group description	Instrument characteristics					
Data Element	Shape	Type	Units	Minimum value	Maximum value	Comments
ils_delta_lambda	Spectrum_Sounding_SciColor_DeltaLambda_Array	Float32	Microns			Wavelength offset from peak response for sampled data
ils_relative_response	Spectrum_Sounding_SciColor_DeltaLambda_Array	Float32				The relative response defined at ils_delta_lambda
full_width_half_maximum	Spectrum_Sounding_SciColor_Array	Float32	Microns			The spectral response width at full-width-half-maximum, per pixel
measureable_signal_max_observed	Spectrum_Array	Float32	$\text{Ph sec}^{-1} \text{ m}^{-2} \text{ sr}^{-1} \text{ um}^{-1}$			Maximum radiance measurable by each spectrometer without detector saturation
snr_coef	Spectrum_Sounding_SciColor_SNRCoef_Array	Float64				Three coefficients of the noise model: photon component (proportional to the square root of signal), a constant background component and a bad sample flag where 0 - OK, 1 - ignore for retrievals
dispersion_coef_samp	Spectrum_Sounding_DispersionCoefficient_Array	Float64				Coefficients that express the relationship between the spectral element index and its associated wavelength
residual_estimate	Spectrum_Sounding_SciColor_ResidualCoefficient_Array	Float32				Empirical estimate of the systematic residuals that cannot be removed by calibration
Group	FrameHeader					

Group description	Frame-level metadata					
Data Element	Shape	Type	Units	Minimum value	Maximum value	Comments
frame_id	Frame_Array	Int64				The mission-unique frame identifier
frame_time_string	Frame_Array	String				Time of telemetry frame (yyyy-mm-ddThh:mm:ss.mmmZ)
frame_time_tai93	Frame_Array	Float64	Seconds			Time of telemetry frame in seconds since Jan 1, 1993
frame_qual_flag	Frame_Array	UInt64				Bit flags indicating the quality of the data in each frame: 0 - good, non-zero - see Product Quality Flags table below
clocking_offset_start	Frame_Spectrum_Array	Int32		-127	128	The first pixel where the flight software applies a focal plane clocking correction - negative value indicates the clocking shift operates downward, positive value indicates clocking shift is upward
clocking_offset_interval	Frame_Spectrum_Array	Int16		0	256	The number of pixels between each successive pixel shift used to apply a clocking correction
Group	FrameTemperatures					
Group description	Selected instrument temperatures for each frame					
Data Element	Shape	Type	Units	Minimum value	Maximum value	Comments
temp_fpa	Frame_Spectrum_Array	Float32	Kelvins			FPA temperatures extracted for this frame time from the temperature data history
temp_optical_bench_grating_mz	Frame_Array	Float32	Kelvins			Temperature of the optical bench grating
temp_relay_sco2_mz	Frame_Array	Float32	Kelvins			Temperature of the relay
temp_telescope	Frame_Array	Float32	Kelvins			Temperature of the telescope

temp_shroud_py_tz1	Frame_Array	Float32	Kelvins			Temperature of the shroud
temp_afe_electronics_enclosure	Frame_Array	Float32	Kelvins			Temperature of the AFE electronics enclosure
temp_smooth_fpa_o2	Frame_Array	Float32	Kelvins			ABO2 FPA temperature after noise-reduction processing
temp_smooth_fpa_strong_co2	Frame_Array	Float32	Kelvins			SCO2 FPA temperature after noise-reduction processing
temp_smooth_fpa_weak_co2	Frame_Array	Float32	Kelvins			WCO2 FPA temperature after noise-reduction processing
temp_smooth_optical_bench_grating_mz	Frame_Array	Float32	Kelvins			Optics temperature for this frame after noise-reduction processing
Group	SpacePointingFrameGeometry					
Group description	Geometric information that applies to all measurements in frame					
Data Element	Shape	Type	Units	Minimum value	Maximum value	Comments
spacecraft_position	Frame_EuclidDim_Array	Float32	Meters			Interpolated spacecraft position at the frame time
spacecraft_velocity	Frame_EuclidDim_Array	Float32	Meters Second ^{-1}			Interpolated spacecraft velocity at the frame time
roll	Frame_Array	Float32	Degrees	-180	180	Interpolated spacecraft attitude at the frame time
pitch	Frame_Array	Float32	Degrees	-180	180	Interpolated spacecraft attitude at the frame time
yaw	Frame_Array	Float32	Degrees	-180	180	Interpolated spacecraft attitude at the frame time
spacecraft_lat	Frame_Array	Float32	Degrees	-90	90	Geodetic latitude of the spacecraft at the frame time

