Global-scale Observations of the Limb and Disk (GOLD)

Public Science Data Products Guide

[Revision 3.0 – September 16, 2019]

Table of Contents

Table of Figures

Table of Tables

1 Starting Material

1.1 Reference Documents

Title	Reference
GOLD Release Notes	Latest release notes are available on the GOLD website: http://gold.cs.ucf.edu/documentation/

1.2 Acronyms/Abbreviations

Acronym	Meaning
CHA	Channel A
CHB	Channel B
DQI	Data Quality Index
FOV	Field of View
GOLD	Global-scale Observations of the Limb and Disk
GSFC	Goddard Space Flight Center
HR	High Resolution
LASP	Laboratory for Atmospheric and Space Physics
LR	Low Resolution
NetCDF	Network Common Data Format
OCC	Occultation
SDC	Science Data Center
SOC	Science Operations Center
SPDF	Space Physics Data Facility
SPICE	Spacecraft, Planet, Instrument, C-matrix, and Events
UCF	University of Central Florida

1.3 Definitions

Archive – Where the GOLD science data is kept in order to be preserved.

Data Quality Index – Flags to indicate quality of the data.

1.4 Scope

This document describes the publicly available science data products for the Global-scale Observations of the Limb and Disk (GOLD) mission.

2 Data Overview

2.1 Data Product Definition

Level	Brief Description	Publicly Available?
0	GOLD telemetry as received from the GOLD Ground Station (GGS). Consultative Committee on Space Data Standards (CCSDS) Coded Virtual Channel Data Unit (CVCDUs) [fill VCDUs removed] contained in Cortex Data Transfer format. Binary files on 1-minute cadence.	No
1A	Time-tagged series of photon detection events, including detector location and pulse heights. Data numbers converted to engineering units. (Time in Coordinated Universal Time (UTC)) Separate A and B channel NetCDF files on 1-minute cadence.	No
1B	Data binned and mapped in GOLD coordinates, with geolocation information included. Retain highest resolution conceivably required for all downstream data products. Converts time series of photon events into an image data cube. Separate A and B channel NetCDF files on 1-minute cadence.	No
1C	Geolocated data in both counts and brightness (calibrated) units. Includes backgrounds and brightness total error. Data are further binned spatially and spectrally, as required for each OBS_TYP and Level 2 algorithm. Separate A and B channel Network Common Data Form (NetCDF) files for each observation, cadence dependent on observation type.	Via the GOLD web site and SPDF
Quicklook (L1D)	Images of disk brightness at key wavelengths. Separate A and B channel PNG files for each disk scan.	Via the GOLD web site
L2	Daily files produced for each geophysical data product.	Via the GOLD web site and SPDF

Table 2-1 Data Product Definition

2.2 Data Processing Levels

Level 1C	
Definition	Calibration Step Geolocated data in both counts and brightness (calibrated) units. Includes backgrounds and brightness total error. Data are further binned spatially and spectrally, as required for each OBS_TYP and Level 2 algorithm. Disk (images): Day: 125×125 km^2 spatial resolution (at nadir). 0.04 nm spectral sampling. Data cube: 104 x 92 x 800 pixels (N/S x E/W x spectral). Night 1: 0.15°×0.15° spatial resolution. 0.04 nm spectral sampling. Data cube: N/S and E/W dimensions vary, 800 pixels in spectral dimension. Limb (profiles): 16 km tangent altitude x 1.25° latitude resolution 0.04 nm spectral sampling. Data cube: 30 x 32 x 800 pixels (tangent altitude x latitude x spectral) Occultations: altitude resolution: 0.9(0.45) km at 0(60) deg latitude 0.12 nm spectral sampling. Data dimensions: 980 x 266 (E/W-altitude x spectral)

<table>
<tr><th colspan="3">Level 1C</th></tr>
<tr><td>Details</td><td colspan="2">Separate files for CH A/B and each OBS_TYP (DAY, DLR, NI1, LIM, OCC)

Multiple L1B files are combined to produce complete event files for each OBS_TYPE.

Cadence specific to OBS_TYPE:
DAY – 30 minutes
LIM – 30 minutes
NIT – 20 minutes
OCC - ~10 per day at irregular cadence</td></tr>
<tr><th colspan="3">Level 1D</th></tr>
<tr><td>Definition</td><td colspan="2">Quick-look products generated from L1C. Will consist of images or profiles of brightness at key wavelengths. One or more files per L1C file.</td></tr>
<tr><td>Details</td><td colspan="2">Images only.</td></tr>
<tr><th colspan="3">Level 2</th></tr>
<tr><td rowspan="5">Definition</td><td colspan="2">Retrieved geophysical parameters</td></tr>
<tr><td>Day Disk</td><td>ON2 - O/N_2 column density ratio (Includes OI and LBH integrated brightness)
QEUV - Solar EUV proxy
TDISK - Neutral temperature</td></tr>
<tr><td>Night Disk</td><td>NMAX - Peak electron density (Includes crest locations and intensities & OI brightness)</td></tr>
<tr><td>Limb (day)</td><td>TLIMB - Exospheric temperature, T_{exo}.</td></tr>
<tr><td>Occultation
(day & night)</td><td>O2DEN - O_2 density profile</td></tr>
<tr><td>Details</td><td colspan="2">Daily files produced for each geophysical data product. Contains each individual specific observation type data taken throughout the corresponding day.</td></tr>
</table>

Table 2-2 Data Processing Levels

2.3 File Naming Conventions

Data Level	Description
L1C	GOLD_L1C_CHX_TYP_yyyy_ddd_hh_mm_vAA_rBB_cCC.nc **X** = "A" or "B" **TYP** is the type of observation: "LIM", "OCC", "DAY", "NI1", "NI2", "DLR", "SP1", "SP2", "SP3" to correspond respectively with Limb, Occultation, Day Disk, Night Disk 1, Night Disk 2, Disk Low Resolution, Special Observation 1, Special Observation 3, Special Observation 3, in the OBS_TYP field, as done in the Level 1B files. **yyyy**_ddd_hh_mm is the year, day of year, hour and minute corresponding to the start of this observation event. **AA** is the file version number, 2 decimal characters from 01 to 99, which increments by 1 when a full-mission reprocessing is required for the given data product. Each data product version, revision and cycle numbers may be independent of the other data product types. **BB** is the file revision number, 2 decimal characters from 01 to 99, which increments by 1 when there is a new input configuration or calibration file is used, or when the change does not require full-mission reprocessing. Each data product version, revision and cycle numbers may be independent of the other data product types. **CC** is the file cycle number, 2 decimal characters from 01 to 99, which increments when a data product must be regenerated due to a loss of data or interruption that can be remedied without new code delivery. Each data product version, revision and cycle numbers may be independent of the other data product types. Example: GOLD_L1C_CHA_OCC_2015_222_23_00_v01_r01_c01.nc

Data Level	Description
L1D	The file naming convention for combined Level 1D data file is: GOLD_L1D_CHX_TYP_yyyy_ddd_hh_mm_vAA_rBB_cCC.png **X** = "A" or "B" **TYP** is the type of observation: "LIM", "OCC", "DAY", "NI1", "NI2", "DLR", "SP1", "SP2", "SP3" to correspond respectively with Limb, Occultation, Day Disk, Night Disk 1, Night Disk 2, Disk Low Resolution, Special Observation 1, Special Observation 3, Special Observation 3 in the OBS_TYP field, as done in the Level 1C files. yyyy_ddd_hh_mm is the year, day of year, hour and minute corresponding to the start of this observation event. **AA** is the file version number, 2 decimal characters from 01 to 99, which increments by 1 when a full-mission reprocessing is required for the given data product. Each data product version, revision and cycle numbers may be independent of the other data product types. **BB** is the file revision number, 2 decimal characters from 01 to 99, which increments by 1 when there is a new input configuration or calibration file is used, or when the change does not require full-mission reprocessing. Each data product version, revision and cycle numbers may be independent of the other data product types. **CC** is the file cycle number, 2 decimal characters from 01 to 99, which increments when a data product must be regenerated due to a loss of data or interruption that can be remedied without new code delivery. ach data product version, revision and cycle numbers may be independent of the other data product types. Example: GOLD_L1D_CHA_OCC_2015_222_23_00_v01_r01_c01.nc
L2 Daily Files	GOLD_L2_PROD_yyyy_ddd_vAA_rBB.nc PROD is the Level 2 data product: "ON2", "QEUV", "TDISK", "TLIMB", "O2DEN" or "NMAX" yyyy_ddd is the year and day of year covered by data in the file. AA is the file version number, 2 decimal characters from 01 to 99, which increments by 1 when a full-mission reprocessing is required for the given data product. Each data product version, revision and cycle numbers may be independent of the other data product types. BB is the file revision number, 2 decimal characters from 01 to 99, which increments by 1 when there is a new input configuration or calibration file is used, or when the change does not require full-mission reprocessing. Each data product version, revision and cycle numbers may be independent of the other data product types. CC is the file cycle number, 2 decimal characters from 01 to 99, which increments when a data product must be regenerated due to a loss of data or interruption that can be remedied without new code delivery. ach data product version, revision and cycle numbers may be independent of the other data product types. Example: GOLD_L2_TDISK_2015_222_v01_r01_c01.nc

Table 2-3 File Naming Conventions

2.4 Data Binning

OBS_TYPE	L1C Binning
Day Disk	Angular space (E-W, N-S): 0.2° x 0.2° x 0.04nm [92 bins E-W, 104 bins N-S, 800 spectral bins] HR slit = 125km x 125km x 0.04nm at nadir LR slit = 125km x 125km x 0.08nm at nadir
Limb	Angular space (radial, azimuthal): 0.022° x 1.25° x 0.04nm array size: [30 tangent altitude (from -44 to 436 km), 32 latitude, 800 spectral bins] 16km tangent altitude x 1.25° lat x 0.04nm
Occultation	3 spectral x 3 time [266 X pixels, 1 Y pixel, 980 (bins of 300ms - for only the 4.9 minutes of occ (294 sec)]
Night Disk - Low Resolution Slit (OBS_TYPE = NI1)	Angular space (E-W, N-S) 0.15° x 0.15° x 0.04nm Unchanged L1B bins summed to dwell time for each mirror position. E-W binning and spectral resolution determined by slit width; N-S binning to approximate the same angular resolution. No further binning is done (does not map to fixed lat-lon grid).

Table 2-4 Data Binning

2.5 Slit Information

Slit	Width	Height
High Resolution	0.0764°, ~47.7 km (nadir at equator)	11°, ~6956 km (nadir)
Low Resolution	0.1528°, ~95.4 km (nadir at equator)	11°, ~6956 km (nadir)
Occultation	1°, ~625 km (nadir at equator)	10°, ~6310 km (nadir)

Table 2-5 Slit Geometry

2.6 Nominal Daily Observing Plan

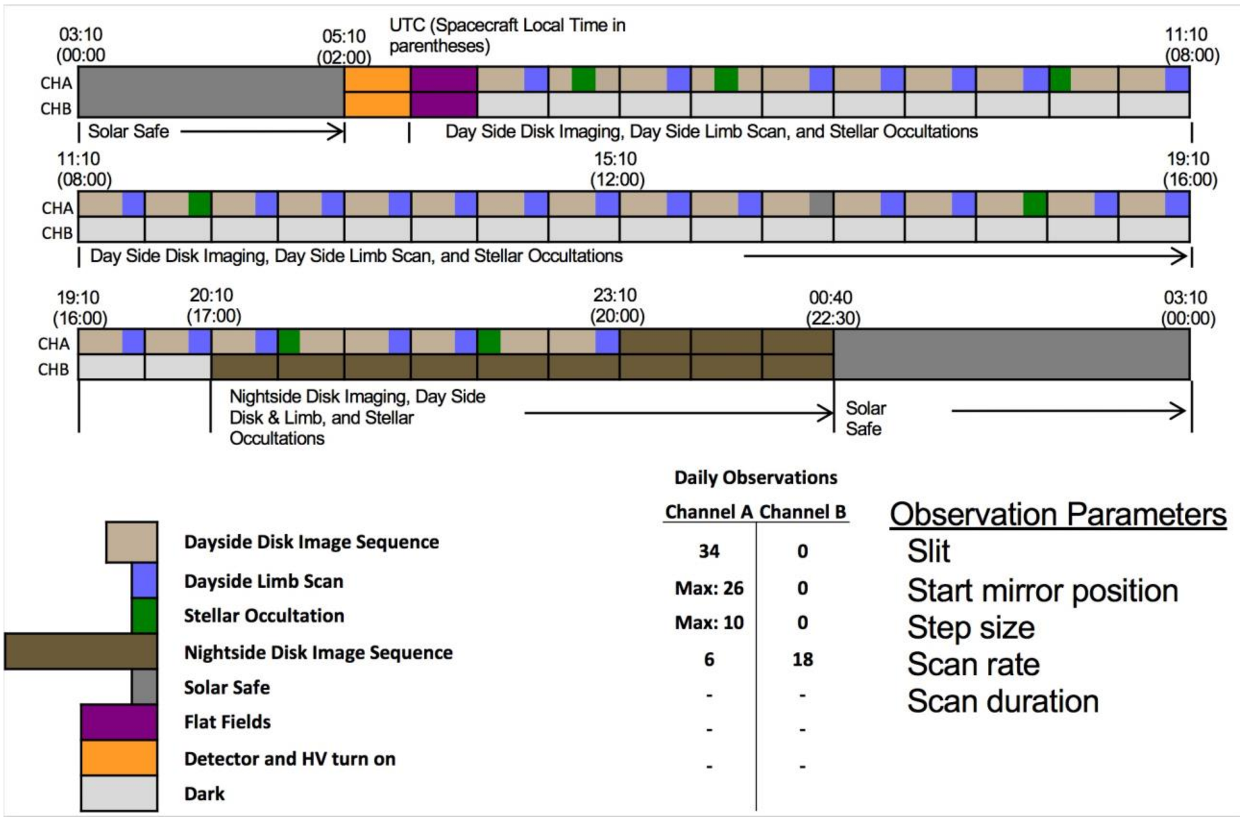

Figure 2-1 Typical Daily Observations

3 Level 1 Data Products

3.1 Common Processing

The following processing is common to all Level 1 data products.

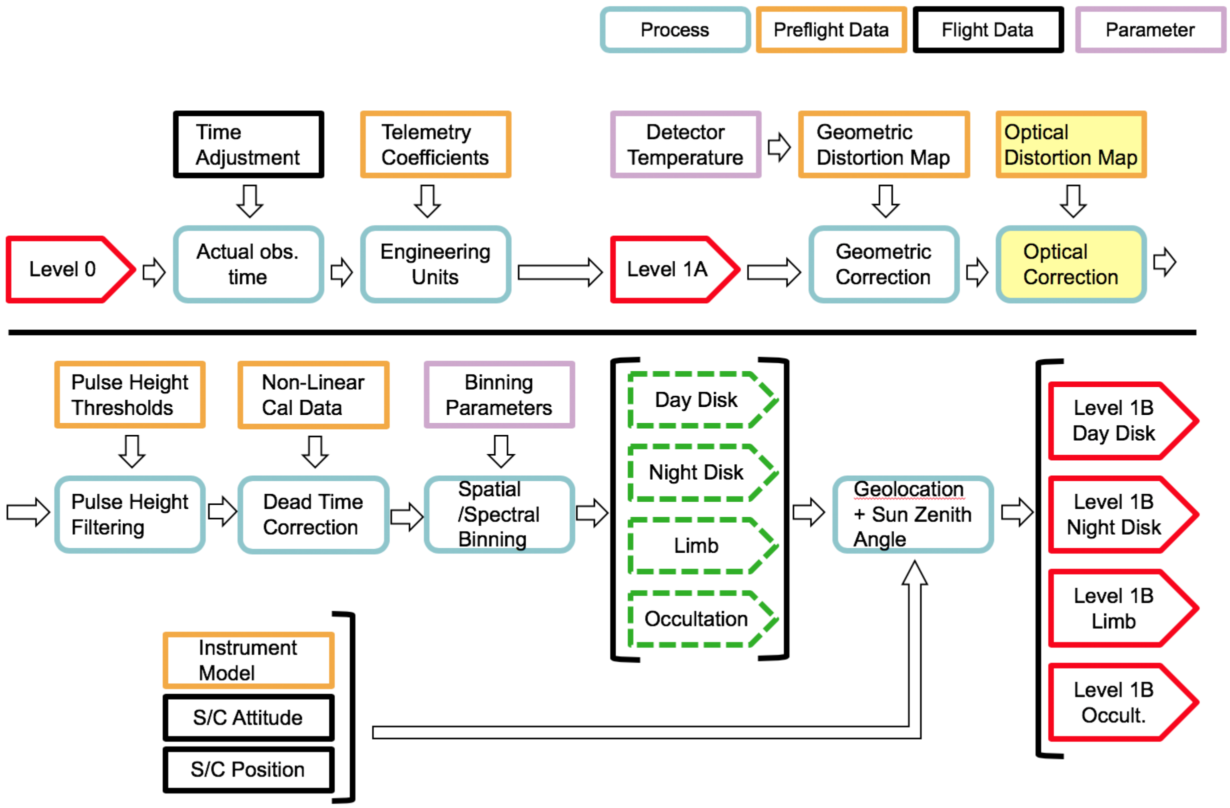

Figure 3-1 Level 1A to Level 1B Corrections

3.1.1 Generating Level 1A

The raw data coming from the ground station is compressed and bit-packed to minimize the data volume to download. On the ground, the various packets are extracted from the L0 data and L1A netCDF files are created at a one-minute cadence, one file per channel. Minimal processing occurs to generate the L1A files as described below.

3.1.2 Time Adjustment

The slowly drifting time from the instrument clock is inserted in the downloaded data packets. With the knowledge of the exact ground receipt time, an adjustment is made to the instrument clock through SPICE time kernels to generate UTC and Ephemeris Time (ET) used in the L1A files.

3.1.3 Telemetry Coefficients

Fixed conversions (polynomial coefficients, state conversions, etc.) are applied to the L0 data telemetry to convert from raw data numbers to engineering units (Volts, Amps, Degree C, etc.).

3.1.4 NetCDF File Format

Level 1A data are stored in NetCDF-4 file format.

3.1.5 Generating Level 1B

3.1.5.1 Stim Pulse Location Correction

The location of a photon event on the detector is measured by a highly accurate timing electronics circuit. Because the response of this circuit varies slightly with temperature, the measured location of a fixed photon stream will appear to move on the detector with temperature. This effect is corrected by tracking the location of fixed and electronically ingested stim pulses. Stretch and shift are applied to the detector photon event locations into the reference frame based on the location of these stim pulses.

3.1.5.2 Geometric Correction

Geometric distortion is due to local variations in the plate scale of the detector. These variations are fixed in physical space and are due to small differences in the propagation speed of the anode and the structure of the MCPs themselves. The variations in the propagation speed are in turn due to local differences in the anode substrate thickness, anode trace resistivity, and the behavior of a charge cloud propagating along a complex network of conductive traces. The correction is derived from images of an equal-spacing pinhole mask provided by Berkley SSL (detector manufacturer). A correction map in X and a correction map in Y are applied.

3.1.5.3 Optical Correction

The GOLD camera system produces slightly curved images of the slit on the detector. To simplify processing and analysis, this effect is removed when generated L1B files. The correction forces the image of the slit to align with detector column and for the spectra to align with a row. This correction is based on ground calibration data. A correction map in X and a correction map in Y are applied.

3.1.5.4 Pulse Height Filtering

Configurable window to filter out non-photon related events identified by unexpected pulse height values. The current filtering window is set to remove all events with pulse height values of 0, 1, 2, or 255.

3.1.5.5 Spatial/Spectral/Temporal Binning

Spatial, spectral and temporal binning based on observation type (see Table 2-1 and Table 2-2).

3.1.5.6 Global Dead Time Correction

The detector electronics has a finite response time and as the rate of photons events increases, at one point, the electronics can't keep up and will start missing photons. This effect has been well characterized on the ground, based on the Fast-Event-Counter (FEC) detector telemetry. A dead time correction is applied globally to binned image based on the FEC.

3.1.5.7 Local Dead Time Correction

Local dead time results from the limited ability of the Micro-Channel-Plates (MCP) to provide current to a locally-intense region of illumination. Local dead time affects both the measured count rate of individual bright sources and the shapes of those sources. Correction factors are based on ground calibration data taken at various brightness levels. For GOLD, only the bright stars observed as part of the Occultations are impacted by this effect. This correction is not currently being applied (for data release 1).