spacecraft_lon	Frame_Array	Float32	Degrees	-180	180	Longitude of the spacecraft at the frame time
spacecraft_alt	Frame_Array	Float32	Meters			Altitude of the spacecraft above the reference ellipsoid at the frame time
ground_track	Frame_Array	Float32	Degrees	0	360	Ground track orientation relative to local North
solar_distance	Frame_Array	Float64	Meters			Distance between satellite and the Sun
solar_azimuth	Frame_Array	Float32	Degrees	0	360	Angle between the spacecraft local north direction and the solar vector
solar_zenith	Frame_Array	Float32	Degrees	0	180	Angle between the spacecraft local zenith direction and the solar vector
boresight_azimuth	Frame_Array	Float32	Degrees	0	360	Angle between the spacecraft local north direction and the instrument boresight direction
boresight_zenith	Frame_Array	Float32	Degrees	0	180	Angle between the spacecraft local zenith direction and the instrument boresight direction
limb_lon	Frame_Array	Float32	Degrees	-90	90	Longitude of the point where the surface normal intersects the LOS at right angle. Fill values used for non-limb observations.
limb_lat	Frame_Array	Float32	Degrees	-180	180	Geodetic latitude of the point where the surface normal intersects the LOS at right angle. Fill values used for non-limb observations.
limb_alt	Frame_Array	Float32	Meters			Altitude of the LOS above the point where the surface normal intersects the LOS at right angle. Fill values used for non-limb observations. Measured using the WGS84 ellipsoid.
Group	FrameConfiguration					

Group description	Configuration information provided for every frame					
Data Element	Shape	Type	Units	Minimum value	Maximum value	Comments
color_slice_position_o2	Frame_O2Slice_Array	Int16		1	1024	Absolute spectral position, in pixels, of each color slice in ABO2 band
color_slice_position_strong_co2	Frame_StrongCO2Slice_Array	Int16		1	1024	Absolute spectral position, in pixels, of each color slice in SCO2 band
color_slice_position_weak_co2	Frame_WeakCO2Slice_Array	Int16		1	1024	Absolute spectral position, in pixels, of each color slice in WCO2 band
footprint_spatial_end_position	Frame_SoundingPosition_Spectrum_Array	UInt8		1	220	Position of end of each footprint, in pixels, relative to initial_unused_pixels
footprint_spatial_start_position	Frame_SoundingPosition_Spectrum_Array	UInt8		1	220	Position of start of each footprint, in pixels, relative to initial_unused_pixels
initial_unused_pixels	Frame_Spectrum_Array	Int16		8	796	Distance in pixels of the start of first footprint from edge of FPA
Group	SoundingMeasurements					
Group description	Radiance measurements for each sounding					
Data Element	Shape	Type	Units	Minimum value	Maximum value	Comments
radiance_o2	Frame_Sounding_SciColor_Array	Float32	$\text{Ph sec}^{-1} \text{ m}^{-2} \text{ sr}^{-1} \text{ um}^{-1}$			Calibrated spectra for ABO2
radiance_weak_co2	Frame_Sounding_SciColor_Array	Float32	$\text{Ph sec}^{-1} \text{ m}^{-2} \text{ sr}^{-1} \text{ um}^{-1}$			Calibrated spectra for WCO2
radiance_strong_co2	Frame_Sounding_SciColor_Array	Float32	$\text{Ph sec}^{-1} \text{ m}^{-2} \text{ sr}^{-1} \text{ um}^{-1}$			Calibrated spectra for SCO2
sounding_qual_flag	Frame_Sounding_Array	UInt64				Bit flags indicating the quality of the data in sounding: 0 - Good, non-zero - see Product Quality Flags table below
snr_o2_l1b	Frame_Sounding_Array	Float32				The mean signal-to-noise ratio of the good samples in the band falling between the 98th and 99th percentile for signal level