3.1.6 Generating Level 1C

The processing of the Level 1B into L1C data requires:

- current Flat-Field data
- measured values for the dark counts and scattered light
- wavelength solution along the length of the current slit and the GYM position
- current radiometric correction as a function of wavelength and location on the detector

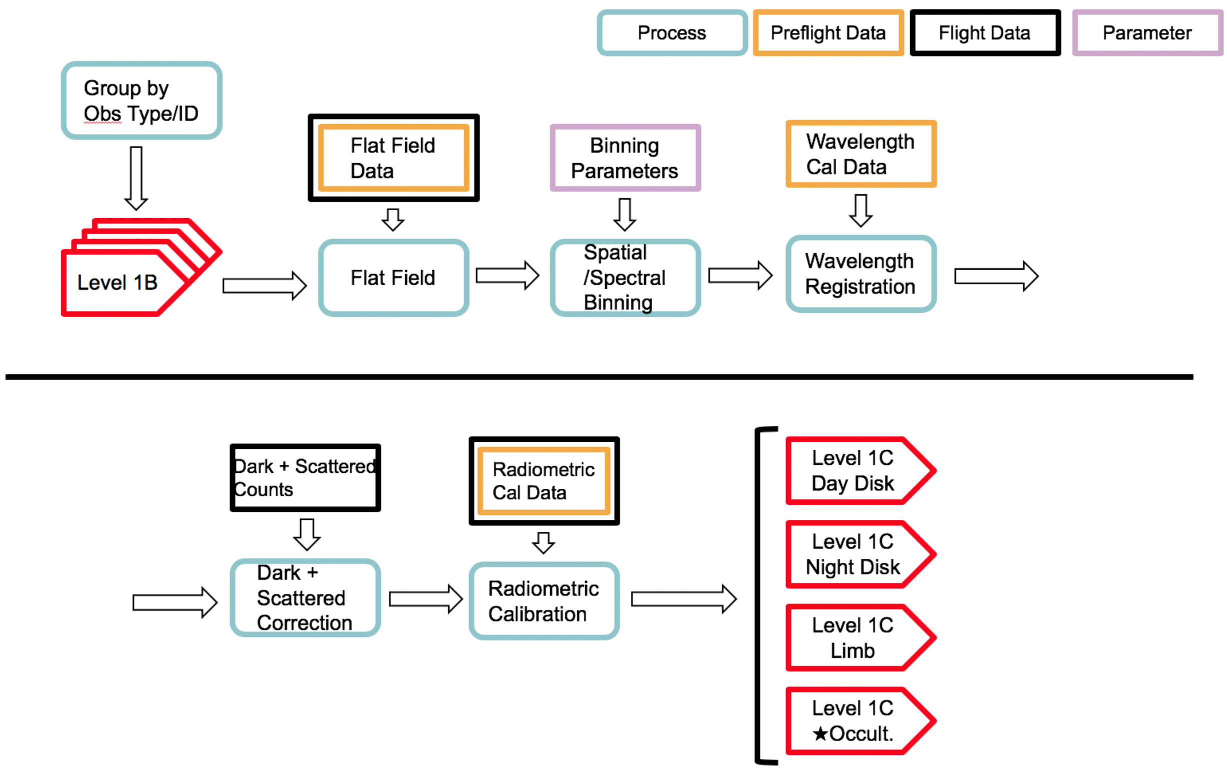

Figure 3-2 Level 1B to Level 1C Corrections

3.1.6.1 Spatial/Spectral/Temporal Binning

3.1.6.2 Flatfield Correction

The flatfield data is used to measure and correct relative drop in detector sensitivity since the start of the mission. A flatfield image is taken once per day. Seven days of flatfield data is then combined to generate a daily calibration file. The daily flatfield calibration file is then applied to the current day's data.

3.1.6.3 Wavelength Registration

Wavelength registration is performed using all of the data from a single L1C file to increase the signal to noise of the combined spectra. This spectrum is then aligned to a reference spectrum consisting of only the OI 135.6 and NI 149.6nm atomic lines, eliminating possible errors due to changing LBH spectral features with time.

3.1.6.4 Radiometric Correction

The equation below describes how we convert the detector raw count rates to fully calibrated radiances in Rayleighs/nm with a definition of all the terms needed.

$$L(\lambda_j,h_k)=\frac{[C(\lambda_j,h_k)\cdot N(C(\lambda_j,h_k))-S_l^{'}(\lambda_j,h_k)-D^{'}(\lambda_j,h_k)]/\Delta t}{R_c(\lambda_j)\cdot r(\lambda_j,h_k)}$$

$$R_c(\lambda_j)=A_T\cdot\Omega_c\cdot\Delta\lambda_j\cdot QT_c(\lambda_j)$$

Green = Calibration Activity
Blue = Metrology, electrical test
Orange = Flight only

- L = Atmosphere radiance
- C = Detector counts for (spectral, spatial) pixel (j,k)
- N = Detector linearity correction
  - MCP gain sag (System measurement, MOBI calibration facility)
  - Detector electronics dead time (Component measurement, bench test)
- S_l'= Stray plus scattered light correction ($S_{stray}+S_l$) (System measurement, MOBI calibration facility)
- D'= Total dark counts collected during an integration period,
  - Detector internal dark count (D) (Component measurement, MOBI calibration facility)
  - Background counts (B) that arise from bremsstrahlung radiation emitted by the detector particle radiation shields (model estimates. Measure on orbit)
- Δt = Integration time (GOLD E-Box Test)
- R_C = Responsivity at FOV center (System measurement, MOBI Calibration Facility)
- r = Responsivity for pixel j,k relative to that for pixel j,k_c ($r(j,k)=1$ for $k=k_c$) (System measurement, MOBI calibration facility, flat field lamp)
- A_T = Telescope area (Optical design, component measurement)
- Ω_C = Spectrograph entrance slit solid angle = $W_S \bullet H_S/F_T^2$is the slit width
  - W_S = Slit width (Component mechanical measurement)
  - H_S = Slit height imaged onto the central row of the detector (Component mechanical measurement)
  - F_T = Telescope focal length at the center of the FOV (Optical design, component measurement)
- $\Delta\lambda_j$ = Spectral passband (System measurement, MOBI calibration facility)
- QTc = Quantum throughput (QT) of the optics and detector at the center of the FOV (System measurement, MOBI calibration facility)

3.1.6.5 Background and Scattered Light Correction

The background is removed based on the principle that the spectrum should be zero at specific wavelength regions. These regions are shown below.

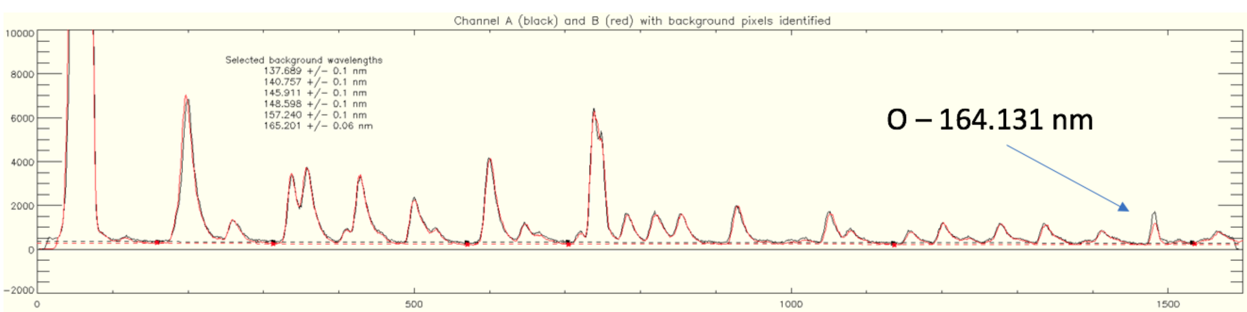

Figure 3-3 Reference Wavelengths for Background

Using these regions, we can show on a first order basis, that the values in a single L1C pixel have very little wavelength dependence and thus a constant background correction is currently applied at all wavelengths.

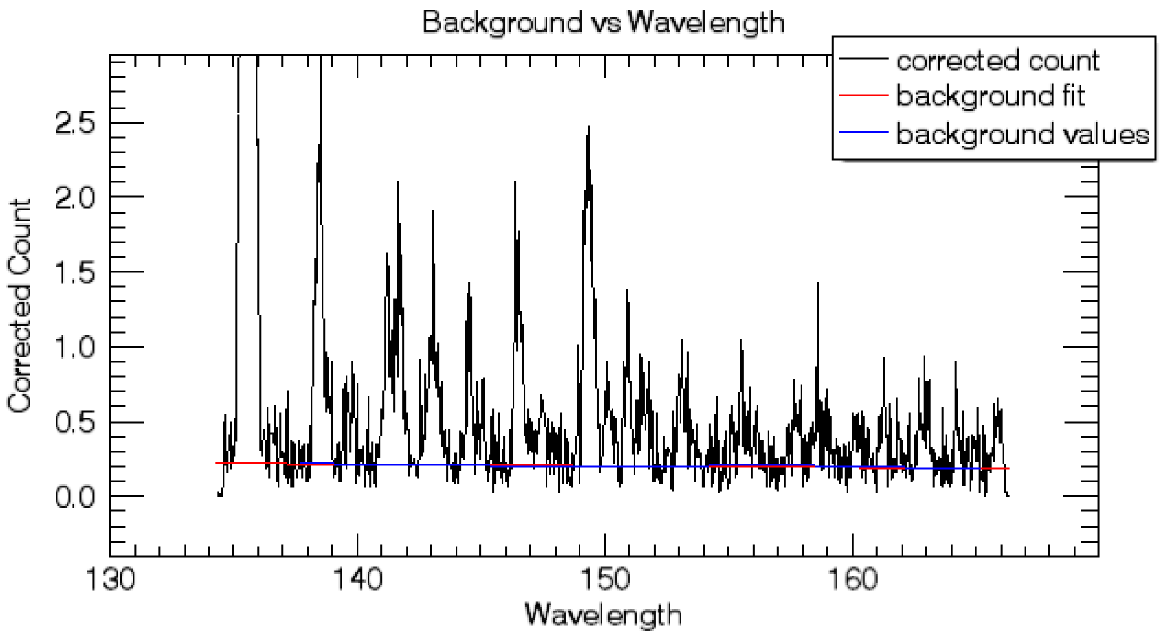

Figure 3-4 Wavelength Dependence of Background at one 1C Position

Unfortunately, and as expected, the counts in these small regions are low. Using the value of the background based on these regions alone, introduces considerable noise to the final data product so a fourth ordered smoothed surface over the L1C grid, is used instead. We additionally drop any contributions due to the presence of stars. Here are a few plots of the signal prior to background subtraction for days with high particle backgrounds.

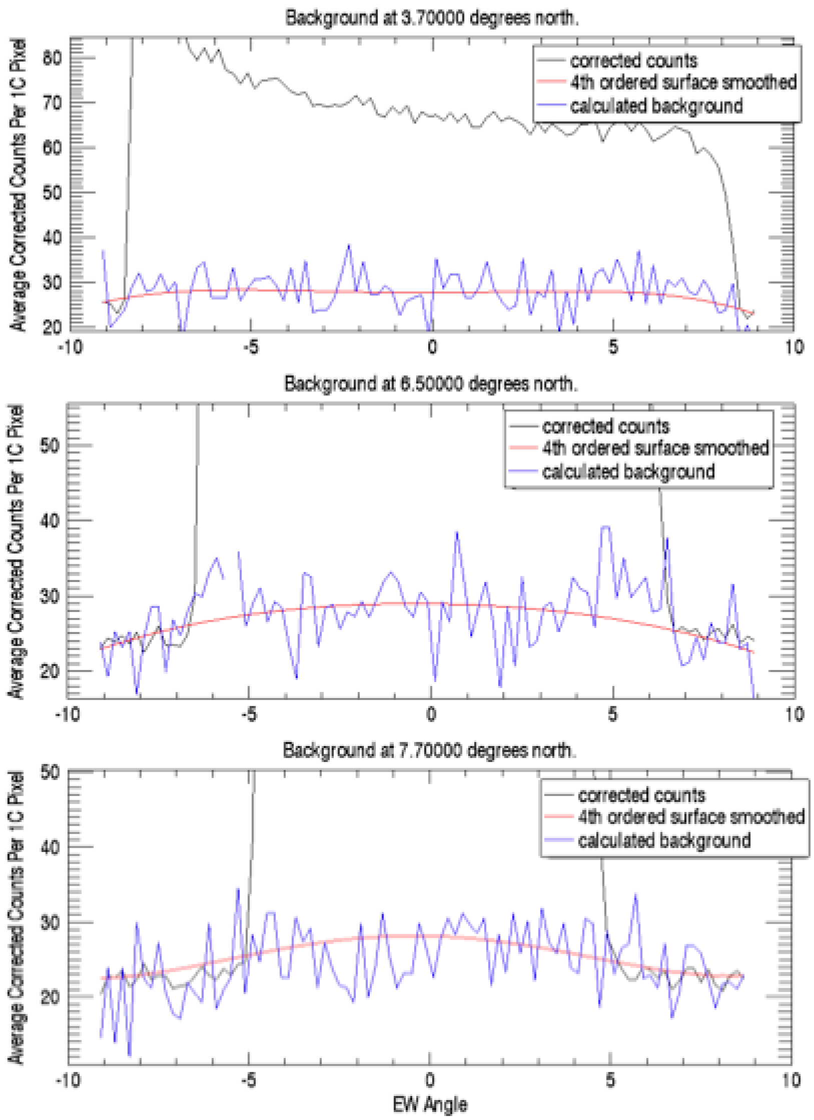

Figure 3-5 Examples of Background Fit

3.2 Day Disk Scan Data Product

3.2.1 Day Disk Scan Observations

Dayside disk and dayside limb scans are performed with channel A (CHA) operating in the High Resolution (HR) slit.

For the Dayside Disk scan, the channel A scan mirror steps the 10.8˚ tall image of its spectrometer entrance slit across the sunlit portions of the disk in two swaths, one covers the northern hemisphere and the other covers the southern hemisphere, as shown in Figure 3-6. Each swath requires 12 minutes to complete including setup (24 minutes for a complete disk image) at a fixed rate of 0.05214˚ per step (nadir ground speed of 32.56 km per step at the sub spacecraft point) for 346 scan mirror positions (17.87˚). It scans the disk +150 km on each side with (+/- 0.073˚) margin for spacecraft pointing. All disk scans are performed East to West.

Day Disk scans: 35,786 km

-step time = 2 sec

-image motion = 32.56 km/step at nadir

-angular coverage = 17.87˚

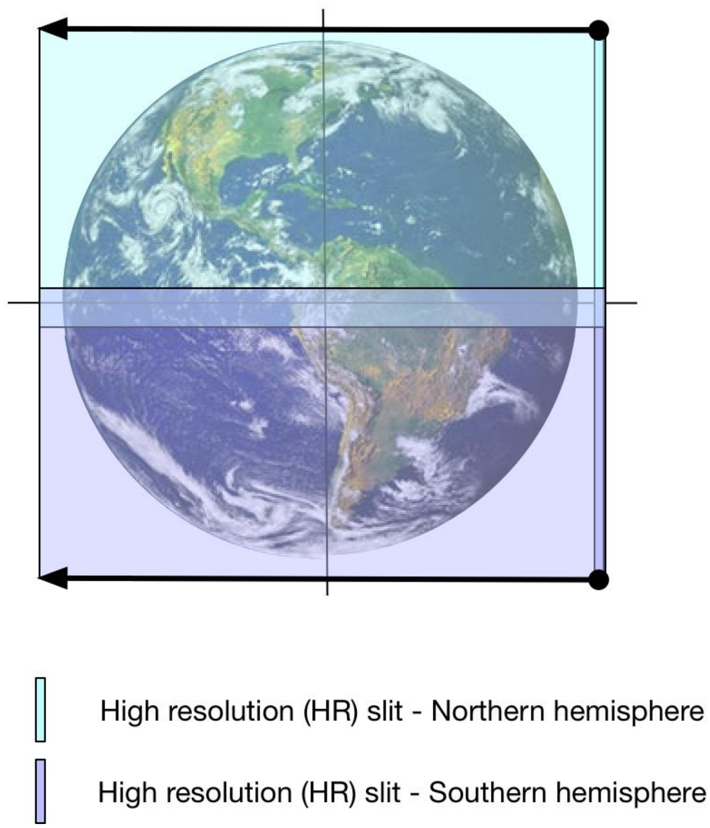

Figure 3-6 Day Disk Scan

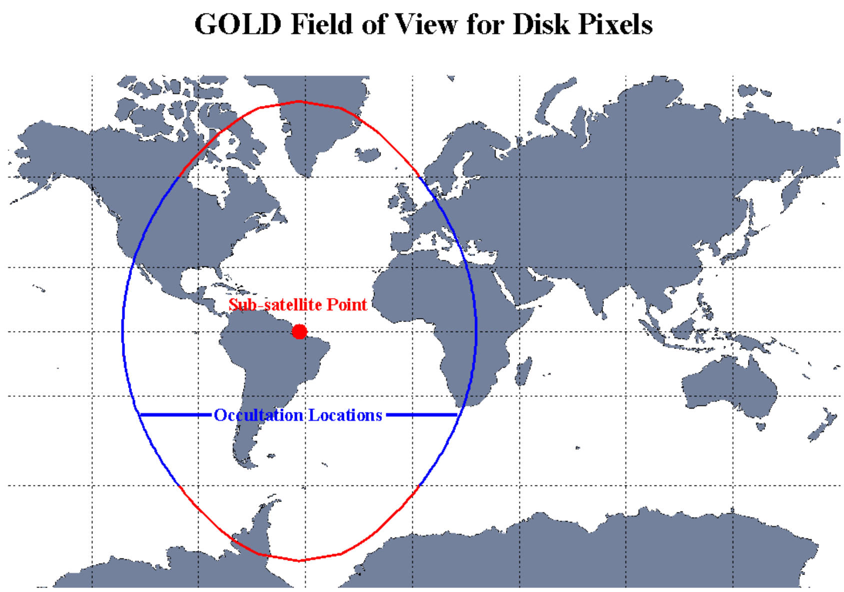

Figure 3-7 GOLD Field of View

3.2.2 Geo-location

The Earth's ellipsoid is defined by WGS 84, giving radius values 6378.1370 km in x/y and 6356.7523 km in z. The latitude and longitude are defined using the geodetic coordinate system.

Day Disk Scans use a fixed reference altitude of 150 km.

3.2.2.1 Reference Altitude Ray Intercept Definitions

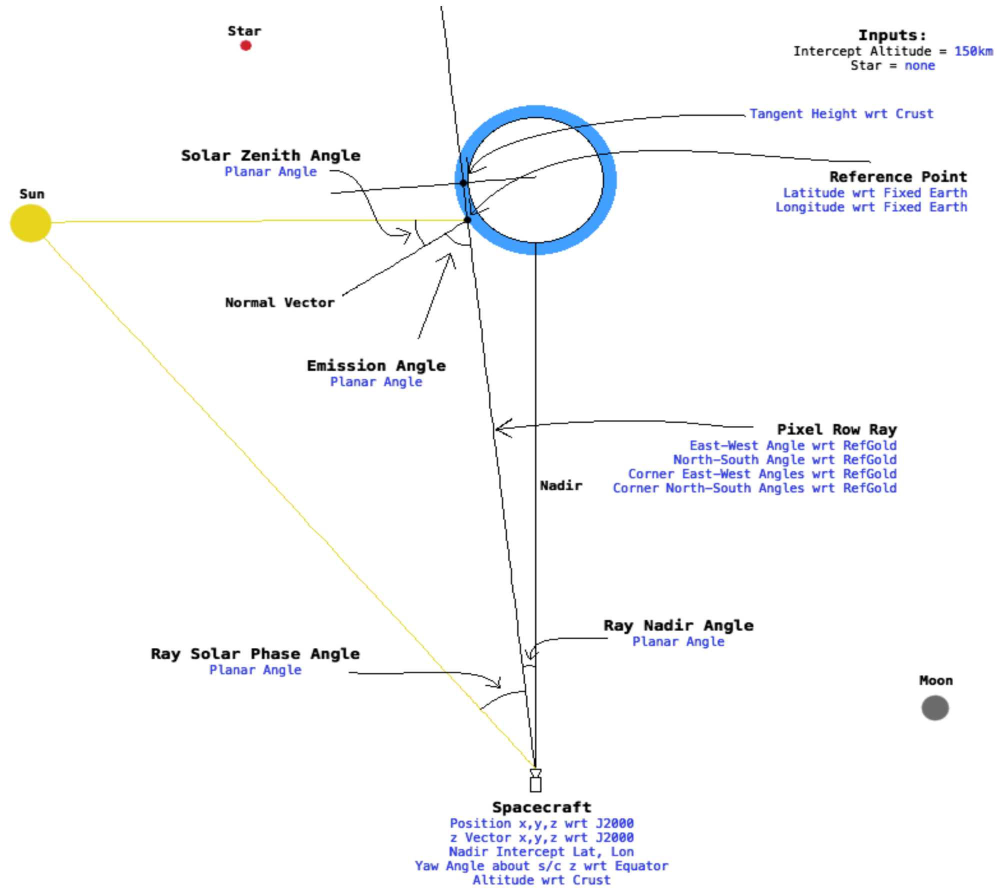

Figure 3-8 Geolocation for Day Disk Scan – Reference Altitude Ray Intercept

3.2.2.2 Ray Miss Definitions

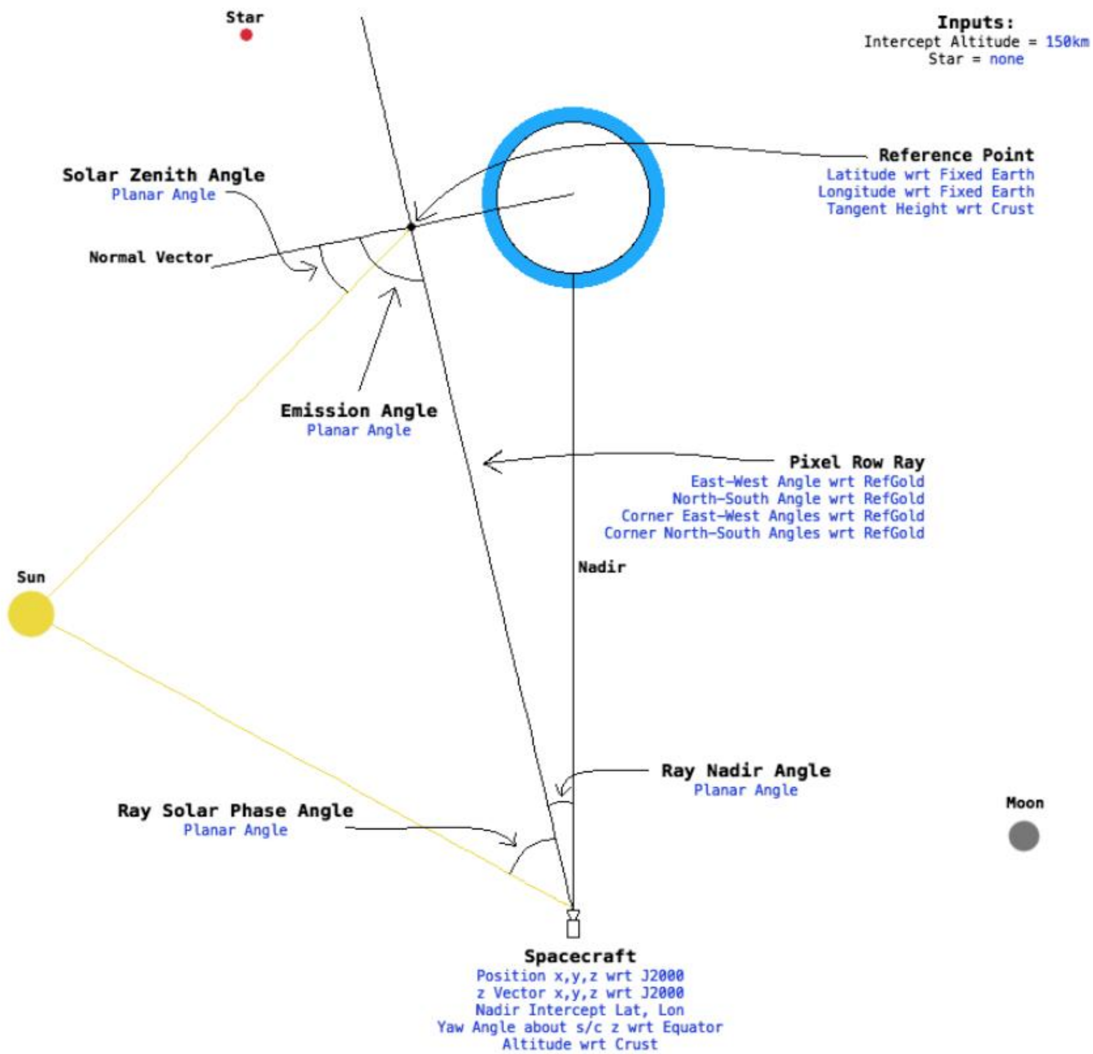

Figure 3-9 Geolocation for Day Disk Scan – Ray Miss

3.2.3 Level 1C Data File Structures

The Level 1C Day Disk data is sampled on a uniform satellite look angle grid of 0.2° in both the Longitude and Latitude directions. The data is resampled as follows:

- About 4 scan mirror positions to fill the 0.2° L1C bin.
- Image displacement per scan mirror step: 0.0494°
- Narrow slit width: 0.075°
- Use center of L1B and L1C bins to resample (nearest neighbor)

- Spectral data is combined within a L1C bin WITHOUT doing any wavelength alignment for each L1B sample
- 92 bins E-W
- 104 bins N-S

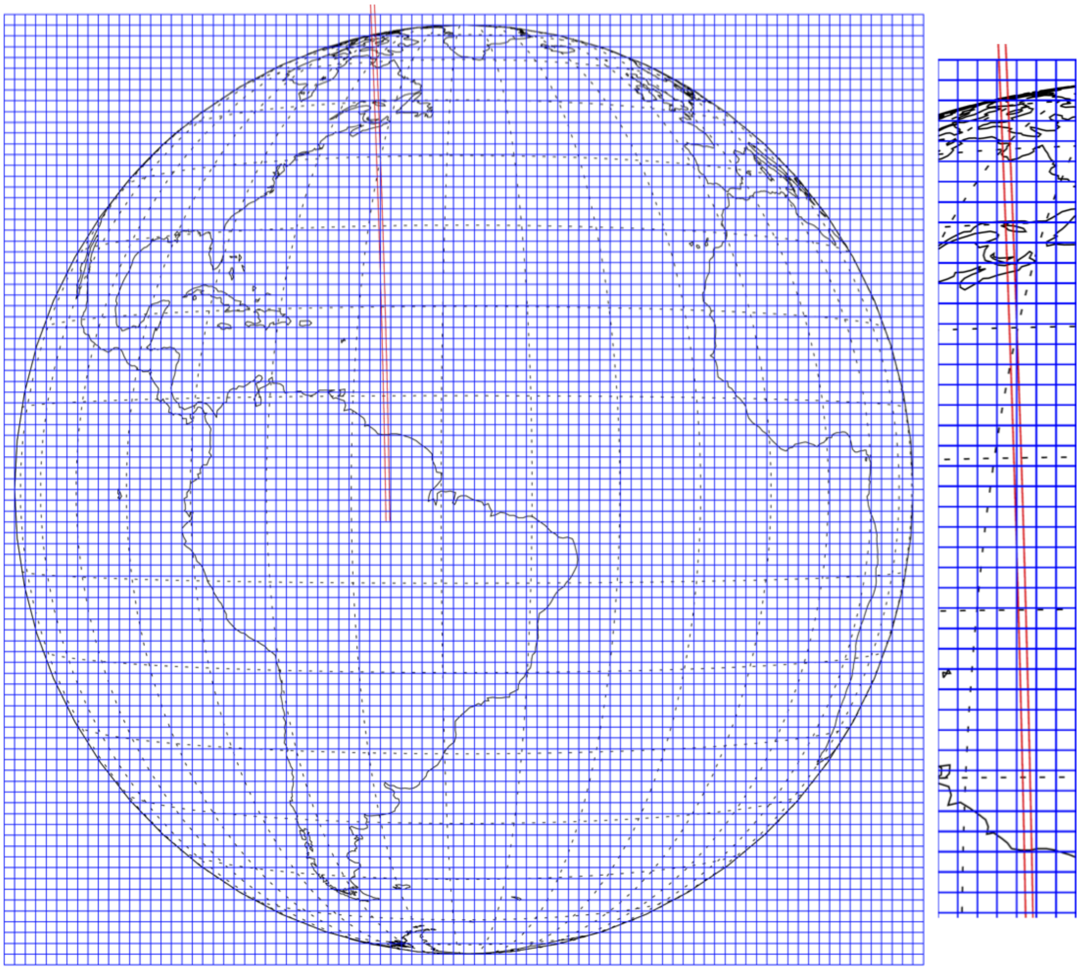

Figure 3-10 Level 1C Bins

3.2.3.1 Level 1C Day Data File Contents

Variable Name	Units	Type/Dim	Description
Grid_EW	Degrees	Float/92	The East/West grid values.
Grid_NS	Degrees	Float/104	The North/South grid values.
Grid_LAT	Degrees	Float/104x92	The fixed L1C pixel center latitude location.
Grid_LON	Degrees	Float/104x92	The fixed L1C pixel center longitude location.
Time_ET	seconds	Double/104x92	TDB seconds from January 1, 2000, 11:58:55.816 UTC at start of L1B time bin
Time_UTC	date/time	Char/104x92x24	UTC date/time string: "2017-06-21T23:46:38.015Z"

Variable Name	Units	Type/Dim	Description
L1b_Time_Bins_Per_Grid	count	int/104x92	The number of L1B dwells in each L1C pixel.
L1b_Pixels_Per_Grid	count	int/104x92	The number of L1B pixels in each L1C pixel.
Quality_FLAG		uint64/104x92	Per pixel quality flags
Wavelength	nm	Float/104x92x800	The wavelengths at each row
Raw_Count	counts	Float/104x92x800	The co-added raw count data.
Raw_Count_Random_Unc	counts	Float/104x92x800	The random uncertainty of the raw counts.
Corrected_Count	counts	Float/104x92x800	The co-added corrected counts
Corrected_Count_Systematic_Unc	counts	Float/104x92x800	Systematic uncertainty of the corrected counts.
Corrected_Count_Random_Unc	counts	Float/104x92x800	Random uncertainty of the corrected counts.
Radiance	Rayleighs/nm	Float/104x92x800	The spectral radiance at each grid position.
Radiance_Systematic_Unc	Rayleighs/nm	Float/104x92x800	The spectral radiance systematic uncertainty.
Radiance_Random_Unc	Rayleighs/nm	Float/104x92x800	The spectral radiance random uncertainty.
Background_Counts	counts	Float/104x92x800	The background counts subtracted in the background correction.
Reference_Point_Lat	Degrees	Float/104x92	Latitude of the reference point.
Reference_Point_Lon	Degrees	Float/104x92	Longitude of the reference point.
Tangent_Height	Km	Float/104x92	The tangent height of the pixel center ray from the Earth's crust.
Ray_Solar_Phase_Angle	Degrees	Float/104x92	The planar angle between the pixel ray from center and the sun direction.
Ray_Nadir_Angle	Degrees	Float/104x92	The planar angle between the pixel ray from center and the spacecraft nadir.
Emission_Angle	Degrees	Float/104x92	The planar angle between the pixel ray from center and the normal to the reference point.
Solar_Zenith_Angle	Degrees	Float/104x92	The planar angle between the sun direction to the reference point and the normal to the reference point.

Table 3-1 Level 1C Day Disk File Content

3.2.3.2 Level 1C Day MetaData

Variable Name	Default value
ADID_Ref	NASA Contract > NNG12PQ28C
Conventions	SPDF ISTP/IACF Modified for NetCDF
Data_Level	L1C
Data_Type	APIDx0F > GOLD Application ID 0x0F: Level 1C Day Disk Science Data
Observation_Type	DAY
OBS_TYPE	1

Variable Name	**Default value**
OBS_ID	4294967295UL
Channel_ID	1
Data_Version	1
Data_Revision	1
Data_Cycle	1
TC_VER	1
GC_VER	1
OC_VER	1
Minimum_PHD	0
Maximum_PHD	255
Spatial_Binning	3
Spectral_Binning	2
Slit_Name	OCC | HI_RES | LO_RES | PINHOLE
GYM_Position	0
Mirror_Hemisphere	N or S
Reference_Altitude	150.0
SC_Ref_Altitude	35785.9
SC_Ref_Lon	-47.5
SC_Alt	0.0
SC_Alt_min_max	NaN, NaN
SC_Pos	0.0, 0.0, 0.0
SC_Pos_x_min_max	NaN, NaN
SC_Pos_y_min_max	NaN, NaN
SC_Pos_z_min_max	NaN, NaN
SC_Z_Dir	0.0, 0.0, 0.0
SC_Z_Dir_x_min_max	NaN, NaN
SC_Z_Dir_y_min_max	NaN, NaN
SC_Z_Dir_z_min_max	NaN, NaN
SC_Nadir_lat	0.0
SC_Nadir_lat_min_max	NaN, NaN
SC_Nadir_lon	0.0
SC_Nadir_lon_min_max	NaN, NaN
SC_Yaw	0.0
SC_Yaw_min_max	NaN, NaN
Date_Processed	2016-11-17 08:26:45.000Z

Variable Name	Default value
Date_Start	2016-11-17 08:26:45.000Z
Date_End	2016-11-17 08:26:45.000Z
Date_Start_ET	0.0
Description	GOLD L1C spectral radiance image in Rayleighs/nm
Descriptor	CHA > GOLD L1C spectral radiance image in Rayleighs/nm
Discipline	Space Physics > Ionospheric Science
File	GOLD_L1C_CHB_2016_016_18_45_v01.nc
File_Date	2016-11-17 08:26:45.000Z
Generated_By	GOLD SOC > GOLD L1C Processor v1.0.0
History	Version 1, Created by GOLD L1C Processor v1.0.0 on 2016-11-17 08:26:45.000Z.
HTTP_LINK	http://gold.cs.ucf.edu
Instrument	CHA
Instrument_Type	UV Imaging Spectrograph (Space)
Link_Text	All GOLD information and data can be found at the HTTP_LINK
Link_Title	GOLD Website
Logical_File_ID	GOLD_L1C_CHC_2016_016_18_45_v01_r01
Logical_Source	GOLD_L1C_CHC_2016_016_18_45
Logical_Source_Description	GOLD Channel-A L1C spectral radiance image in Rayleighs/nm
Mission_Group	Thermospheric and Ionospheric Investigations
PI_Affiliation	University of Colorado > LASP
PI_Name	Richard Eastes
Project	NASA > GOLD
Rules_of_Use	Public Data for Scientific Use
Software_Version	GOLD SOC > GOLD L1C Processor v1.0.0
Source_Name	GOLD > Global-scale Observations of the Limb and Disk (GOLD) Heliophysics Explorer mission of opportunity
Spacecraft_ID	SES > GOLD – 518
Text	The GOLD mission of opportunity flies an ultraviolet (UV) imaging spectrograph on a geostationary satellite to measure densities and temperatures in Earth's thermosphere and ionosphere and to understand the global-scale response to forcing in the integrate Sun-Earth system. Visit \'http://www.gold-mission.org/\' for more details.
Time_Resolution	Fixed with integration time at each Scan Mirror Position
Title	GOLD Level 1C spectral radiance image in Rayleighs/nm
_Format	netCDF-4

Table 3-2 Level 1C Metadata

3.2.4 Level 1D Data File Structures

Level 1D files contain a thumbnail image (PNG) for individual disk scans. There are individual thumbnail files created for 1356 Angstrom (Atomic Oxygen), for total Lyman-Birge-Hopfield (LBH), and for Solar Zenith Angle (SZA). There is also a combined thumbnail image file created that contains 4 images: 1356 Angstrom, LBH Short (denoted LBH1), LBH Long (denoted LBH2), and SZA (see example shown below). Separate files are created for Channel A and Channel B data. A new L1D file is generated for each new L1C file. These correspond to either the Northern or Southern hemisphere.

Combined file definition (image size = 1024 x 1024 pixels)

- Header information (at the top of the set of 4 images)
    - Date of image
    - Time of image
    - File name
- 1356 brightness map (in Rayleighs) integrates the signal from 133 to 137 nm.
- LBH band 1 brightness map (in Rayleighs) integrates the signal from 140 to 148 nm.
- LBH band 2 brightness map (in Rayleighs) integrates the signal from 150 to 160 nm.
- SZA solar zenith angle map is at the reference altitude of 150 km.

Individual file definitions (image size = 512 x 512 pixels)

- 1356 brightness map (in Rayleighs) integrates the signal from 133 to 137 nm.
- Total LBH brightness map (in Rayleighs) integrates the signal from 137 to 155 nm with 148.5 to 150.0 nm masked.
- SZA solar zenith angle map is at the reference altitude of 150 km.

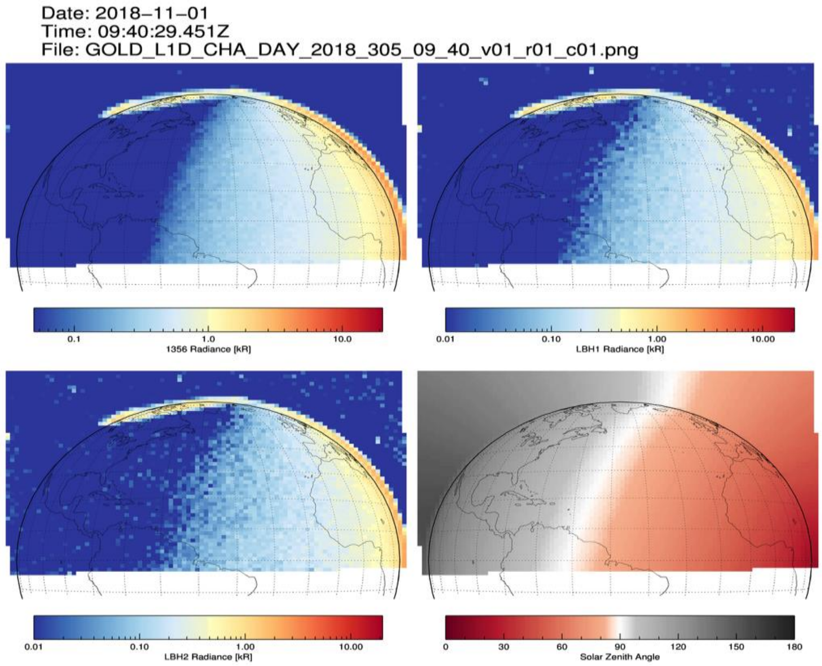

Figure 3-11 Example Level 1D Combined Day Disk File

3.3 Limb Scan Data Products

3.3.1 Limb Scan Observations

Following the disk observation (if an occultation observation is not available within the 30-minute block), Channel A scans both the north and south hemispheres of the dayside limb, as shown in Figure 3-12. The limb scans begin on the disk at a limb-height of -50 km at the equator and scan to a limb height of 430 km with a step size of 8 km at the equator and a cadence of 2.0 seconds per step with a total of 59 steps (for 60 positions). These two scans require a total of 6 minutes to complete. Detector dark counts are measured with the scan mirrors turned inward for 18 seconds, once per hemisphere, in order to monitor particle backgrounds. The entire sequence of dayside disk image and limb scan, without occultations, requires 30 minutes to execute.

Limb scans: 41650 km

-step time = 2 sec

-image motion = 8.0 km/step at nadir

-angular coverage = 486 km at limb

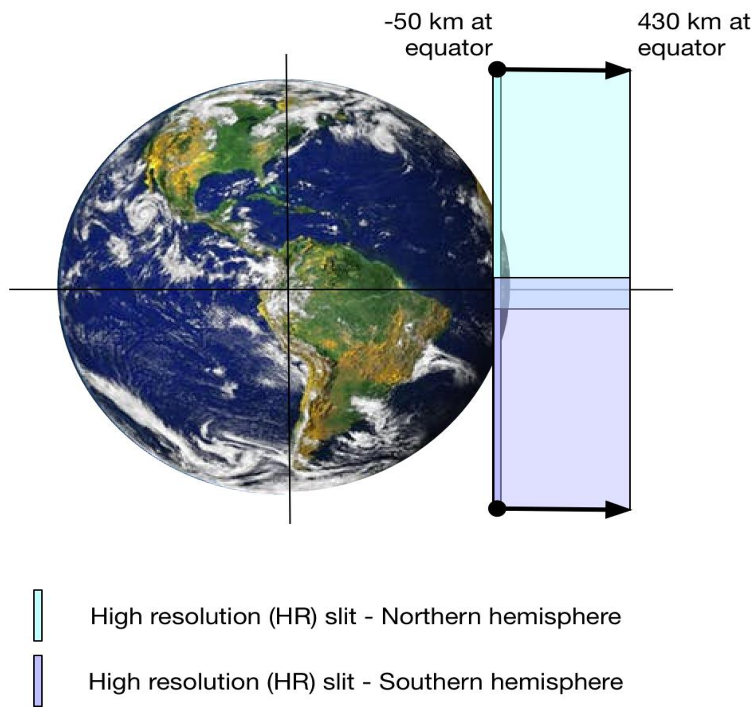

Figure 3-12 Limb Scan

3.3.2 Geo-location

The Earth's ellipsoid is defined by WGS 84, giving radius values 6378.1370 km in x/y and 6356.7523 km in z.