snr_weak_co2_l1b	Frame_Sounding_Array	Float32				The mean signal-to-noise ratio of the good samples in the band falling between the 98th and 99th percentile for signal level
snr_strong_co2_l1b	Frame_Sounding_Array	Float32				The mean signal-to-noise ratio of the good samples in the band falling between the 98th and 99th percentile for signal level
Group	SliceMeasurements					
Group description	Radiance measurements for each color slice					
Data Element	Shape	Type	Units	Minimum value	Maximum value	Comments
radiance_slice_o2	Frame_O2Slice_SpatialRow_Array	Float32	Ph sec ^{-1} m ^{-2} sr ^{-1} um ^{-1}			Radiance values for all slice pixels (ABO2)
radiance_slice_weak_co2	Frame_WeakCO2Slice_SpatialRow_Array	Float32	Ph sec ^{-1} m ^{-2} sr ^{-1} um ^{-1}			Radiance values for all ABO2 color slice pixels
radiance_slice_strong_co2	Frame_StrongCO2Slice_SpatialRow_Array	Float32	Ph sec ^{-1} m ^{-2} sr ^{-1} um ^{-1}			Radiance values for all WCO2 color slice pixels
Group	RadianceClockingCorrection					
Group description	Results of clocking analysis and correction					
Data Element	Shape	Type	Units	Minimum value	Maximum value	Comments
declocking_color_indicator	Spectrum_SciColor_Array	Int8				Declocking color selection over all science colors: 0 - the color is not selected, non-zero - the color is selected for declocking and the value is the aggregated color slice group index in the declocking processing
clocking_shift_color_indicator	Spectrum_SciColor_Array	Int8				Indicator of clocking-related spatial shift at the color: 0 - no shift, 1 - shift occurred
radiance_jump_ratio_o2	Frame_Sounding_DeclockingGroupO2_JumpColorO2_Array	Float32				Ratio of the mean ABO2 radiances after a jump to that of before the jump within a footprint from a color slice group
radiance_jump_ratio_weak_co2	Frame_Sounding_DeclockingGroupStrongCO2_JumpColorStrongCO2_Array	Float32				Ratio of the mean WCO2 radiances after a

						jump to that of before the jump within a footprint from a color slice group
radiance_jump_ratio_strong_co2	Frame_Sounding_DeclockingGroupWeakCO2_JumpColorWeakCO2_Array	Float32				Ratio of the mean SCO2 radiances after a jump to that of before the jump within a footprint from a color slice group
max_declocking_factor_o2	Frame_Sounding_Array	Float32				Maximum clocking correction factor of the ABO2 footprint
max_declocking_factor_weak_co2	Frame_Sounding_Array	Float32				Maximum clocking correction factor of the WCO2 footprint
max_declocking_factor_strong_co2	Frame_Sounding_Array	Float32				Maximum clocking correction factor of the SCO2 footprint
Group	SpikeEOF					
Group description	Results of spectral spike identification and removal					
Data Element	Shape	Type	Units	Minimum value	Maximum value	Comments
spike_eof_bad_colors_o2	Frame_Sounding_Array	Int16				Number of bad colors in ABO2 spectrum
spike_eof_bad_colors_weak_co2	Frame_Sounding_Array	Int16				Number of bad colors in WCO2 spectrum
spike_eof_bad_colors_strong_co2	Frame_Sounding_Array	Int16				Number of bad colors in SCO2 spectrum
spike_eof_weighted_residual_o2	Frame_Sounding_SciColor_Array	Int8				Weighted residual of EOF-based spectral reconstruction for ABO2: (measured-model)/noise
spike_eof_weighted_residual_weak_co2	Frame_Sounding_SciColor_Array	Int8				Weighted residual of EOF-based spectral reconstruction for WCO2: (measured-model)/noise
spike_eof_weighted_residual_strong_co2	Frame_Sounding_SciColor_Array	Int8				Weighted residual of EOF-based spectral reconstruction for SCO2: (measured-