Limb Scans do not use a fixed reference altitude. The reference point is always the tangent point regardless of where the ray intercepts the earth/atmosphere.

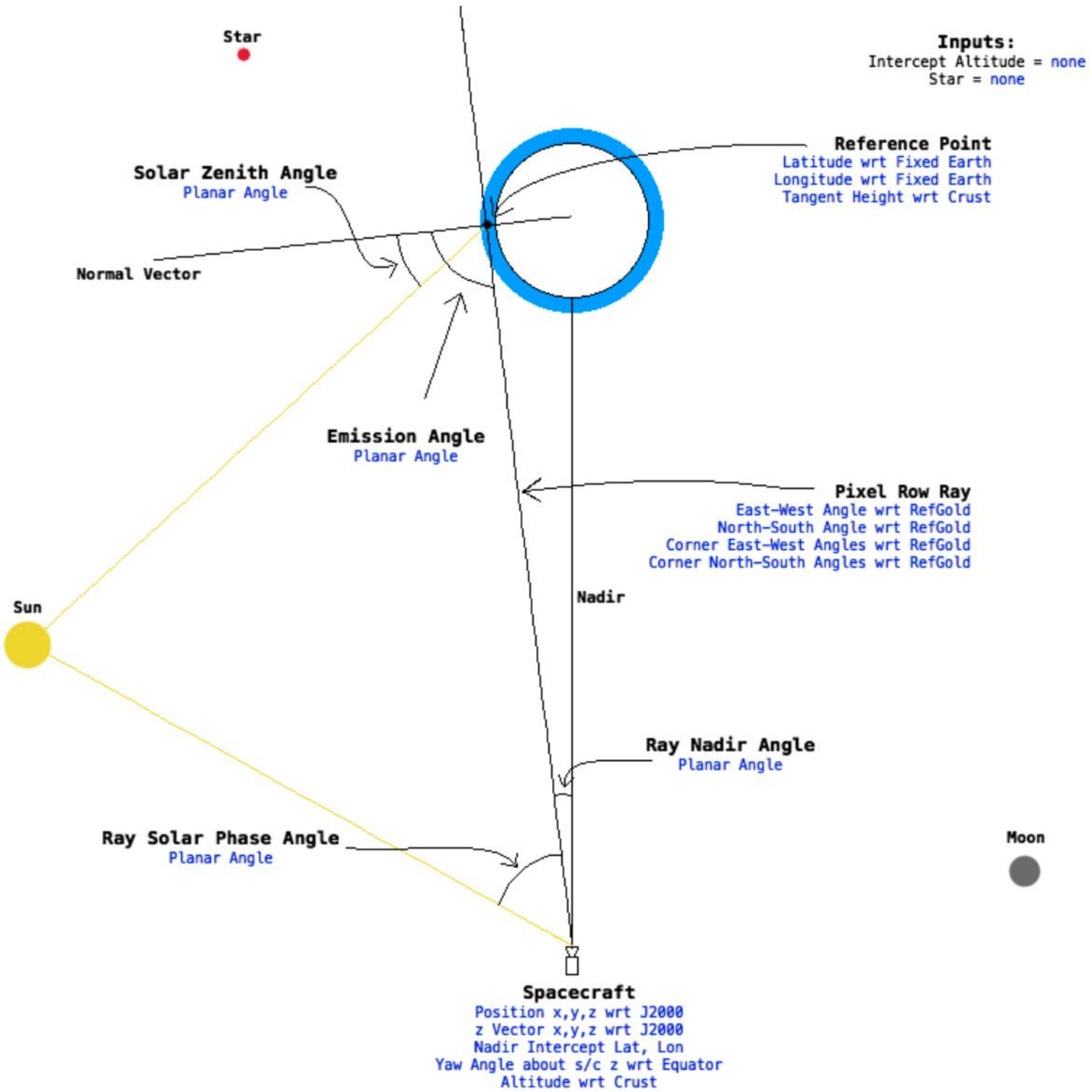

Figure 3-13 Geolocation for Limb Scan

3.3.3 Level 1C Data File Structures

The Level 1C Limb data is sampled on a radial grid of 1.25° in Latitude and 16 Km in tangent altitude from -44 Km to 435 Km above the surface. The data is resampled as follows:

- Image displacement per scan mirror step: 0.011°
- 2 scan mirror positions to cover the 16 Km at the equator for L1C bin.
- Narrow slit width: 0.075°

- Use center of L1B and L1C bins to resample (nearest neighbor)
- Spectral data is combined within a L1C bin WITHOUT doing any wavelength alignment for each L1B sample
- Going from -20 to +20 degree latitudes

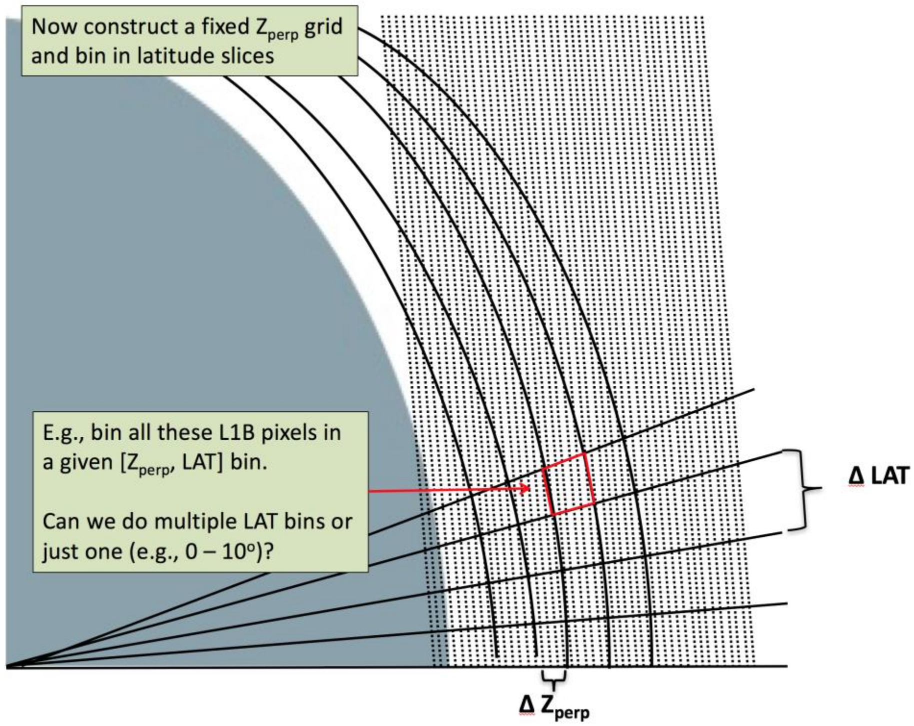

Figure 3-14 Grid for Limb Scan

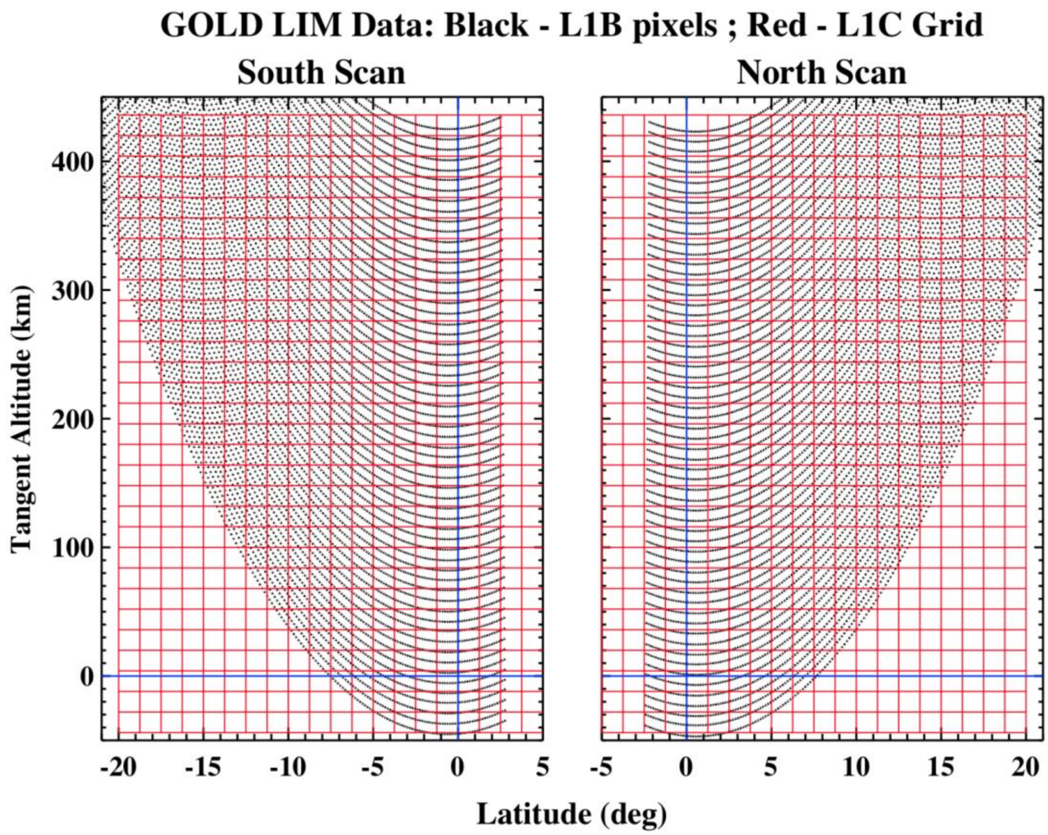

Figure 3-15 Fixed Grid for Limb Scan

3.3.3.1 Level 1C Limb Data File Contents

Variable Name	Units	Type/Dim	Description
Grid_ALT	Km	Float/30	The Tangent Height Altitude grid values.
Grid_LAT	Degrees	Float/32	The Radial Latitude grid values.
Time_ET	seconds	Double/32x30	Ephemeris Time seconds from January 1, 2000, 11:58:55.816 UTC at start of L1B time bin
Time_UTC	date/time UTC	Char/32x30x24	UTC date/time string: "2017-06-21T23:46:38.015Z"
L1b_Time_Bins_Per_Grid	count	int/32x30	The number of L1B dwells in each L1C pixel.
L1b_Pixels_Per_Grid	count	int/32x30	The number of L1B pixels in each L1C pixel.
Quality		uint64/32x30	The per pixel quality flags.
Wavelength	nm	Float/32x30x800	The wavelengths at each row
Raw_Count	counts	Float/32x30x800	The co-added raw count data.
Raw_Count_Random_Unc	counts	Float/32x30x800	The co-added raw count data random uncertainties
Corrected_Count	counts	Float/32x30x800	The co-added corrected count data.

Variable Name	Units	Type/Dim	Description
Corrected_Count_Systematic_Unc	counts	Float/32x30x800	The corrected count systematic uncertainty.
Corrected_Count_Random_Unc	counts	Float/32x30x800	The corrected count random uncertainty.
Radiance	Rayleighs/nm	Float/32x30x800	The Radiance data in Rayleighs/nm.
Radiance_Systematic_Unc	Rayleighs/nm	Float/32x30x800	The Radiance systematic uncertainties in Rayleighs/nm.
Radiance_Random_Unc	Rayleighs/nm	Float/32x30x800	The Radiance random uncertainties in Rayleighs/nm.
Background_Counts	counts	Float/32x30x800	The background counts subtracted in the background correction.
Reference_Point_Lat	Degrees	Float/32x30	Latitude of the reference point.
Reference_Point_Lon	Degrees	Float/32x30	Longitude of the reference point.
Tangent_Height	km	Float/32x30	The tangent height of the pixel center ray from the Earth's crust.
Ray_Solar_Phase_Angle	Degrees	Float/32x30	The planar angle between the pixel ray from center and the sun direction.
Ray_Nadir_Angle	Degrees	Float/32x30	The planar angle between the pixel ray from center and the spacecraft nadir.
Emission_Angle	Degrees	Float/32x30	The planar angle between the pixel ray from center and the normal to the reference point.
Solar_Zenith_Angle	Degrees	Float/32x30	The planar angle between the sun direction to the reference point and the normal to the reference point.

Table 3-3 Level 1C Limb File Content

3.3.3.2 Level 1C Limb MetaData

Variable Name	Default value
ADID_Ref	NASA Contract > NNG12PQ28C
Conventions	SPDF ISTP/IACF Modified for NetCDF
Data_Level	L1C
Data_Type	APIDx0F > GOLD Application ID 0x0F: Level 1C Limb Science Data
Observation_Type	LIM
OBS_TYPE	2
OBS_ID	0
Channel_ID	1
Data_Version	1
Data_Revision	1
Data_Cycle	1
TC_VER	1
GC_VER	1

Variable Name	**Default value**
OC_VER	1
Minimum_PHD	0
Maximum_PHD	255
Spatial_Binning	3
Spectral_Binning	2
Slit_Position	OCC | HI_RES | LO_RES | PINHOLE
GYM_Position	0
Mirror_Hemisphere	N or S
Limb	“EAST or WEST”
Reference_Altitude	-1.0
SC_Ref_Altitude	35785.9
SC_Ref_Lon	-47.5
SC_Alt	0.0
SC_Alt_min_max	NaN, NaN
SC_Pos	0.0, 0.0, 0.0
SC_Pos_x_min_max	NaN, NaN
SC_Pos_y_min_max	NaN, NaN
SC_Pos_z_min_max	NaN, NaN
SC_Z_Dir	0.0, 0.0, 0.0
SC_Z_Dir_x_min_max	NaN, NaN
SC_Z_Dir_y_min_max	NaN, NaN
SC_Z_Dir_z_min_max	NaN, NaN
SC_Nadir_lat	0.0
SC_Nadir_lat_min_max	NaN, NaN
SC_Nadir_lon	0.0
SC_Nadir_lon_min_max	NaN, NaN
SC_Yaw	0.0
SC_Yaw_min_max	NaN, NaN
Date_Processed	2016-11-17 08:26:45.000Z
Date_Start	2016-11-17 08:26:45.000Z
Date_End	2016-11-17 08:26:45.000Z
Date_Start_ET	0.0
Description	GOLD L1C spectral radiance image in Rayleighs/nm
Descriptor	CHA > GOLD L1C spectral radiance image in Rayleighs/nm
Discipline	Space Physics > Ionospheric Science

Variable Name	Default value
File	GOLD_L1C_CHB_2016_016_18_45_v01.nc
File_Date	2016-11-17 08:26:45.000Z
Generated_By	GOLD SOC > GOLD L1C Processor v1.0.0
History	Version 1, Created by GOLD L1C Processor v1.0.0 on 2016-11-17 08:26:45.000Z.
HTTP_LINK	http://gold.cs.ucf.edu
Instrument	CHA
Instrument_Type	UV Imaging Spectrograph (Space)
Link_Text	All GOLD information and data can be found at the HTTP_LINK
Link_Title	GOLD Website
Logical_File_ID	GOLD_L1C_CHC_2016_016_18_45_v01_r01
Logical_Source	GOLD_L1C_CHC_2016_016_18_45
Logical_Source_Description	GOLD Channel-A L1C spectral radiance image in Rayleighs/nm
Mission_Group	Thermospheric and Ionospheric Investigations
MODS	Version 1, Created by GOLD L1C Processor v1.0.0 on 2016-11-17 08:26:45.000Z.
Parents	
PI_Affiliation	University of Colorado > LASP
PI_Name	Richard Eastes
Project	NASA > GOLD
Rules_of_Use	Public Data for Scientific Use
Software_Version	GOLD SOC > GOLD L1C Processor v1.0.0
Source_Name	GOLD > Global-scale Observations of the Limb and Disk (GOLD) Heliophysics Explorer mission of opportunity
Spacecraft_ID	SES > GOLD – 518
Text	The GOLD mission of opportunity flies an ultraviolet (UV) imaging spectrograph on a geostationary satellite to measure densities and temperatures in Earth's thermosphere and ionosphere and to understand the global-scale response to forcing in the integrate Sun-Earth system. Visit \'http://www.gold-mission.org/\' for more details.
Time_Resolution	Fixed with integration time at each Scan Mirror Position
Title	GOLD Level 1C spectral radiance image in Rayleighs/nm
_Format	netCDF-4

Table 3-4 Level 1C Limb Metadata

3.3.4 Level 1D Data File Structures

Level 1D files contain a thumbnail image (PNG) for individual limb scans. There are individual thumbnail files created for 1356 Angstrom (Atomic Oxygen), for total Lyman-Birge-Hopfield (LBH), stack of 8 slices for different latitudes of brightness as a function of wavelength and tangent altitude, and a single line plot with brightness of 1356, LBH Short (denoted LBH1), and LBH Long (denoted LBH2) as a function of tangent altitude. There is also a combined thumbnail image file created that contains 4 images: 1356 Angstrom (Atomic Oxygen), total Lyman-Birge-Hopfield (LBH), stack of 8 slices for different latitudes of brightness as a function of wavelength and tangent altitude, and a single line plot with brightness of 1356, LBH Short (denoted LBH1), and LBH Long (denoted LBH2) as a function of tangent altitude (see example shown below). Separate files are created for Channel A and Channel B data. A new L1D file is generated for each new L1C file. These correspond to either the Northern or Southern hemisphere.

Combined file definition (image size = 1024 x 1024 pixels)

- Header information (at the top of the set of 4 images)
  - Date of image
  - Time of image
  - File name
  - Mean Solar Zenith Angle (SZA)
- 1356 brightness map (in Rayleighs) integrates the signal from 133 to 137 nm.
- Total LBH brightness map (in Rayleighs) integrates the signal from 137 to 155 nm with 148.5 to 150.0 nm masked.
- Single line plot of the lowest latitude brightness in (kilo-Rayleighs) as a function of tangent altitude (in kilometers) with the following 3 lines
  - 1356 from 133 to 137 nm.
  - LBH band 1 from 140 to 148 nm.
  - LBH band 2 from 150 to 160 nm.
- Stack of 8 slices for different latitudes of intensity as a function of wavelength and altitude
  - Use the 8 latitudes that correspond to the scan hemisphere (since there are 16 latitudes per hemisphere, 2 latitude bins are co-added to get to 8 latitudes)
  - Latitudes are +/- [0.625, 1.875, 3.125, 4.375, 5.625, 6.875, 8.125, 9.375]

Individual file definitions (image size = 512 x 512 pixels)

- 1356 brightness map (in Rayleighs) integrates the signal from 133 to 137 nm.
- Total LBH brightness map (in Rayleighs) integrates the signal from 137 to 155 nm with 148.5 to 150.0 nm masked.