						model)/noise
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Product Quality Flags

frame_qual_flag	Bit	footprint_*_qual_flag	Bit	sounding_qual_flag	Bit
QAScienceCompleteO2 0=All O2 band science data (sample/hi-res pixels) present	0	CompleteSpectra 0=all spectral values present in footprint, 1=some spectral values missing from footprint	0	Spare	0-28
QAOHKCompleteO2 0=All O2 band OHK data is present	1	Spare	1	0 = Radiance for all colors is less than or equal to measureable_signal_max_observed for ABO2	29
QAScienceCompleteWeakCO2 0=All Weak CO2 band science data (sample/hi-res pixels) present	2	CompleteFootprintInput 0=All input values used to calculate footprint descriptive information (footprint_time, footprint_spatial_start_position, and footprint_spatial_end_position) were present	2	0 = Radiance for all colors is less than or equal to measureable_signal_max_observed for WCO2	30
QAOHKCompleteWeak CO2 0=All WeakCO2 band OHK data is present	3	CompleteFootprintOutput 0=All footprint descriptive information (footprint_time, footprint_spatial_start_position, and footprint_spatial_end_position) could be calculated	3	0 = Radiance for all colors is less than or equal to measureable_signal_max_observed for SCO2	31
QAScienceCompleteStrongCO2 0=All Strong CO2 band science data (sample/hi-res pixels) present	4	Spare	4-7	Spare	32-47
QAOHKCompleteStrongCO2 0=All Strong CO2 band OHK data is present	5	Reserved for higher-level products	8-15	Reserved for higher-level processing	48-63
QAIInstHKComplete 0 = All instrument housekeeping data is present	6				
QAIInstHKMostRecent 0 = Most recent instrument housekeeping data was generated within an acceptable time period of the science data. The acceptable gap is reported in the AllowedIHKGap metadata field.	7				

frame_qual_flag	Bit	footprint_*_qual_flag	Bit	sounding_qual_flag	Bit
CompleteFrame 0=All input data for this frame are available, 1=At least one data element is missing	8				
CompleteHeader 0=All header data for this frame are available, 1=At least one data element in the header is missing.	9				
AlgorithmicError 0=PGE successfully calculated all output elements in this frame, 1=Algorithmic errors detected in the frame	10				
0 = Successfully calculated all ABO2 FPA temperatures	11				
0 = Successfully calculated all WCO2 FP	12				
0 = Successfully calculated all SCO2 FP	13				
0 = Data from all bands acquired simultaneously. 1 = Data from one band offset in time from the other bands (Pixel-resolution data only). The offset is provided in the FrameTimeOffset Metadata field.	14				
Calibration Door (Diffuser) position 0=Open for science, 1=Not open for science	15				
0 = All frame geometry calculated successfully 1 = Some frame geometry fields not calculated successfully.	16				
0 = Valid frame time received 1 = Invalid frame time received or no frame time received	17				
0 = Valid ephemeris data received 1 = Invalid ephemeris data received	18				

frame_qual_flag	Bit	footprint_*_qual_flag	Bit	sounding_qual_flag	Bit
0 = Valid attitude data received 1 = Invalid attitude data received	19				
Spare	20-31				
Reserved for higher-level processing	32-63				

OCO-2 Standard Metadata

Group	Metadata					
Data Element	Shape	Type	Units	Minimum value	Maximum value	Comments
Group description	This table describes the metadata contained in all OCO-2 HDF products. These metadata fields appear in the Metadata group in each of these products. Each product may also contain product-specific fields in that group.					
AncillaryDataDescriptors	AncFile_Array	String				The file names of the ancillary data files that were used to generate this product (ancillary data sets include all input files except for the primary input files)
BuildId	Scalar	String				The ID of build in which included the software that created this product
CollectionLabel	Scalar	String				Label of the data collection containing this product
DataFormatType	Scalar	String				'NCSA HDF' - A character string that describes the internal format of the data product.
GapStartTime	Gap_Array	String				The timestamp after which a nonexistent, unnecessary, spurious, questionable, or erroneous data segment begins
GapStopTime	Gap_Array	String				The timestamp before which a nonexistent, unnecessary, spurious, questionable, or erroneous data segment ends
GranulePointer	Scalar	String				The filename of this product
HDFVersionId	Scalar	String				'5.x' - A character string that identifies the version of the HDF (Hierarchical Data Format) software that was used to generate this data file
InputPointer	InputPtr_Array	String				A pointer to one or more data granules that provide the major input that was used to generate this product.
InstrumentShortName	Scalar	String				'OCO-2' - The name of the instrument that collected the telemetry data
LongName	Scalar	String				A complete descriptive name for the data type of this product
PlatformLongName	Scalar	String				'Orbiting Carbon Observatory 2'

PlatformShortName	Scalar	String				'OCO-2'
PlatformType	Scalar	String				'spacecraft' - The type of platform associated with the instrument which acquires the accompanying data
ProcessingLevel	Scalar	String				Indicates data level (Level 0, Level 1A, Level 1B, Level 2) in this product
ProducerAgency	Scalar	String				'NASA' - Identification of the agency that provides the project funding
ProducerInstitution	Scalar	String				'JPL' - Identification of the institution that provides project management.
ProductionDateTime	Scalar	String				The date and time at which the product was created (yyyy-mm-ddThh:mm:ss.mmmZ)
ProductionLocation	Scalar	String				Facility in which this file was produced, typically: 'Operations Pipeline', 'Operations Pipeline 2', 'Science Computing Facility', 'Test Pipeline', Test Pipeline 2'
ProductionLocationCode	Scalar	String				One-letter code indicating the ProductionLocation, typically: 'O' - Operations Pipelines (1) or 2, 'S' - Science Computing Facility, 'T' - Test Pipelines (1) or 2
ProjectId	Scalar	String				'OCO-2' - The project identification string
QAGranulePointer	Scalar	String				A pointer to the quality assessment product that was generated with this product
RangeBeginningDate	Scalar	String				The date on which the earliest data contained in the product were acquired (yyyy-mm-dd)
RangeBeginningTime	Scalar	String				The time at which the earliest data contained in the product were acquired (hh:mm:ss.mmmZ)
RangeEndingDate	Scalar	String				The date on which the latest data contained in the product were acquired (yyyy-mm-dd)
RangeEndingTime	Scalar	String				The time at which the latest data contained in the product were acquired (hh:mm:ss.mmmZ)

ShortName	Scalar	String				The short name identifying the data type of this product
SISName	Scalar	String				The name of the document describing the contents of the product
SISVersion	Scalar	String				The version of the document describing the contents of the product
SizeMBECSDataGranule	Scalar	Float32	Megabytes			The size of this data granule in Megabytes
StartOrbitNumber	Scalar	Int32		1	99999	The first orbit on which data contained in the product were acquired
StartPathNumber	Scalar	Int32		1	233	The first WRS path on which data contained in the product was collected
StopOrbitNumber	Scalar	Int32		1	99999	The last orbit on which data contained in the product were acquired
StopPathNumber	Scalar	Int32		1	233	The last WRS path on which data contained in the product was collected

7 Appendix 1: Shape Descriptions

The shape name of a data element is a descriptive label that describes the rank and dimensions of that element.