- Single line plot of the lowest latitude brightness in (kilo-Rayleighs) as a function of tangent altitude (in kilometers) with the following 3 lines
  - 1356 from 133 to 137 nm.
  - LBH band 1 from 140 to 148 nm.
  - LBH band 2 from 150 to 160 nm.
- Stack of 8 slices for different latitudes of intensity as a function of wavelength and altitude
  - Use the 8 latitudes that correspond to the scan hemisphere (since there are 16 latitudes per hemisphere, 2 latitude bins are co-added to get to 8 latitudes)
  - Latitudes are +/- [0.625, 1.875, 3.125, 4.375, 5.625, 6.875, 8.125, 9.375]

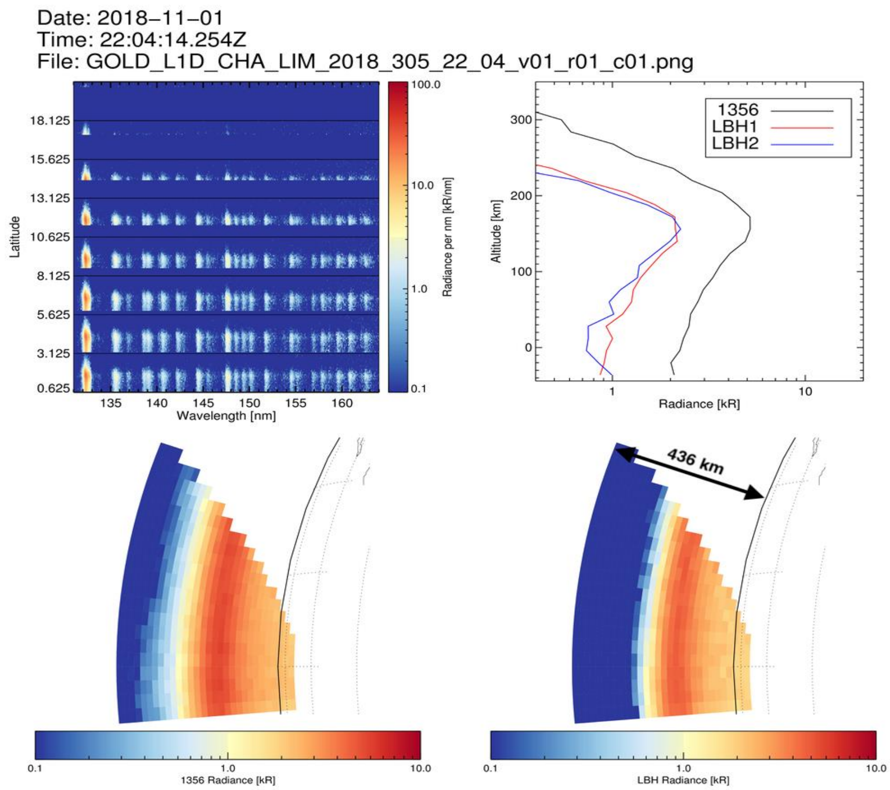

Figure 3-16 Example Level 1D Combined Limb File

3.4 Night Disk Scan Data Products

3.4.1 Night Disk Scan Observations

Night disk scans may be performed independently on each channel (CHA and CHB).

For the Night Disk Scan, each channel may use the low resolution slit (observation type = NI1) or the occultation slit (observation type = NI2). Each swath requires 15 minutes to complete including setup using a variable number of steps and variable step time, depending on time of day and day of year.

Night Disk scans - Low Resolution Slit: 35786 km

-step time = variable (increments of 2 sec)

-image motion = 92.73 km/step at nadir

-angular coverage = variable

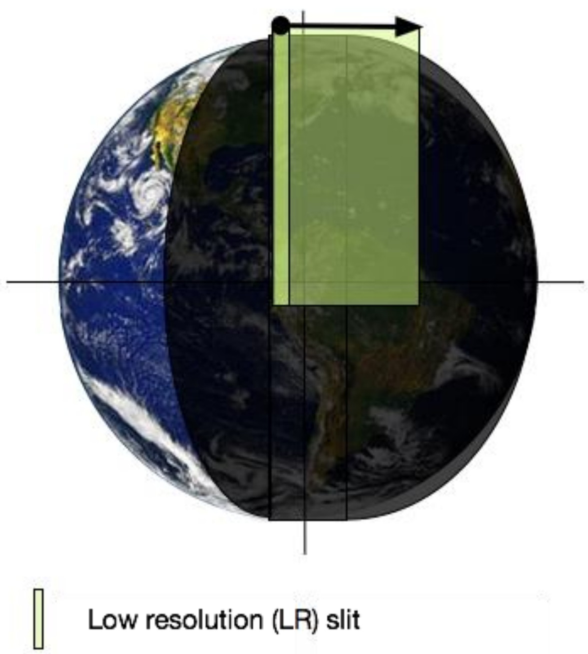

Figure 3-17 Night Disk Scan - Low Resolution Slit (NI1)

3.4.2 Geo-location

The Earth's ellipsoid is defined by WGS 84, giving the values of radius in x/y is 6378.1370 km and radius in z is 6356.7523 km.

Night Disk Scans use a fixed reference altitude of 300 km.

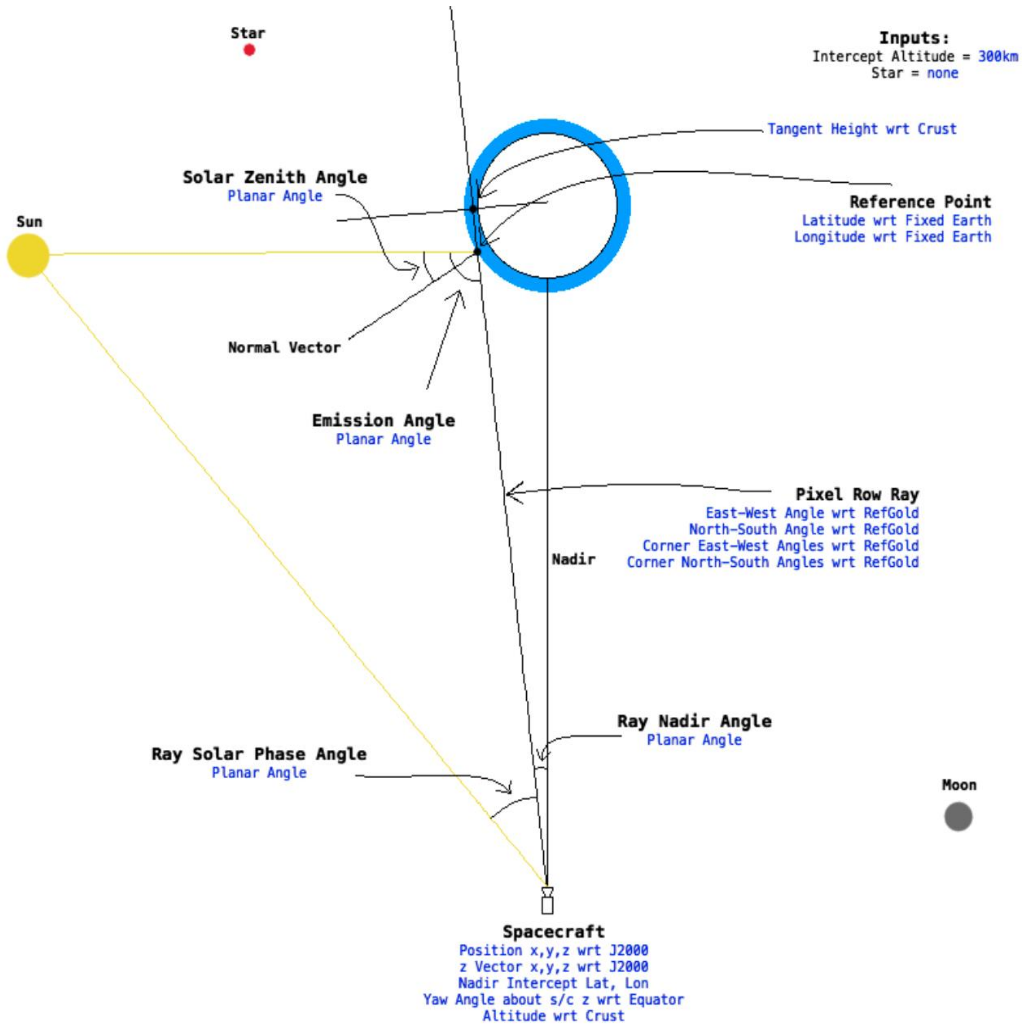

Figure 3-18 Geolocation for Night Disk Scans

3.4.3 Level 1C Data File Structures

3.4.3.1 Level 1C Night Disk File Contents

Variable Name	Units	Type/Dim	Description
Grid_EW	Degrees	Float/n_ns x n_ew	The East/West grid values.
Grid_NS	Degrees	Float/n_ns x n_ew	The North/South grid values.
Time_ET	seconds	Double/n_ew	TDB seconds from January 1, 2000, 11:58:55.816 UTC at start of L1B time bin
Time_UTC	date/time	Char/n_ew x 24	The date/time string
Wavelength	nm	Float/n_ns x n_ew x 800	The wavelengths at each row

Variable Name	**Units**	**Type/Dim**	**Description**
L1b_Time_Bins_Per_Grid	counts	int/n_ns x n_ew	The number of l1b dwells in each grid.
L1b_Pixels_Per_Grid	counts	int/n_ns x n_ew	The number of l1b pixels in each grid.
Quality_Flag		int64/n_ew	
Reference_Point_Lat	Degrees	Float/n_ns x n_ew	Latitude of the reference point.
Reference_Point_Lon	Degrees	Float/n_ns x n_ew	Longitude of the reference point.
Tangent_Height	Km	Float/n_ns x n_ew	The tangent height of the pixel center ray from the Earth's crust.
Ray_Solar_Phase_Angle	Degrees	Float/n_ns x n_ew	The planar angle between the pixel ray from center and the sun direction.
Ray_Nadir_Angle	Degrees	Float/n_ns x n_ew	The planar angle between the pixel ray from center and the spacecraft nadir.
Emission_Angle	Degrees	Float/n_ns x n_ew	The planar angle between the pixel ray from center and the normal to the reference point.
Solar_Zenith_Angle	Degrees	Float/n_ns x n_ew	The planar angle between the sun direction to the reference point and the normal to the reference point.
Raw_Count	counts	Float/n_ns x n_ew x 800	The co-added raw count data.
Raw_Count_Random_unc	counts	Float/n_ns x n_ew x 800	The random uncertainty of the raw counts.
Corrected_Count	counts	Float/n_ns x n_ew x 800	Corrected counts
Corrected_Count_Systematic_Unc	counts	Float/n_ns x n_ew x 800	Corrected counts systematic uncertainty
Corrected_Count_Random_Unc	counts	Float/n_ns x n_ew x 800	Corrected counts random uncertainty
Radiance	Rayleighs/ nm	Float/n_ns x n_ew x 800	The spectral radiance at each grid position.
Radiance_Systematic_Unc	Rayleighs/ nm	Float/n_ns x n_ew x 800	
Radiance_Random_Unc	Rayleighs/ nm	Float/n_ns x n_ew x 800	
Background_Counts	counts	Float/600 x 800	The background counts subtracted in the background correction.

Table 3-5 Level 1C Night Disk Scan File Content

3.4.3.2 Level 1C Night Disk Metadata

Variable Name	**Default value**
ADID_Ref	NASA Contract > NNG12PQ28C
Conventions	SPDF ISTP/IACF Modified for NetCDF
Data_Level	L1C

Variable Name	Default value
Data_Type	APIDx0F > GOLD Application ID 0x0F: Level 1C Night Disk Science Data
Observation_Type	NI1
OBS_TYPE	8
OBS_ID	0
Channel_ID	1
Data_Version	1
Data_Revision	1
Data_Cycle	1
TC_VER	1
GC_VER	1
OC_VER	1
Minimum_PHD	0
Maximum_PHD	255
Spatial_Binning	3
Spectral_Binning	2
Slit_Name	OCC | HI_RES | LO_RES | PINHOLE
GYM_Position	0
Mirror_Hemisphere	N or S
Reference_Altitude	300.0
SC_Ref_Altitude	35785.9
SC_Ref_Lon	-47.5
SC_Ref_Lat	0.0
SC_Alt	0.0
SC_Alt_min_max	NaN, NaN
SC_Pos	0.0, 0.0, 0.0
SC_Pos_x_min_max	NaN, NaN
SC_Pos_y_min_max	NaN, NaN
SC_Pos_z_min_max	NaN, NaN
SC_Z_Dir	0.0, 0.0, 0.0
SC_Z_Dir_x_min_max	NaN, NaN
SC_Z_Dir_y_min_max	NaN, NaN
SC_Z_Dir_z_min_max	NaN, NaN
SC_Nadir_lat	0.0
SC_Nadir_lat_min_max	NaN, NaN
SC_Nadir_lon	0.0

Variable Name	Default value
SC_Nadir_lon_min_max	NaN, NaN
SC_Yaw	0.0
SC_Yaw_min_max	NaN, NaN
Date_Processed	2016-11-17 08:26:45.000Z
Date_Start	2016-11-17 08:26:45.000Z
Date_End	2016-11-17 08:26:45.000Z
Date_Start_ET	0.0
Description	GOLD L1C spectral radiance image in Rayleighs/nm
Descriptor	CHA > GOLD L1C spectral radiance image in Rayleighs/nm
Discipline	Space Physics > Ionospheric Science
File	GOLD_L1C_CHB_2016_016_18_45_v01.nc
File_Date	2016-11-17 08:26:45.000Z
Generated_By	GOLD SOC > GOLD L1C Processor v1.0.0
History	Version 1, Created by GOLD L1C Processor v1.0.0 on 2016-11-17 08:26:45.000Z.
HTTP_LINK	http://gold.cs.ucf.edu
Instrument	CHA
Instrument_Type	UV Imaging Spectrograph (Space)
Link_Text	All GOLD information and data can be found at the HTTP_LINK
Link_Title	GOLD Website
Logical_File_ID	
Logical_Source	
Logical_Source_Description	GOLD Channel-A L1C spectral radiance image in Rayleighs/nm
Mission_Group	Thermospheric and Ionospheric Investigations
MODS	Version 1, Created by GOLD L1C Processor v1.0.0 on 2016-11-17 08:26:45.000Z.
Parents	
PI_Affiliation	University of Colorado > LASP
PI_Name	Richard Eastes
Project	NASA > GOLD
Rules_of_Use	Public Data for Scientific Use
Software_Version	GOLD SOC > GOLD L1C Processor v1.0.0
Source_Name	GOLD > Global-scale Observations of the Limb and Disk (GOLD) Heliophysics Explorer mission of opportunity
Spacecraft_ID	SES > GOLD – 518
Text	The GOLD mission of opportunity flies an ultraviolet (UV) imaging spectrograph on a geostationary satellite to measure densities and temperatures in Earth's thermosphere and ionosphere and to understand the global-scale response to forcing in the integrate Sun-Earth system. Visit \'http://www.gold-mission.org/\' for more details.

Variable Name	Default value
Time_Resolution	Variable width integration time at each Scan Mirror Position
Title	GOLD Level 1C spectral radiance image in Rayleighs/nm
Format	netCDF-4

Table 3-6 Level 1C Night Disk Scan Metadata

3.4.4 Level 1D Data File Structures

Level 1D files contain a thumbnail image (PNG) for individual night scans. There are individual thumbnail files created for 1356 Angstrom (Atomic Oxygen), for total Lyman-Birge-Hopfield (LBH), and for Solar Zenith Angle (SZA). There is also a combined thumbnail image file created that contains 3 images: 1356 Angstrom, Total LBH, and SZA (see example shown below). Separate files are created for Channel A and Channel B data. A new L1D file is generated for each new L1C file. These correspond to either the Northern or Southern hemisphere.

Combined file definition (image size = 1024 x 1024 pixels)

- Header information (at the top of the set of 3 images)
  - Date of image
  - Time of image
  - File name
- 1356 brightness map (in Rayleighs) integrates the signal from 133 to 137 nm.
- Total LBH brightness map (in Rayleighs) integrates the signal from 137 to 155 nm with 148.5 to 150.0 nm masked.
- SZA solar zenith angle map is at the reference altitude of 150 km.

Individual file definitions (image size = 512 x 512 pixels)

- 1356 brightness map (in Rayleighs) integrates the signal from 133 to 137 nm.
- Total LBH brightness map (in Rayleighs) integrates the signal from 137 to 155 nm with 148.5 to 150.0 nm masked.
- SZA solar zenith angle map is at the reference altitude of 150 km.

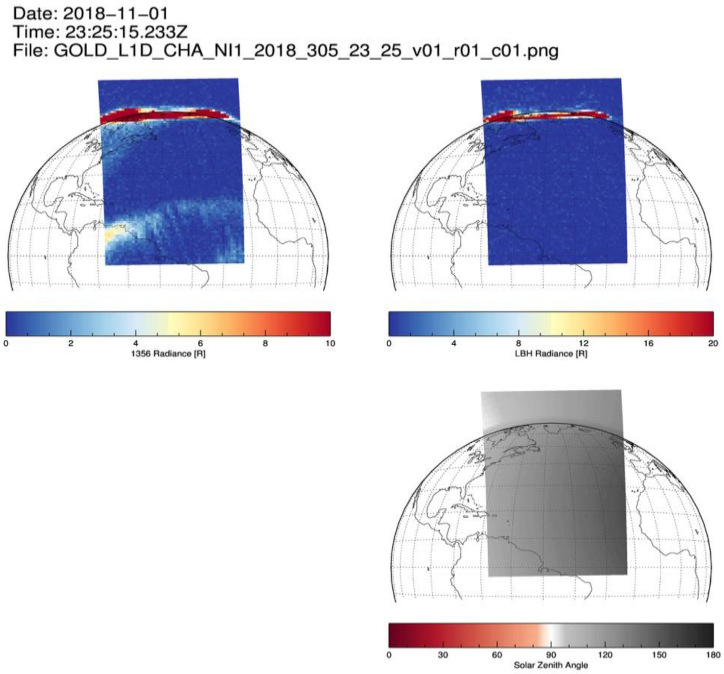

Figure 3-19 Example Level 1D Combined Night 1 File

3.5 Stellar Occultation Data Products

3.5.1 Stellar Occultation Observations

Dayside Disk Images are interrupted via stored instrument commands when target stars suitable for occultation measurements approach either limb, as shown in Figure 3-20. To perform the occultation measurement, the slit mechanism inserts the 1˚ wide occultation (OCC) slit at the spectrometer focal plane, and the scan mirrors slew the Field of View to the star. The mirror is centered at a 225 km tangent point altitude. Occultations require 6 minutes to execute (30 seconds to configure the instrument, 30 seconds for uncertainty in timing and pointing, 4 minutes for the actual occultation, 30 seconds for uncertainty in timing and pointing, and 30 seconds to return to HR slit). Once the occultation is complete, the HR slit is inserted, the scan mirror returns to its departure point in the original mapping observation, and Dayside Disk Image is resumed. By choice GOLD is limited to performing ~10 occultations a day for most of the year, reducing the dayside mapping duty cycle by ~5%.

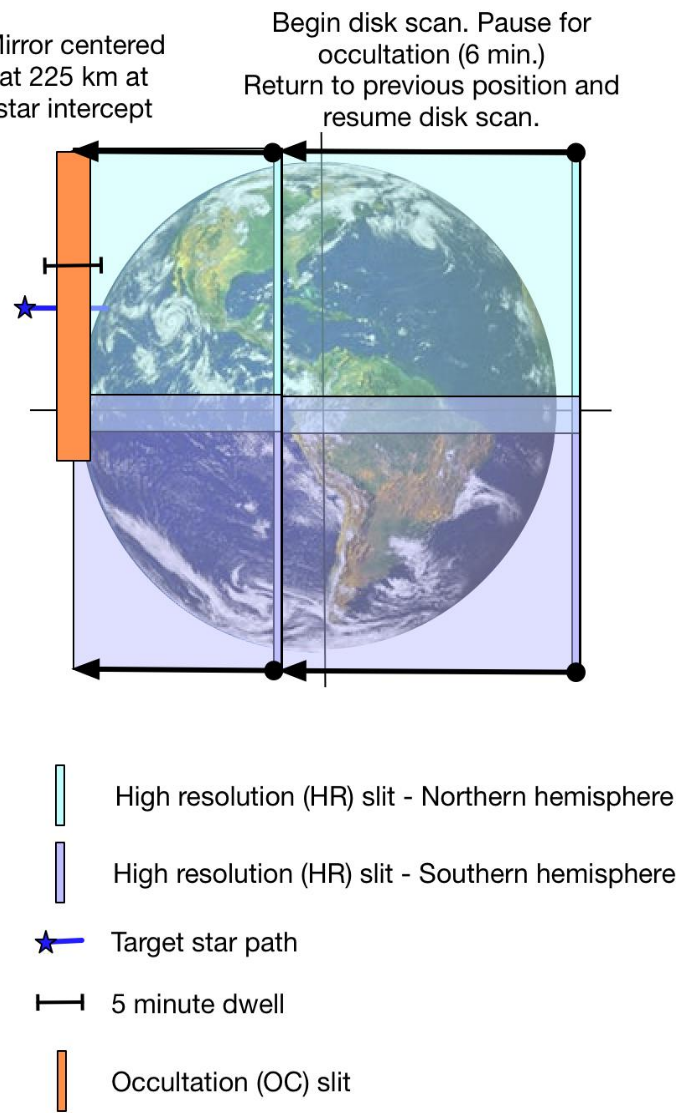

Figure 3-20 Occultation Observation

3.5.2 Level 1B Corrections

The L1B Occultation data is processed the same way as the DAY disk data except that it is not binned.

3.5.3 Geo-location

The Earth's ellipsoid is defined by WGS 84, giving the values of radius in x/y is 6378.1370 km and radius in z is 6356.7523 km. Stellar Occultations do not use a fixed reference altitude (uses surface).

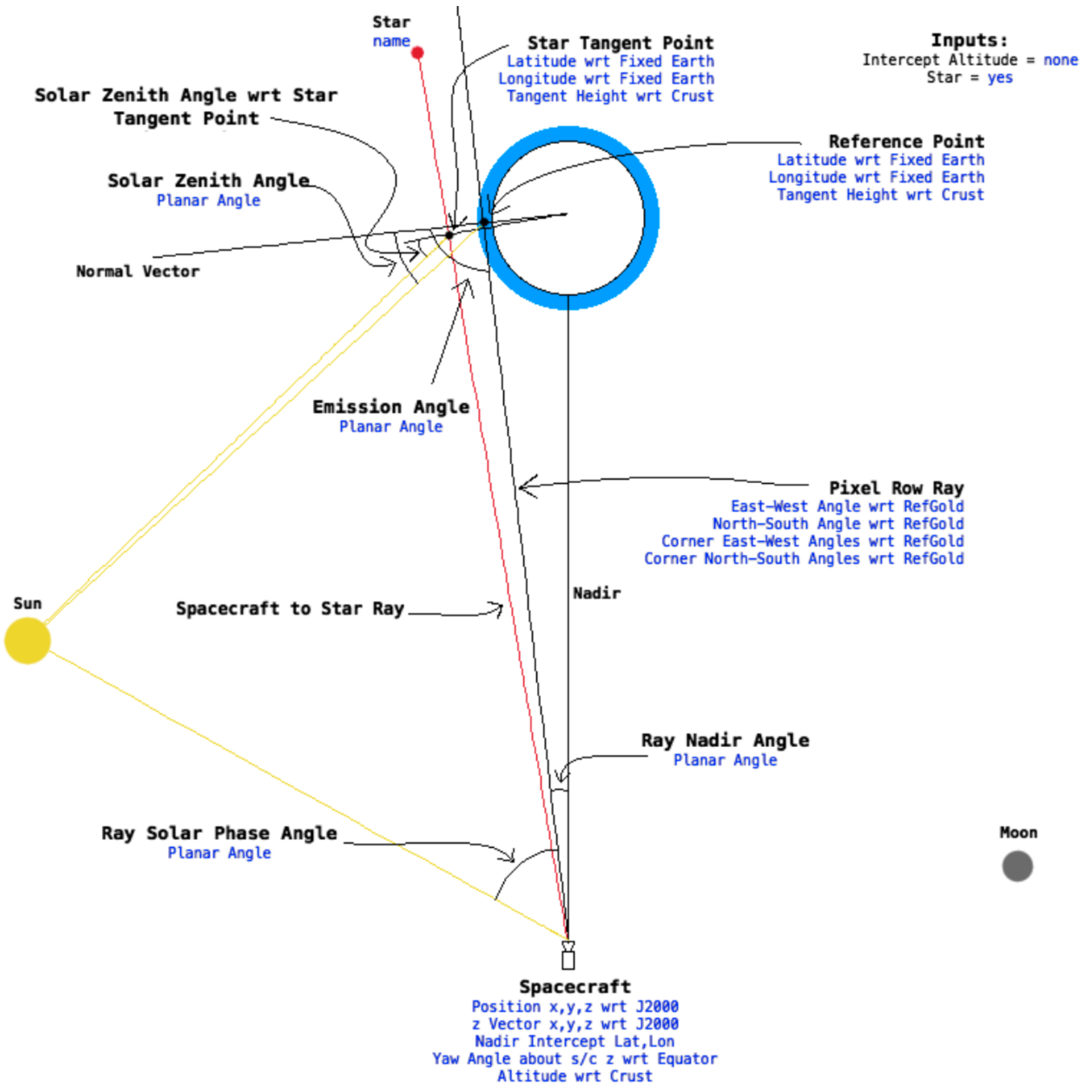

Figure 3-21 Geolocation for Stellar Occultations

3.5.4 Level 1C Wavelength Determination

As the star moves across the occultation slit, the light path through the instrument changes, and therefore the wavelength component of the spectrum moves relative to the detector. This means that the wavelength registration needs to be calculated for each time step in the L1C file. This is done by using the wavelength solution for the high resolution slit at the time when the light from the star is passing through the instrument as if the high res slit was being used. This gives us the wavelength solution at one time. To calculate the wavelengths at other times, we can calculate the shift in wavelength due to the light from the star entering the occultation slit at different positions.

One thing to note. The wavelength returned is purely a function of the star and so the solution is not applicable when the star is outside the view of the occultation slit. For the time steps outside of the occultation slit, the default high resolution slit wavelength solution is used. This can add an unrealistic discontinuity in the wavelength data. This is intentional until a better approach is agreed on.

3.5.5 Level 1C Background Subtraction

The background subtraction for occultations includes the removal of any airglow from the limb. This is particularly important on day side occultations. The wavelength dependent background is found by using a small portion of the data when the star is obscured by the limb. This reference background spectrum is then adjusted as the background varies in time. For night side occultations (solar zenith angle greater than 110 degrees) a linear fit is used to determine the reference background. This is done because the background counts during night side occultations are too low to make reliable fits with higher wavelength resolution.

3.5.6 Level 1C Data File Structures

3.5.6.1 Level 1C Stellar Occultation File Contents

Variable Name	Units	Type/Dim	Description
Time_ET	seconds	Double/980	Ephemeris Time seconds from January 1, 2000, 11:58:55.816 UTC at start of L1B time bin
Time_UTC	date/time UTC	Char/980x24	UTC date/time string: "2017-06-21T23:46:38.015Z"
L1b_Time_Bins_Per_Grid	count	int/980	The number of L1B dwells in each L1C pixel.
L1b_Pixels_Per_Grid	count	int/980	The number of L1B pixels in each L1C pixel.
Quality_Flag		uint64/980	The per pixel quality flags.
Wavelength	nm	Float/980x266	The wavelengths at each row
Raw_Count	counts	Float/980x266	The co-added raw count data.
Raw_Count_Random_Unc	counts	Float/980x266	The co-added raw count data random uncertainties
Corrected_Count	counts	Float/980x266	
Corrected_Count_Systematic_Unc	counts	Float/980x266	The corrected count systematic uncertainty.
Corrected_Count_Random_Unc	counts	Float/980x266	The corrected count random uncertainty.
Radiance	Rayleighs/nm	Float/980x266	The Radiance data in Rayleighs/nm.
Radiance_Systematic_Unc	Rayleighs/nm	Float/980x266	The Radiance systematic uncertainties in Rayleighs/nm.
Radiance_Random_Unc	Rayleighs/nm	Float/980x266	The Radiance random uncertainties in Rayleighs/nm.
Background_Counts	counts	Float/600x800	The background counts subtracted in the background correction.

Variable Name	Units	Type/Dim	Description
Reference_Point_Lat	Degrees	Float/980	Latitude of the reference point.
Reference_Point_Lon	Degrees	Float/980	Longitude of the reference point.
Tangent_Height	km	Float/980	
Ray_Solar_Phase_Angle	Degrees	Float/980	The planar angle between the pixel ray from center and the sun direction.
Ray_Nadir_Angle	Degrees	Float/980	The planar angle between the pixel ray from center and the spacecraft nadir.
Emission_Angle	Degrees	Float/980	The planar angle between the pixel ray from center and the normal to the reference point.
Solar_Zenith_Angle	Degrees	Float/980	The planar angle between the sun direction to the reference point and the normal to the reference point.
Star_Tangent_Height	km	Float/980	The tangent height of the star with respect to GOLD.
Solar_Zenith_Angle_Wrt_Star	Degrees	Float/980	The planar angle between the sun direction to the star tangent point normal.
Star_Tangent_Lat	Degrees	Float/980	Tangent point Latitude relative to fixed Earth frame of line to star.
Star_Tangent_Lon	Degrees	Float/980	Tangent point Longitude relative to fixed Earth frame of line to star.

Table 3-7 Level 1C Stellar Occultation Disk File Contents

3.5.6.2 Level 1C Stellar Occultation Metadata

Variable Name	Default value
ADID_Ref	NASA Contract > NNG12PQ28C
Conventions	SPDF ISTP/IACF Modified for NetCDF
Data_Level	L1C
Data_Type	APIDx0F > GOLD Application ID 0x0F: Level 1C Limb Science Data
Observation_Type	LIM
OBS_TYPE	2
OBS_ID	0
Channel_ID	1
Data_Version	1
Data_Revision	1
Data_Cycle	
TC_VER	1
GC_VER	1
OC_VER	1
Minimum_PHD	0
Maximum_PHD	255

Variable Name	Default value
Spatial_Binning	3
Spectral_Binning	2
Slit_Position	OCC | HI_RES | LO_RES | PINHOLE
GYM_Position	0
Mirror_Hemisphere	N or S
Reference_Altitude	150.0
Occ_Star	“none”
Occ_Star_ID	“none”
Occ_Star_RA	0.0
Occ_Star_Dec	0.0
Occ_Star_Brightness_Rank	0
SC_Ref_Altitude	35785.9
SC_Ref_Lon	-47.5
SC_Alt	0.0
SC_Alt_min_max	NaN, NaN
SC_Pos	0.0, 0.0, 0.0
SC_Pos_x_min_max	NaN, NaN
SC_Pos_y_min_max	NaN, NaN
SC_Pos_z_min_max	NaN, NaN
SC_Z_Dir	0.0, 0.0, 0.0
SC_Z_Dir_x_min_max	NaN, NaN
SC_Z_Dir_y_min_max	NaN, NaN
SC_Z_Dir_z_min_max	NaN, NaN
SC_Nadir_lat	0.0
SC_Nadir_lat_min_max	NaN, NaN
SC_Nadir_lon	0.0
SC_Nadir_lon_min_max	NaN, NaN
SC_Yaw	0.0
SC_Yaw_min_max	NaN, NaN
Date_Processed	2016-11-17 08:26:45.000Z
Date_Start	2016-11-17 08:26:45.000Z
Date_End	2016-11-17 08:26:45.000Z
Date_Start_ET	0.0
Description	GOLD L1C spectral radiance image in Rayleighs/nm
Descriptor	CHA > GOLD L1C spectral radiance image in Rayleighs/nm

Variable Name	Default value
Discipline	Space Physics > Ionospheric Science
File	GOLD_L1C_CHA_2016_016_18_45_v01.nc
File_Date	2016-11-17 08:26:45.000Z
Generated_By	GOLD SOC > GOLD L1C Processor v1.0.0
History	Version 1, Created by GOLD L1C Processor v1.0.0 on 2016-11-17 08:26:45.000Z.
HTTP_LINK	http://gold.cs.ucf.edu
Instrument	CHA
Instrument_Type	UV Imaging Spectrograph (Space)
Link_Text	All GOLD information and data can be found at the HTTP_LINK
Link_Title	GOLD Website
Logical_File_ID	GOLD_L1C_CHC_2016_016_18_45_v01_r01
Logical_Source	GOLD_L1C_CHC_2016_016_18_45
Logical_Source_Description	GOLD Channel-A L1C spectral radiance image in Rayleighs/nm
Mission_Group	Thermospheric and Ionospheric Investigations
MODS	Version 1, Created by GOLD L1C Processor v1.0.0 on 2016-11-17 08:26:45.000Z.
Parents	
PI_Affiliation	University of Colorado > LASP
PI_Name	Richard Eastes
Project	NASA > GOLD
Rules_of_Use	Public Data for Scientific Use
Software_Version	GOLD SOC > GOLD L1C Processor v1.0.0
Source_Name	GOLD > Global-scale Observations of the Limb and Disk (GOLD) Heliophysics Explorer mission of opportunity
Spacecraft_ID	SES > GOLD – 518
Text	The GOLD mission of opportunity flies an ultraviolet (UV) imaging spectrograph on a geostationary satellite to measure densities and temperatures in Earth's thermosphere and ionosphere and to understand the global-scale response to forcing in the integrate Sun-Earth system. Visit \'http://www.gold-mission.org/\' for more details.
Time_Resolution	Fixed with integration time at each Scan Mirror Position
Title	GOLD Level 1C spectral radiance image in Rayleighs/nm
_Format	netCDF-4

Table 3-8 Level 1C Stellar Occultation Metadata

3.5.7 Level 1D Data File Structures

Level 1D files contain a thumbnail image (PNG) for individual occultations. There are individual thumbnail files created for a 2D image of counts vs. wavelength and tangent altitude, and line plots of counts vs. time, tangent altitude, and wavelength. There is also a combined thumbnail image file created that contains all 4 of these images (see example shown below). The line plots show counts from three separate spectral bins, which are defined in Table 3-9 and Table 3-10. Separate files are created for Channel A and Channel B data. A new L1D file is generated for each new L1C file.

Spectral Bin Center [nm]	Bin Width [# of L1C Pixels]
140	12
152	12
159	12

Table 3-9 Occultation L1D Spectral Bins

Spectral Bin Center [km]	Bin Width [# of L1C Pixels]
140	10
180	10
250	10

Table 3-10 Occultation L1D Altitude Bins

Combined file definition (image size = 1024 x 1024 pixels)

- Header information (at the top of the set of 4 images)
    - Date of image
    - Time of image
    - File name
    - Star name, HD and brightness rank
    - RA and declination
    - Latitude, longitude, SZA
- Wavelength vs. Tangent altitude over full wavelength range in counts.
- Counts vs. time for each spectral bin (see Table 3-9).

- Counts vs. tangent altitude for each spectral bin (see Table 3-9).
- Counts vs. wavelength for each altitude bin (see Table 3-10).

Individual file definitions (image size = 512 x 512 pixels)

- Wavelength vs. Tangent altitude over full wavelength range in counts.
    - Name:
- Counts vs. time for each spectral bin (see Table 3-9).
- Counts vs. tangent altitude for each spectral bin (see Table 3-9).
- Counts vs. wavelength for each altitude bin (see Table 3-10).

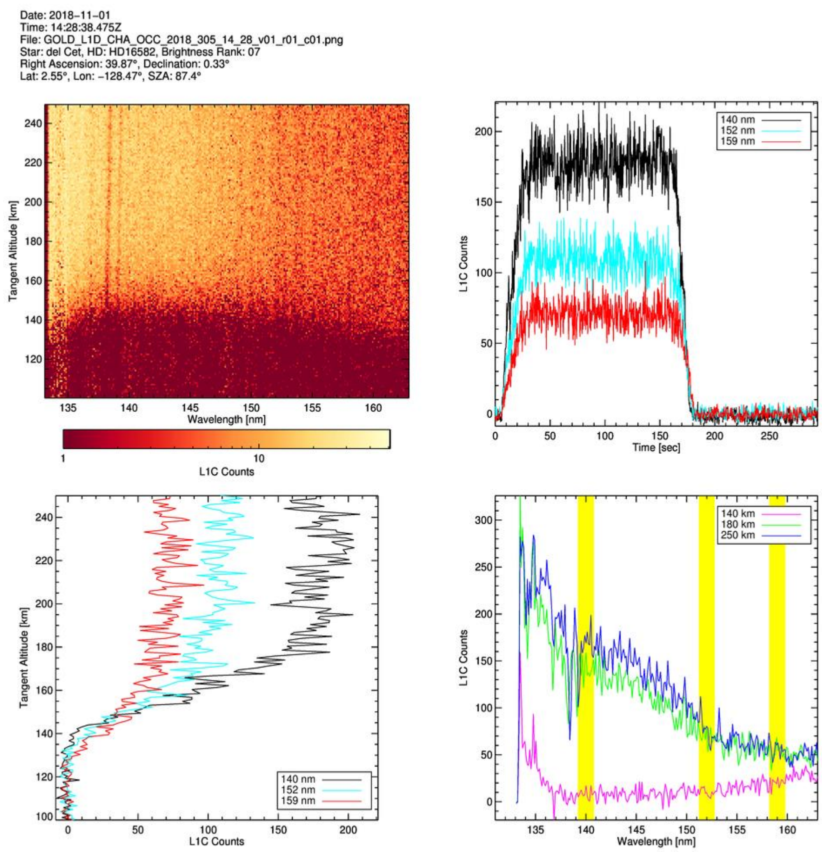

Figure 3-22 Example Level 1D Combined Occultation File

4 Level 2 Data Products

There are six GOLD Level 2 (L2) data products. The physical descriptions, L2 data product names, and mapping back to the four primary GOLD measurement modes and L1C data products are as follows:

Measurement mode/L1C data product	**Derived L2 data products**
Dayside disk measurements (L1C DAY)	Disk neutral temperature - TDISK
	O/N_2 column density ratio - ON2
	Solar EUV flux proxy - QEUV
Limb measurements (L1C LIM)	Limb exospheric temperature - TLIMB
Stellar occultation measurements (L1C OCC)	O_2 density profile - O2DEN
Nightside disk measurements (L1C NI1)	Peak electron density - NMAX

Table 4-1 Level 2 data products and L1C dependence

In routine daily processing, the Level 2 algorithms operate on each individual L1C file as soon as they are created by the GOLD data processing pipeline. Each application of the algorithms produces an individual L2 file for each event. Thus, for example, there are individual TDISK, ON2 and QEUV files created for each dayside disk scan during the day, individual O2DEN files for each occultation, and so forth. At the end of the day (after midnight satellite local time) all individual files of the same type are combined into a single file containing all data of that type for the day. These daily summary files are the publicly released L2 data products.

4.1 NMAX Data Product

The GOLD night disk scan (NI1) measurements are used to derive the peak electron density (NMAX, electrons/cm^3) on the disk. GOLD performs NI1 scans in both hemispheres from 17:00 to 21:00 hours spacecraft local time each night. NMAX is retrieved on a 2D rectangular (latitude vs. longitude) grid of fixed dimensions for each scan. However, the actual latitude and longitude values in the grid vary from scan to scan as the NI1 sequence utilizes a pattern of short (15 minute) localized scans that progress from east to west across the disk throughout the sequence (see Section 3.4.1).

4.1.1 Algorithm Description

There are two primary sources of the O I 135.6 nm nightglow emission: radiative recombination and ion-ion mutual neutralization. In addition, there is a small enhancement in the brightness due to multiple scattering from lower altitudes. The complexity of the algorithm depends on the extent to which each of these components are accounted for.

The primary source is radiative recombination, which is due to the recombination of O^+ ions with electrons to produce O atoms in an excited state that decays via various channels, including the emission of a photon at 135.6 nm:

$$O^+ + e \rightarrow O(^5P) + h\nu_{1356}$$

A secondary source is ion-ion mutual neutralization, which involves the interaction of an O^+ ion with an O^- ion that results in two O atoms, one or both of which may be in an excited state, which can result in the emission of a photon at 135.6 nm. The O^- ion comes from the attachment of an electron to a neutral O atom, and it can also interact with a neutral O atom to produce an O_2 molecule and an electron. This competes with ion-ion neutralization, resulting in a very low ambient density of O^-, but the throughput of production and loss is sufficient to produce an observable amount of 135.6 radiation.

Finally, although both of these sources of 135.6 nm radiation occur at high altitudes where the atmosphere is optically thin at 135.6 nm, the downward directed photons encounter increasing densities of O so they can be resonantly scattered back in the upward direction. Preliminary AURIC runs indicate that, depending on geometry, this multiple scattering can result in an enhancement of the brightness by 10% or more.

The algorithm used for Version 1 of the NMAX data product is the simplest possible implementation, and makes the following assumptions:

1. Ignore ion-ion mutual neutralization
2. Neglect multiple scattering
3. Assume the electron and O^+ densities are identical, $N_e = N_{O+}$
4. Assume a assume a Chapman layer profile for the electron density profile, $N_e(z)$.

Given these assumptions one can derive the following formula relating the peak of the electron density profile, N_{max}, directly to the measured 135.6 nm intensity, I_{1356}:

$$N_{max} = \sqrt{\frac{4\pi I_{1356}}{\alpha_{1356} eH}}$$

Here α_{1356} is the radiative recombination rate, H is the Chapman function scale height and *e* is the base of natural logarithms. The bandpass used to derive I_{1356} is taken to be 133-137 nm. The value of α_{1356} = 7.3 x 10^{-13} cm^3 s^{-1} is taken from Melendez-Alvira et al. [1999]. The scale height is essentially a free parameter in this formula, as it is unknown *a priori*. We have assumed a value of 100 km in the Version 1 algorithm.

References

Melendez-Alvira et al. (1999), Analysis of the oxygen nightglow measured by the Hopkins Ultraviolet Telescope: Implications for ionospheric partial radiative recombination rate coefficients, *J. Geophys. Res.*, 104, 14,901-14,913.