Rules for creating shapes:

1. Shape names do not include any context information, such as what mode the instrument is in when it takes data with that shape. Any context information needed to distinguish between similarly named dimensions is appended as a label, just before the "_Array" suffix.
2. Any "temporal" dimension, e.g. Frame, is always outermost.
3. If Frame and Sounding are both present, they occur in direct sequence, i.e. Frame_Sounding_.
4. Shapes that include Frame, Sounding, and Spectrum cannot have any additional dimensions.
5. Spectrum precedes all other physical instrument dimensions, except when this rule contradicts any of the above rules.
6. If Spectrum and Sounding are present in the absence of Frame, they occur in direct sequence, i.e., Spectrum_Sounding.
7. Color comes after SinglePixel.
8. SinglePixel comes after Slice.

Shape	Rank	Max dimension sizes (Units)	Dimensions
AncFile_Array	1	20 (Number of ancillary input files)	AncFile
Frame_Array	1	10512 (Frames)	Frame
Frame_EuclidDim_Array	2	10512 (Frames) x 3 (Attitude dimensions)	Frame, EuclidDim
Frame_O2Slice_Array	2	10512 (Frames) x 20 (Spectral Pixels)	Frame, O2Slice
Frame_O2Slice_SpatialRow_Array	3	10512 (Frames) x 20 (Spectral Pixels) x 220 (Spatial Rows)	Frame, O2Slice, SpatialRow
Frame_Sounding_Array	2	10512 (Frames) x 8 (Soundings)	Frame, Sounding
Frame_Sounding_CornerPt_Array	3	10512 (Frames) x 8 (Soundings) x 4 (Vertices)	Frame, Sounding, CornerPt
Frame_Sounding_ECMWFLevel_Array	3	10512 (Frames) x 8 (Soundings) x 137 (Atmospheric Levels)	Frame, Sounding, ECMWFLevel
Frame_Sounding_DeclockingGroupO2_JumpColorO2_Array	4	10512 (Frames) x 8 (Soundings) x 20 (Groups of color slices) x 1024 (Positions of clocking jump)	Frame, Sounding, DeclockingGroupO2, JumpColorO2
Frame_Sounding_DeclockingGroupStrongCO2_JumpColorStrongCO2_Array	4	10512 (Frames) x 8 (Soundings) x 20 (Groups of color slices) x 1024 (Positions of clocking jump)	Frame, Sounding, DeclockingGroupStrongCO2, JumpColorStrongCO2
Frame_Sounding_DeclockingGroupWeakCO2_JumpColorWeakCO2_Array	4	10512 (Frames) x 8 (Soundings) x 20 (Groups of color slices) x 1024 (Positions of clocking jump)	Frame, Sounding, DeclockingGroupWeakCO2, JumpColorWeakCO2
Frame_Sounding_SciColor_Array	3	10512 (Frames) x 8 (Soundings) x 1016 (Spectral Pixels)	Frame, Sounding, SciColor
Frame_Sounding_Spectrum_Array	3	10512 (Frames) x 8 (Soundings) x 3 (Spectrometers)	Frame, Sounding, Spectrum
Frame_Sounding_Spectrum_StokesCoefficient_Array	4	10512 (Frames) x 8 (Soundings) x 3 (Spectrometers) x 4 (Stokes Coefficients)	Frame, Sounding, Spectrum, StokesCoefficients
Frame_Spectrum_Array	2	10512 (Frames) x 3 (Spectrometers)	Frame, Spectrum
Frame_StrongCO2Slice_Array	2	10512 (Frames) x 20 (Spectral Pixels)	Frame, StrongCO2Slice
Frame_StrongCO2Slice_SpatialRow_Array	3	10512 (Frames) x 20 (Spectral Pixels) x 220 (Spatial Rows)	Frame, StrongCO2Slice, SpatialRow
Frame_WeakCO2Slice_Array	2	10512 (Frames) x 20 (Spectral Pixels)	Frame, WeakCO2Slice
Frame_WeakCO2Slice_SpatialRow_Array	3	10512 (Frames) x 20 (Spectral Pixels) x 220 (Spatial Rows)	Frame, WeakCO2Slice, SpatialRow
Gap_Array	1	10 (Number of gaps)	Gap
InputPtr_Array	1	20 (Number of primary input files)	InputFile
O2Slice_Array	1	20 (Spectral Pixels)	O2Slice
OrbitParamPtr_Array	1	16 (Attitude and ephemeris files)	OrbitFile
SoundingPosition_Array	1	8 (Maximum number of footprints)	SoundingPosition