4.1.1 Data File Structures

4.1.1.1 NMAX File Contents

Variable Name	Units	Type/Dim	Description
Parameters defined per day/file			
NSCANS		Long/1	Number of scans in file.
NLATS		Long/1	Latitude grid dimension.
NLONS		Long/1	Longitude grid dimension.
NMASK		Long/1	Spectral mask dimension.
Parameters defined per scan			
DQI		Long/[NSCANS]	NMAX data quality index (see table below).
HEMISPHERE		String/[NSCANS]	Hemisphere scanned (‘N’ or ‘S’).
INPUT_L1C_FILE		String/[NSCANS]	L1C file for each scan.
CHANNEL		String/[NSCANS]	GOLD channel (‘A’ or ‘B’).
SCAN_START_TIME		String/[NSCANS]	UTC start time of scan, e.g., "2017-06-21T23:46:38.015Z".
SCAN_STOP_TIME		String/[NSCANS]	UTC end time of scan, e.g., "2017-06-21T23:46:38.015Z".
TIME_UTC		String/[NLONS, NSCANS]	UTC time for each slit position, e.g., "2017-06-21T23:46:38.015Z".
LATITUDE	Degrees	Float/[NLONS, NLATS, NSCANS]	Pixel latitude.
LONGITUDE	Degrees	Float/[NLONS, NLATS, NSCANS]	Pixel longitude.
SOLAR_ZENITH_ANGLE	Degrees	Float/[NLONS, NLATS, NSCANS]	Pixel solar zenith angle.

EMISSION_ANGLE	Degrees	Float/[NLONS, NLATS, NSCANS]	Pixel emission angle (relative to zenith).
COUNTS_OI_1356	Counts	Float/[NLONS, NLATS, NSCANS]	Counts in Oxygen 135.6-nm bandpass.
RADIANCE_OI_1356	Rayleighs/nm	Float/[NLONS, NLATS, NSCANS]	Radiance in Oxygen 135.6-nm bandpass.
OI_1356_UNC_RAN	Rayleighs/nm	Float/[NLONS, NLATS, NSCANS]	Random uncertainty in 135.6-nm radiance.
OI_1356_UNC_SYS	Rayleighs/nm	Float/[NLONS, NLATS, NSCANS]	Systematic uncertainty in 135.6-nm radiance.
OI_1356_UNC_MOD	Rayleighs/nm	Float/[NLONS, NLATS, NSCANS]	Model uncertainty in 135.6-nm radiance.
NMAX	electrons/cm^3	Float/[NLONS, NLATS, NSCANS]	Retrieved peak electron density.
NMAX_DQI		Long/[NLONS, NLATS, NSCANS]	NMAX data quality index per pixel (see table below).
NMAX_UNC_RAN	electrons/cm^3	Float/[NLONS, NLATS, NSCANS]	Random uncertainty in retrieved peak electron density.
NMAX_UNC_SYS	electrons/cm^3	Float/[NLONS, NLATS, NSCANS]	Systematic uncertainty in retrieved peak electron density.
NMAX_UNC_MOD	electrons/cm^3	Float/[NLONS, NLATS, NSCANS]	Model uncertainty in retrieved peak electron density.
MASK_OI_1356		Long/[NMASK]	Wavelength mask defining the 135.6-nm emission passband.
MASK_WAVELENGTH		Float/[NMASK]	Wavelength grid for 1356 mask.

Table 4-2 NMAX File Content

4.1.1.2 NMAX Data Quality Index

Value	Description
File Level	
0	No known data quality issues.
1	Solar zenith angle out of bounds.
2	Invalid O I 135.6 nm counts.
4	Invalid O I 135.6 nm radiance.
8	Invalid O I 135.6 nm radiance random uncertainties.
16	Invalid O I 135.6 nm radiance systematic uncertainties.
32	Invalid emission angle.
64	Algorithm failure.
128	Invalid wavelength.
256	No valid input.

512	High background.
1024	No valid output.
Pixel Level	
0	No known data quality issues.
1	Solar zenith angle out of bounds.
2	Invalid O I 135.6 nm counts.
4	Invalid O I 135.6 nm radiance.
8	Invalid O I 135.6 nm radiance random uncertainties.
16	Invalid O I 135.6 nm radiance systematic uncertainties.
32	Invalid emission angle.
64	Algorithm failure.
128	High background.

Table 4-3 NMAX Data Quality Index

4.2 O2DEN Data Product

The GOLD stellar occultation (OCC) measurements are used to derive the molecular oxygen (O_2) absolute density profile (mol/cm^3) on the limb. Of the six GOLD Level 2 data products this is the only one that provides altitude-resolved geophysical information. GOLD performs approximately 10 occultation measurements per day in nominal operation, sampling from a set of thirty bright type O and B target stars. Stars are observed to rise (set) on the East (West) limbs relative to the satellite's fixed position in geosynchronous orbit. Occultations occur at latitudes from 60^o S to 45^o N and at all local times during the day.

4.2.1 Algorithm Description

Algorithm heritage

The O2DEN algorithm is based on the Polar Ozone and Aerosol Measurement (POAM) solar occultation algorithms (Lumpe et al., [2002]). These algorithms were used to generate operational retrievals of aerosol and trace gas densities in the polar stratosphere from the POAM II and III instruments between 1993 and 2005. The algorithm was subsequently modified and used to retrieve thermospheric O_2 density profiles from both SUSIM/UARS solar occultation measurements (Lumpe et al., [2007]) and SOLSTICE/SORCE stellar occultation measurements (Lumpe et al., [2006]).

Algorithm theoretical basis

O_2 is derived from measurements of stellar occultation in the Shumann Runge continuum. As the star rises or sets relative to the satellite position the stellar spectrum is measured across the GOLD spectral bandpass, from 132 to 162 nm. Geolocation of the OCC L1B data provides the line-of-sight tangent altitude vs. time during the occultation. This results in a 2-dimensional map of the stellar signal, in counts or calibrated geophysical units (irradiance), vs. wavelength and tangent altitude. A sample of this image is represented in the top left panel of the OCC L1D image in Figure 3-22.

The measured counts profile is then normalized by the unattenuated, exo-atmospheric spectrum, yielding the slant path transmission profile vs. wavelength at the native L1C spectral sampling of 0.12 nm. The defining characteristic of the atmospheric transmission is that it is completely independent of instrument calibration or absolute accuracy. The full transmission spectrum is binned into a small number of 2-nm spectral channels for use in the retrievals. These retrieval channels are chosen to span the spectral dependence of the O_2 absorption cross-section in order to maximize the O_2 retrieval altitude range (approximately 120-240 km). In the Version 1 O2DEN data set two spectral channels are used, centered at 142- and 159-nm.

Since stars rise or set at approximately 3 km/sec, as observed from orbit, the 100-msec occultation cadence results in a measurement of extremely high (sub-km) vertical resolution. The data are binned to enhance signal-to-noise, producing an effective vertical resolution of 10 km or less, which is sufficient to easily resolve the scale height of the O_2 thermospheric profile.

The algorithm uses an optimal estimation routine, which provide a complete error analysis and retrieval diagnostics such as averaging kernels and information content. A data vector constructed from the multiple spectral channels of slant path transmission is used to derive the atmospheric state vector – O_2 density vs. geometric altitude – via a nonlinear, iterative inversion. The retrieved O_2 density profile is reported on a fixed altitude grid with 5-km spacing. The valid altitude range varies for each event, but generally ranges from ~120 – 240 km.

<u>References</u>

Lumpe, J. D., R. M. Bevilacqua, K. W. Hoppel, & C. E. Randall (2002), POAM III retrieval algorithm and error analysis, *J. Geophys. Res*., 107(D21), 4575, 10.1029/2002JD002137.

Lumpe, J. D., L. Floyd, M. Snow, and T. Woods (2006), Thermospheric Remote Sensing by Occultation: Comparison of SUSIM and SOLSTICE O_2 Measurements, Presented at the Fall 2006 AGU meeting, San Francisco, CA.

Lumpe, J. D., L. E. Floyd, L. C. Herring, S. T. Gibson, and B. R. Lewis (2007), Measurements of thermospheric molecular oxygen from the Solar Ultraviolet Spectral Irradiance Monitor, *J. Geophys. Res.*, 112, D16308, doi:10.1029/2006JD008076.

4.2.2 Data File Structures

4.2.2.1 O2DEN File Contents

Variable Name	Units	Type/Dim	Description
Parameters defined per day/file			
DQI		Long/1	File level Data Quality Index.
NEVENTS		Long/1	Number of occultations in file.
NZRET_MAX		Long/1	Maximum value of NZRET.
NZDAT_MAX		Long/1	Maximum value of NZDAT.
N_WAVELENGTH		Long/1	Number of spectral channels used in retrieval.
Parameters defined per occultation event			
DQI		Long/[NEVENTS]	O_2 data quality index (see table below).
TARGET_STAR		String/[NEVENTS]	Name of target star.
INPUT_L1C_FILE		String/[NEVENTS]	L1C file name for each occultation.
CHANNEL		String/[NEVENTS]	GOLD channel ("A" or "B")
TIME_UTC		String/[NEVENTS]	UTC date/time string, e.g. "2017-06-21T23:46:38.015Z"
LAT_REF	Degrees	Float/[NEVENTS]	Latitude at 225 km tangent point.
LON_REF	Degrees	Float/[NEVENTS]	Longitude at 225 km tangent point.
SZA_REF	Degrees	Float/[NEVENTS]	Solar zenith angle at 225 km tangent point.
CONVERGENCE		Long/[NEVENTS]	Retrieval convergence flag (= 1 if retrieval converged).
N_ITER		Long/[NEVENTS]	Number of iterations to converge.
NZRET		Long/[NEVENTS]	Number of levels in retrieval altitude grid.
SPECTRAL_WIDTH	nm	Float/[NEVENTS]	Width of each data spectral channel.
ZRET	km	Float/[NZRET_MAX, NEVENTS]	Retrieval geometric altitude grid.
O2_APRIORI	mol/cm^3	Float/[NZRET_MAX, NEVENTS]	A priori O_2 density used in retrieval.
O2DEN	mol/cm^3	Float/[NZRET_MAX, NEVENTS]	Retrieved O_2 density.

O2DEN_DQI		Long/[NZRET_MAX, NEVENTS]	O_2 data quality indicator per altitude (see table below).
O2DEN_UNC_RAN	mol/cm^3	Float/[NZRET_MAX, NEVENTS]	Random uncertainty of retrieved O_2.
O2DEN_UNC_SYS	mol/cm^3	Float/[NZRET_MAX, NEVENTS]	Systematic uncertainty of retrieved O_2.
O2DEN_UNC_MOD	mol/cm^3	Float/[NZRET_MAX, NEVENTS]	Model uncertainty of retrieved O_2.
TEMPERATURE	K	Float/[NZRET_MAX, NEVENTS]	Assumed temperature profile.
CENTRAL_WAVELENGTH	nm	Float/[N_WAVELENGTH, NEVENTS]	Center wavelength of each data channel.
NORMALIZATION	Counts	Float/[N_WAVELENGTH, NEVENTS]	Transmission normalization factor (unattenuated stellar brightness).
SIGNAL_TO_NOISE		Float/[N_WAVELENGTH, NEVENTS]	Effective signal to noise (above atmosphere).
NZDAT		Long/[N_WAVELENGTH, NEVENTS]	Number of points in data altitude grid.
ZDAT	km	Float/[NZDAT_MAX, N_WAVELENGTH, NEVENTS]	Data tangent altitude grid.
TRANSMISSION		Float/[NZDAT_MAX, N_WAVELENGTH, NEVENTS]	Measured slant path transmission profile.
TRANSMISSION_UNC		Float/[NZDAT_MAX, N_WAVELENGTH, NEVENTS]	Transmission variance.
TRANSMISSION_FIT		Float/[NZDAT_MAX, N_WAVELENGTH, NEVENTS]	Forward model fit to data.

Table 4-4 O2DEN File Contents

4.2.2.2 O2DEN Data Quality Index Definitions

Value	Description
File Level	
0	No known data quality issues.
2	Dayside occultation.
4	Invalid NORMALIZATION value (max altitude not high enough).
8	Retrieval non-convergence.
16	Wavelengths out of bounds.
32	Invalid tangent altitude grid in input transmission data.
64	Counts array out of bounds

128	Counts random errors out of bounds.
256	Counts systematic errors out of bounds.
512	Transmission array out of bounds.
1024	O2DEN non-finite or out of bounds.
2048	O2DEN random error non-finite or out of bounds.
8192	Algorithm failure.
Pixel Level	
0	No known data quality issues.
1	O2DEN non-finite or out of bounds.
2	O2DEN random error non-finite or out of bounds.

Table 4-5 O2DEN Data Quality Index

4.3 ON2 Data Product

GOLD daytime disk scan (DAY) measurements are used to derive the ratio of the column abundance of thermospheric O relative to N_2, conventionally referred to as O/N_2 or $\Sigma O/N_2$, but abbreviated to ON2 for the GOLD data product. ON2 is derived for each valid dayside Level 1C pixel for approximately 68 disk scan measurements performed per day by GOLD in nominal operation.

4.3.1 Algorithm Description

Algorithm heritage

The disk ON2 retrieval algorithm was originally developed by Computational Physics, Inc. (CPI) for use with GUVI and SSUSI radiance images (Strickland et al., 1995). The GOLD implementation of this algorithm takes advantage of GOLD's ability to transmit the full spectrum to maximize the signal-to-noise ratio and eliminate atomic emission lines that contaminate the N_2 LBH bands (e.g., N I 149.3 nm). This algorithm has been extensively documented and applied over the past several decades (e.g., Evans et al. [1995]; Christensen et al. [2003]; Strickland et al. [2004]).

Algorithm theoretical basis

The geophysical parameter retrieved, O/N_2, is the ratio of the vertical column density of O relative to N_2, defined at a standard reference N_2 depth of 10^{17} cm^{-2}, which is chosen to minimize uncertainty in the derived O/N_2. It is retrieved directly from the ratio of the O I 135.6 nm and N_2 LBH band intensities measured by GOLD on the dayside disk (DAY measurement mode). The AURIC atmospheric radiance model (Strickland et al. [1999]) is used to derive this relationship as a function of solar zenith angle and to create the look-up table (LUT) used by the algorithm.

References

Christensen, A. B., et al. (2003), Initial observations with the Global Ultraviolet Imager (GUVI) in the NASA TIMED satellite mission, *J. Geophys. Res*., vol. 108, NO. A12, 1451, doi:10.1029/2003JA009918.

Evans, J. S., D. J. Strickland and R. E. Huffman (1995), Satellite remote sensing of thermospheric O/N_2 and solar EUV: 2. Data analysis, *J. Geophys. Res*., vol. 100, NO. A7, pages 12,227-12,233.

Strickland, D. J., R. R. Meier, R. L. Walterscheid, J. D. Craven, A. B. Christensen, L. J. Paxton, D. Morrison, and G. Crowley (2004), Quiet-time seasonal behavior of the thermosphere seen in the far ultraviolet dayglow, *J. Geophys. Res*., vol. 109, A01302, doi:10.1029/2003JA010220.

Strickland, D.J., J. Bishop, J.S. Evans, T. Majeed, P.M. Shen, R.J. Cox, R. Link, and R.E. Huffman (1999), Atmospheric Ultraviolet Radiance Integrated Code (AURIC): theory, software architecture, inputs and selected results, *JQSRT*, 62, 689-742.

Strickland, D. J., J. S. Evans, and L. J. Paxton (1995), Satellite remote sensing of thermospheric O/N_2 and solar EUV: 1. Theory, *J. Geophys. Res*., 110, A7, pages 12,217-12,226.

4.3.2 Data File Structures

4.3.2.1 ON2 File Contents

Variable Name	Units	Type/Dim	Description
Parameters defined per day/file			
NSCANS		Long/1	Number of scans in file.
NLATS		Long/1	Latitude grid dimension.
NLONS		Long/1	Longitude grid dimension.
NMASK		Long/1	Spectral mask dimension.
Parameters defined per scan			
DQI		Long/[NSCANS]	Overall data quality index per scan (see table below).
HEMISPHERE		String/[NSCANS]	Hemisphere scanned (‘N’ or ‘S’).
CHANNEL		String/[NSCANS]	GOLD channel (‘A’ or ‘B’).
INPUT_L1C_FILE		String/[NSCANS]	L1C file for each scan.

SCAN_START_TIME		String/[NSCANS]	UTC start time of scan, e.g., "2017-06-21T23:46:38.015Z".
SCAN_STOP_TIME		String/[NSCANS]	UTC end time of scan, e.g., "2017-06-21T23:46:38.015Z".
LOOKUP_TABLE		String/[NSCANS]	Lookup table filename.
LATITUDE	Degrees	Float/[NLONS, NLATS]	Pixel latitude.
LONGITUDE	Degrees	Float/[NLONS, NLATS]	Pixel longitude.
TIME_UTC		String/[NLONS, NLATS, NSCANS]	UTC time for each pixel, e.g., "2017-06-21T23:46:38.015Z".
SOLAR_ZENITH_ANGLE	Degrees	Float/[NLONS, NLATS, NSCANS]	Pixel solar zenith angle.
EMISSION_ANGLE	Degrees	Float/[NLONS, NLATS, NSCANS]	Pixel emission angle (relative to zenith).
RADIANCE_OI_1356	Rayleighs	Float/[NLONS, NLATS, NSCANS]	Oxygen 135.6 nm brightness used in retrieval.
OI_1356_UNC_RAN	Rayleighs	Float/[NLONS, NLATS, NSCANS]	Random uncertainty in oxygen 135.6 nm brightness.
OI_1356_UNC_SYS	Rayleighs	Float/[NLONS, NLATS, NSCANS]	Systematic uncertainty in oxygen 135.6 nm brightness.
RADIANCE_N2_LBH	Rayleighs	Float/[NLONS, NLATS, NSCANS]	N_2 LBH brightness used in retrieval.
N2_LBH_UNC_RAN	Rayleighs	Float/[NLONS, NLATS, NSCANS]	Random uncertainty in N_2 LBH brightness.
N2_LBH_UNC_SYS	Rayleighs	Float/[NLONS, NLATS, NSCANS]	Systematic uncertainty in N_2 LBH brightness.
ON2		Float/[NLONS, NLATS, NSCANS]	Retrieved O/N_2 column density ratio, per pixel.
ON2_DQI		Long/[NLONS, NLATS, NSCANS]	ON2 data quality index per pixel (see table below).
ON2_UNC_RAN		Float/[NLONS, NLATS, NSCANS]	Random uncertainty in retrieved O/N_2 column density ratio.
ON2_UNC_SYS		Float/[NLONS, NLATS, NSCANS]	Systematic uncertainty in retrieved O/N_2 column density ratio.
ON2_UNC_MOD		Float/[NLONS, NLATS, NSCANS]	Model uncertainty in retrieved O/N_2 column density ratio.
MASK_WAVELENGTH	nm	Float/[NMASK]	Wavelength grid for MASK_N2_LBH and MASK_OI_1356.
MASK_N2_LBH		Long/[NMASK]	Wavelength mask defining LBH bandpass used in retrieval.
MASK_OI_1356		Long/[NMASK]	Wavelength mask defining OI 1356 bandpass used in retrieval.

Table 4-6 ON2 File Content

4.3.2.2 ON2 Data Quality Index

Value	Description
File Level	
0	No known data quality issues.
1	Invalid wavelength mask.
2	No valid input.
4	No valid output.
8	Invalid lookup table.
Pixel Level	
0	No known data quality issues.
1	Invalid solar zenith angle.
2	Invalid intensity ratio 135.6 nm/N_2 LBH.
4	Invalid 135.6 nm radiance random uncertainty.
8	Invalid N_2 LBH radiance random uncertainty.
16	Invalid 135.6 nm radiance systematic random uncertainty.
32	Invalid N_2 LBH radiance systematic random uncertainty.
64	Algorithm failure.

Table 4-7 ON2 Data Quality Index

4.4 QEUV Data Product

Q_{EUV} is a proxy for the integrated solar EUV irradiance below 45 nm, which can be derived directly from far ultraviolet (FUV) radiance measurements. Q_{EUV} is a dayside disk data product, derived from the GOLD DAY measurement mode.

4.4.1 Algorithm Description

Algorithm heritage

The disk Q_{EUV} retrieval algorithm was originally developed for use with GUVI and SSUSI images (Strickland et al., [1995]). The GOLD implementation of this algorithm takes advantage of GOLD's ability to transmit the full spectrum to maximize the signal-to-noise ratio and eliminate atomic emission lines that contaminate the N_2 LBH bands (e.g., N I 149.3 nm). This algorithm has been extensively documented and applied (e.g., Strickland et al. [2004]; Evans et al., [1995]). The associated GOLD Level 2 data product is called QEUV.

Algorithm theoretical basis

Like ON2, the QEUV data product is also produced via a look-up-table (LUT) approach, and depends on the observed O I 135.6 nm brightness, the solar zenith angle, and the derived O/N_2 ratio. The AURIC airglow model is used to derive this relationship as a function of solar zenith angle in order to create the LUT used by the algorithm.

In order to avoid contamination of O I 135.6 nm by sources other than photoelectron impact, QEUV is only calculated for a row of pixels from DAY disk scans corresponding to mid-latitudes. This avoids both low latitude contamination from O^+ recombination in the EIA and energetic particle precipitation in the auroral region at polar latitudes. Due to the asymmetry of the magnetic equator and EIA, the latitude used for the northern and southern hemispheres differs: 30^o N latitude and -37.5^o S latitude, respectively. O I 135.6 nm and N_2 LBH intensities are calculated from L1C spectra at these latitudes and used as inputs for the QEUV algorithm. Temporal sampling is approximately 5 seconds.

References

Evans, J. S., D. J. Strickland and R. E. Huffman (1995), Satellite remote sensing of thermospheric O/N_2 and solar EUV: 2. Data analysis, *J. Geophys. Res.*, Vol. 100, NO. A7, pages 12,227-12,233.

Strickland, D. J., J. S. Evans, and L. J. Paxton (1995), Satellite remote sensing of thermospheric O/N_2 and solar EUV: 1. Theory, *J. Geophys. Res.*, 110, A7, pages 12,217-12,226.

Strickland, D. J., J. L. Lean, R. R. Meier, A. B. Christensen, L. J. Paxton, D. Morrison, J. D. Craven, R. L. Walterscheid, D. L. Judge, and D. R. McMullin, (2004), Solar EUV irradiance variability derived from terrestrial far ultraviolet dayglow observations, Vol. 31, L03801, doi:10.1029/2003GL018415.

4.4.2 Data File Structures

4.4.2.1 QEUV File Contents

Variable Name	Units	Type/Dim	Description
Parameters defined per day/file			
NSCANS		Long/1	Number of scans in file.
NTIMES		Long/1	Time grid dimension.
NMASK		Long/1	Spectral mask dimension.
Parameters defined per scan			
DQI		Long/[NSCANS]	Overall data quality index per scan (see table below).

CHANNEL		String/[NSCANS]	GOLD channel (‘A’ or ‘B’).
HEMISPHERE		String/[NSCANS]	Hemisphere scanned (‘N’ or ‘S’).
INPUT_L1C_FILE		String/[NSCANS]	L1C file for each scan.
SCAN_START_TIME		String/[NSCANS]	UTC start time of scan, e.g., "2017-06-21T23:46:38.015Z".
SCAN_STOP_TIME		String/[NSCANS]	UTC end time of scan, e.g., "2017-06-21T23:46:38.015Z".
QEUV_LOOKUP_TABLE		String/[NSCANS]	QEUV lookup table filename.
ON2_LOOKUP_TABLE		String/[NSCANS]	ON2 lookup table filename.
TIME_UTC		String/[NTIMES, NSCANS]	UTC time for each QEUV value e.g., "2017-06-21T23:46:38.015Z".
SOLAR_ZENITH_ANGLE	Degrees	Float/[NTIMES, NSCANS]	Solar zenith angle.
EMISSION_ANGLE	Degrees	Float/[NTIMES, NSCANS]	Emission angle (relative to zenith).
RADIANCE_OI_1356	Rayleighs	Float/[NTIMES, NSCANS]	Oxygen 135.6 nm brightness used in retrieval.
OI_1356_UNC_RAN	Rayleighs	Float/[NTIMES, NSCANS]	Random uncertainty in oxygen 135.6 nm brightness.
OI_1356_UNC_SYS	Rayleighs	Float/[NTIMES, NSCANS]	Systematic uncertainty in oxygen 135.6 nm brightness.
RADIANCE_N2_LBH	Rayleighs	Float/[NTIMES, NSCANS]	N_2 LBH brightness used in retrieval.
N2_LBH_UNC_RAN	Rayleighs	Float/[NTIMES, NSCANS]	Random uncertainty in N_2 LBH brightness.
N2_LBH_UNC_SYS	Rayleighs	Float/[NTIMES, NSCANS]	Systematic uncertainty in N_2 LBH brightness.
ON2		Float/[NTIMES, NSCANS]	Retrieved O/N_2 column density ratio used in QEUV retrieval.
ON2_DQI		Long/[NTIMES, NSCANS]	ON2 data quality index.
ON2_UNC_RAN		Float/[NTIMES, NSCANS]	Random uncertainty in ON2.
ON2_UNC_SYS		Float/[NTIMES, NSCANS]	Systematic uncertainty in ON2.
ON2_UNC_MOD		Float/[NTIMES, NSCANS]	Model uncertainty in ON2.
QEUV	$erg/cm^2/s$	Float/[NTIMES, NSCANS]	Retrieved QEUV value.
QEUV_DQI		Long/[NTIMES, NSCANS]	QEUV data quality index per pixel (see table below).
QEUV-UNC_RAN	$erg/cm^2/s$	Float/[NTIMES, NSCANS]	Random uncertainty in retrieved QEUV.
QEUV_UNC_SYS	$erg/cm^2/s$	Float/[NTIMES, NSCANS]	Systematic uncertainty in retrieved QEUV.
QEUV_UNC_MOD	$erg/cm^2/s$	Float/[NTIMES, NSCANS]	Model uncertainty in retrieved QEUV.
MASK_WAVELENGTH	nm	Float/[NMASK]	Wavelength grid for MASK_N2_LBH and MASK_OI_1356.

MASK_N2_LBH		Long/[NMASK]	Wavelength mask defining LBH bandpass used in retrieval.
MASK_OI_1356		Long/[NMASK]	Wavelength mask defining OI 1356 bandpass used in retrieval.

Table 4-8 QEUV File Content

4.4.2.2 QEUV Data Quality Index

Value	Description
File Level	
0	No known data quality issues.
1	Invalid wavelength mask.
2	No valid input.
4	No valid output.
8	Insufficient latitude coverage.
16	Invalid lookup table.
Pixel Level - ON2	
0	No known data quality issues.
1	Invalid solar zenith angle.
2	Invalid intensity ratio 135.6 nm/N2 LBH.
4	Invalid 135.6 nm radiance random uncertainty.
8	Invalid N2 LBH radiance random uncertainty.
16	Invalid 135.6 nm radiance systematic random uncertainty.
32	Invalid N2 LBH radiance systematic random uncertainty.
64	Algorithm failure.
Pixel Level - QEUV	
0	No known data quality issues.
1	Invalid solar zenith angle.
2	Invalid 135.6 nm radiance.
4	Invalid 135.6 nm radiance random uncertainty.
8	Invalid 135.6 nm radiance sytematic uncertainty.
16	Invalid ON2.
32	Invalid ON2 random uncertainty.
64	Invalid ON2 systematic uncertainty.
128	Invalid ON2 model uncertainty.
256	Algorithm failure.

Table 4-9 QEUV Data Quality Index

4.5 TDISK Data Product

The GOLD daytime disk scan measurements are used to derive the TDISK data product, which is the effective disk neutral temperature at a height of approximately 150 km. TDISK is derived for each valid dayside Level 1C pixel for approximately 68 disk scan measurements performed per day by GOLD in nominal operation.

4.5.1 Algorithm Description

Algorithm heritage

The retrieval algorithm is an extension of those previously used to derive temperature from limb measurements of LBH intensity from the HITS instrument (Aksnes et al., [2006]; Krywonos et al. [2012]).

Algorithm theoretical basis

GOLD measurements have a higher signal-to-noise ratio than HITS and a spectral range that includes more of the total N_2 LBH emission (132 – 162 nm). Effective neutral temperatures near ~150 km altitude are retrieved by fitting the observed rotational structure of the N_2 LBH bands using an optimal estimation routine. Retrieved parameters also include the upper vibrational level (v'=0-6) relative intensities (i.e. populations), a constant background, wavelength shift, and wavelength dispersion (constant term).

References

Aksnes, A., R. Eastes, S. Budzien, & K. Dymond (2006), Neutral temperatures in the lower thermosphere from N2 Lyman-Birge-Hopfield (LBH) band profiles, *Geophys. Res. Lett*., 33, L15103, doi:10.1029/2006GL026255.

Krywonos, A., D. J. Murray, R. W. Eastes, A. Aksnes, S. A. Budzien, and R. E. Daniell (2012), Remote sensing of neutral temperatures in the Earth's thermosphere using the Lyman-Birge-Hopfield bands of N_2: Comparisons with satellite drag data, *J. Geophys. Res*., 117, A09311, doi:10.1029/2011JA017226.

4.5.2 Data File Structures

4.5.2.1 TDISK File Contents

Variable Name	Units	Type/Dim	Description
Parameters defined per day/file			

NSCANS		Long/1	Number of scans in file.
NLATS		Long/1	Latitude grid dimension.
NLONS		Long/1	Longitude grid dimension.
NMASK		Long/1	Spectral mask dimension.
NPOP		Long/1	Vibrational population grid dimension.
Parameters defined per scan			
DQI		Long/[NSCANS]	NMAX data quality index (see table below).
HEMISPHERE		String/[NSCANS]	Hemisphere scanned (‘N’ or ‘S’).
INPUT_L1C_FILE		String/[NSCANS]	L1C file for each scan.
CHANNEL		String/[NSCANS]	GOLD channel (‘A’ or ‘B’).
SCAN_START_TIME		String/[NSCANS]	UTC start time of scan, e.g., "2017-06-21T23:46:38.015Z".
SCAN_STOP_TIME		String/[NSCANS]	UTC end time of scan, e.g., "2017-06-21T23:46:38.015Z".
LOOKUP_TABLE		String/[NSCANS]	Retrieval lookup table filename.
LATITUDE	Degrees	Float/[NLONS, NLATS]	Pixel latitude.
LONGITUDE	Degrees	Float/[NLONS, NLATS]	Pixel longitude.
TIME_UTC		String/[NLONS, NLATS, NSCANS]	UTC time for each pixel, e.g., "2017-06-21T23:46:38.015Z".
SOLAR_ZENITH_ANGLE	Degrees	Float/[NLONS, NLATS, NSCANS]	Pixel solar zenith angle.
EMISSION_ANGLE	Degrees	Float/[NLONS, NLATS, NSCANS]	Pixel emission angle (relative to zenith).
EFFECTIVE_ALTITUDE	km	Float/[NLONS, NLATS, NSCANS]	Effective altitude of retrieved temperature.
TDISK	K	Float/[NLONS, NLATS, NSCANS]	Retrieved neutral temperature.
TDISK_DQI		Long/[NLONS, NLATS, NSCANS]	TDISK data quality index per pixel (see table below).
TDISK_UNC_RAN	K	Float/[NLONS, NLATS, NSCANS]	Random uncertainty in retrieved neutral temperature.
TDISK_UNC_SYS	K	Float/[NLONS, NLATS, NSCANS]	Systematic uncertainty in retrieved neutral temperature.
TDISK_UNC_MOD	K	Float/[NLONS, NLATS, NSCANS]	Model uncertainty in retrieved neutral temperature.
WAVELENGTH_STRETCH	nm	Float/[NLONS, NLATS, NSCANS]	Retrieved wavelength stretch parameter in each pixel.
WAVELENGTH_SHIFT	nm	Float/[NLONS, NLATS, NSCANS]	Retrieved wavelength stretch parameter in each pixel.

BACKGROUND	counts	Float/[NLONS, NLATS, NSCANS	Retrieved background per pixel.
VIBRATIONAL_POPULATIONS		Float/[NLONS, NLATS, NSCANS]	Retrieved temperature vibrational populations.
MASK_N2_LBH		Long/[NMASK]	Wavelength mask defining LBH spectrum used in retrieval.
MASK_WAVELENGTH	nm	Float/[NMASK]	Wavelength grid for N2_LBH mask.

Table 4-10 TDISK File Content

4.5.2.2 TDISK Data Quality Index

Value	Description
File Level	
0	No known data quality issues.
1	Invalid solar zenith angle.
2	Invalid N_2 LBH counts.
4	Invalid N_2 LBH counts random uncertainty.
8	Invalid emission angle.
16	Invalid wavelength.
32	No valid input.
64	No valid output.
Pixel Level	
0	No known data quality issues.
1	Invalid solar zenith angle.
2	Invalid N_2 LBH counts.
4	Invalid N_2 LBH counts random uncertainty.
8	Invalid emission angle.
16	Algorithm failure.

Table 4-11 TDISK Data Quality Index

4.6 TLIMB Data Product

GOLD retrieves the exospheric temperature from the integrated N_2 LBH radiance profile obtained from atmospheric limb scans (LIM observation mode). This data product, referred to as TLIMB, is derived from limb scan data by fitting the shape of the LBH radiance profile between 100 and 300 km.

4.6.1 Algorithm Description

Algorithm heritage

An approach similar to the GOLD TLIMB retrieval has been used to analyze data from TIMED/GUVI, Cassini/UVIS and MAVEN/IUVS. The GOLD TLIMB algorithm is most similar to the operational algorithm used to retrieve exospheric temperature on Mars from MAVEN/IUVS CO_2 density retrievals. The GOLD algorithm follows the procedure outlined in Lo et al. [2015] as originally applied to the atmosphere of Mars. The operational code is implemented in IDL and has been generalized to be used with any species in any planetary atmosphere.

Algorithm theoretical basis

Limb profiles of thermospheric airglow emissions depend fundamentally on temperature, particularly the decay rate with altitude above the peak of the emission. This has been exploited in retrieval algorithms for analyzing far-ultraviolet limb emissions from low-Earth orbit (e.g., Picone and Meier [2000]). For GOLD, the low spatial resolution on the limb mandates that, rather than attempting to fit an entire temperature profile, we only infer a single parameter, the exospheric temperature (TLIMB), defined as the temperature of the atmosphere when in diffusion equilibrium.

We use daytime, non-auroral N_2 LBH emission limb brightness profiles where the only excitation mechanism is photoelectron impact on N_2. LBH emission bands in the 137-160 nm range are integrated spectrally, excluding the N I 149.3 nm line. The GOLD limb scan measurements are done in one hemisphere at a time, and the L1C LIMB data covers a latitude range from the equator to ~20 degree.

The specific steps involved in the TLIMB retrieval are as follows:

- Filter data using topside tangent height range (~100-300 km).
- Fit a Chapman function to the emission brightness profile.
- Obtain the N_2 scale height $H(Z_o)$ from the Chapman fit.
- Obtain T_∞ from $H(Z_o) = kT/Mg$, where k is Boltzmann's constant, M is the molecular mass of N_2, and g is the gravitational acceleration.

Note that this fit is independent of the absolute brightness calibration of the airglow intensity, it depends only on the shape of the radiance profile. For this reason, it is necessary to detect stars in the field-of-view, since the emission from stars can produce a profile shape that can be very different from a profile produced solely by thermospheric airglow.

References

Picone and Meier (2000), Similarity transformations for fitting of geophysical properties: Application to altitude profiles of upper atmospheric species, *J. Geophys. Res., 105*, 18599, doi:10.1029/1999JA000385].

Lo, D. Y., et al. (2015), Nonmigrating tides in the Martian atmosphere as observed by MAVEN IUVS, Geophys. Res. Lett., 42, 9057–9063, doi:10.1002/2015GL066268.

Snowden, D., R. V. Yelle, J. Cui, J.-E. Wahlund, N. J. T. Edberg, and K. Ågren (2013), The thermal structure of Titan's upper atmosphere, I: Temperature profiles from Cassini INMS observations, Icarus, 226, 52–582.

4.6.2 Data File Structures

4.6.2.1 TLIMB File Contents

Variable Name	Units	Type/Dim	Description
Parameters defined per day/file			
NSCANS		Long/1	Number of scans in file.
NLATS		Long/1	Latitude grid dimension.
NLONS		Long/1	Longitude grid dimension.
NMASK		Long/1	Spectral mask dimension.
Parameters defined per scan			
DQI		Long/[NSCANS]	TLIMB data quality index (see table below).
HEMISPHERE		String/[NSCANS]	Hemisphere scanned ('N' or 'S').
INPUT_L1C_FILE		String/[NSCANS]	L1C file for each scan.
CHANNEL		String/[NSCANS]	GOLD channel ('A' or 'B').
SCAN_START_TIME		String/[NSCANS]	UTC start time of scan, e.g., "2017-06-21T23:46:38.015Z".
SCAN_STOP_TIME		String/[NSCANS]	UTC end time of scan, e.g., "2017-06-21T23:46:38.015Z".
TLIMB_LOOKUP_TABLE		String/[NSCANS]	Retrieval lookup table filename.
TIME_UTC		String/[NLONS, NLATS, NSCANS]	UTC time for each pixel, e.g., "2017-06-21T23:46:38.015Z".
TANGENT_POINT_ALTITUDE	km	Float/[NLONS, NLATS, NSCANS]	Tangent point altitude at each latitude/longitude grid point.
TANGENT_POINT_LATITUDE	Degrees	Float/[NLONS, NLATS, NSCANS]	Latitude at each tangent point.
TANGENT_POINT_LONGITUDE	Degrees	Float/[NLONS, NLATS, NSCANS]	Longitude at each tangent point.
TANGENT_POINT_SOLAR_ZENITH_ANGLE	Degrees	Float/[NLONS, NLATS, NSCANS]	Solar zenith angle at each tangent point.
RADIANCE_NH_LBH	Rayleighs	Double/[NLONS, NLATS, NSCANS]	N2 LBH slant path radiance.
N2_LBH_UNC_RAN	Rayleighs	Double/[NLONS, NLATS, NSCANS]	Random uncertainty in LBH slant path radiance.

NH_LBH_UNC_SYS	Rayleighs	Double/[NLONS, NLATS, NSCANS]	Systematic uncertainty in LBH slant path radiance.
N2_SCALE_HEIGHT	km	Float/[NLATS, NSCANS]	Top side scale height of N2 LBH radiance profile.
N2_SCALE_HEIGHT_UNC_RAN	km	Float/[NLATS, NSCANS]	Random uncertainty in top side LBH scale height.
N2_SCALE_HEIGHT_UNC_SYS	km	Float/[NLATS, NSCANS]	Systematic uncertainty in top side LBH scale height.
N2_SCALE_HEIGHT_UNC_MOD	km	Float/[NLATS, NSCANS]	Model uncertainty in top side LBH scale height.
TLIMB	K	Float/[NLATS, NSCANS]	Retrieved exospheric temperature.
TLIMB_DQI		Long/[NLONS, NLATS, NSCANS]	TLIMB data quality index per pixel (see table below).
TLIMB_UNC_RAN	K	Float/[NLONS, NLATS, NSCANS]	Random uncertainty in retrieved exospheric temperature.
TLIMB_UNC_SYS	K	Float/[NLONS, NLATS, NSCANS]	Systematic uncertainty in retrieved exospheric temperature.
TLIMB_UNC_MOD	K	Float/[NLONS, NLATS, NSCANS]	Model uncertainty in retrieved exospheric temperature.
MASK_N2_LBH		Long/[NMASK]	Wavelength mask defining LBH bandpass used in retrieval.
MASK_WAVELENGTH	nm	Float/[NMASK]	Wavelength grid for N2_LBH mask.

Table 4-12 TLIMB File Contents

4.6.2.2 TLIMB Data Quality Index

Value	Description
File Level	
0	No known data quality issues.
1	Invalid solar zenith angle.
2	Degraded algorithm performance due to high solar zenith angle.
4	Invalid N_2 LBH radiance.
8	Invalid N_2 LBH radiance random uncertainty.
16	Invalid N_2 LBH radiance systematic uncertainty.
32	Invalid or insufficient tangent altitude coverage.
64	Invalid wavelength.
128	No valid output.

Pixel Level	
0	No known data quality issues.
1	Invalid solar zenith angle.
2	Degraded algorithm performance due to high solar zenith angle.
4	Invalid N_2 LBH radiance.
8	Invalid N_2 LBH radiance random uncertainty.
32	Invalid or insufficient tangent altitude coverage.
64	Algorithm failure.
128	Low signal-to-noise ratio.
256	Star in the field-of-view.

Table 4-13 TLIMB Data Quality Index

5 Level 3 Data Products

Level 3 data products are not part of the current release. The following are placeholders for information that will be added for a future release.

5.1 Limb Temperature (TLIMB) Average Data Product

Limb temperature: T_{exo} average for ±10° latitude, one value per limb scan, single file.

This product is not part of this release.

5.2 QEUV Daily Average Data Product

QEUV: Daily averages, single file.

This product is not part of this release.