Spectrum_Array	1	3 (Spectrometers)	Spectrum
Spectrum_SciColor_Array	2	3 (Spectrometers) x 1016 (Spectral Pixels)	Spectrum, SciColor
Spectrum_Sounding_DispersionCoefficient_Array	3	3 (Spectrometers) x 8 (Soundings) x 10 (Dispersion coefficients)	Spectrum, Sounding, DispersionCoefficient
Spectrum_Sounding_SciColor_Array	3	3 (Spectrometers) x 8 (Soundings) x 1016 (Spectral Pixels)	Spectrum, Sounding, SciColor
Spectrum_Sounding_SciColor_DeltaLambda_Array	4	3 (Spectrometers) x 8 (Soundings) x 1016 (Spectral Pixels) x 200 (Coefficients)	Spectrum, SciColor, DeltaLambda
Spectrum_Sounding_SciColor_ResidualCoefficient_Array	4	3 (Spectrometers) x 8 (Soundings) x 1016 (Spectral Pixels) x 5 (Coefficients)	Spectrum, Sounding, SciColor, ResidualCoefficient
Spectrum_Sounding_SciColor_SNRCoef_Array	4	3 (Spectrometers) x 8 (Soundings) x 1016 (Spectral Pixels) x 2 (Coefficients)	Spectrum, Sounding, SciColor, SNRCoef
StrongCO2Slice_Array	1	20 (Spectral Pixels)	StrongCO2Slice
WeakCO2Slice_Array	1	20 (Spectral Pixels)	WeakCO2Slice

8 Appendix 2: Acronyms

APID	Application Process Identifier
ASCII	American Standard Code for Information Interchange
ASD	Algorithm Specification Document
ATBD	Algorithm Theoretical Basis Document
CO ₂	Carbon Dioxide
DAAC	Distributed Active Archive Center
DOORS	Dynamic Object Oriented Requirements
ECHO	Earth observing system Clearing HOuse - The NASA-developed spatial and temporal metadata registry
ECMWF	European Center for Medium-range Weather Forecast
EDOS	EOS Data and Operations System
EOS	Earth Observing System
GES DISC	Goddard Earth Sciences Data and Information Services Center
HDF	Hierarchical Data Format
HECC	High-end Computing Capability
ICD	Interface Control Document
IMAP-DOAS	<i>Iterative Maximum A Posteriori</i> Differential Optical Absorption Spectroscopy
IOC	In-Orbit Checkout
ITAR	International Traffic in Arms Regulations
LOS	Line-of-sight; the instrument boresight direction; the look vector
MOS	Mission Operations System
MOU	Memorandum of Understanding
NAS	NASA Advanced Supercomputing
NASA	National Aeronautics and Space Administration
O ₂	Oxygen
OCO	Orbiting Carbon Observatory
PGE	Product Generation Executive
SCF	Science Computing Facility
SDOS	Science Data Operations System
SIS	Software Interface Specification
SP4A	Simple, Scalable Script-based Science Processor Archive
TBD	To Be Determined
TCCON	Total Carbon Column Observing Network
UTC	Coordinated Universal Time
X _{CO2}	Column-averaged dry air mole fraction of atmospheric CO ₂