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

Release Notes

Revision 2.0 - June 3, 2019

Changes

Revision	Date	Changes
1.0	2/28/2019	Initial release
1.1	5/14/2019	Added “Incorrect Radiance values for the Night observations” to Known Issues
2.0	6/3/2019	Fixed issue with L1C NI1 data product and updated L1C NI1 and L1D NI1 to version 02.
		Initial limited release of Level 2 data products.

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1 Data Products:

This release adds the Level 2 TDISK, TLIMB, ON2 and O2DEN data products over a limited range of the GOLD operational period. The L1C NI1 product has been updated to v02. Table 1-1 below provides the list of Version and Revision numbers associated with each data product for this release.

We refer users of these data products to the "***GOLD Public Data Product Guide***", available at http://gold.cs.ucf.edu/documentation/ for details about how these were obtained, about their file format and content.

Future releases will include the following additional Level 2 data products: NMAX and QEUV. These products have been held back from the current release because they are more susceptible to biases and artifacts propagating from several instrument and calibration issues that have not yet been corrected in the L1C data, primarily the flat field corrections (see the discussions in Section 3.1).

Data Product	Version Number	Revision Number
L1C: DAY	01	01
L1C: LIM	01	01
L1C: OCC	01	01
L1C: NI1	02	01
L1D: DAY	01	01
L1D: LIM	01	01
L1D: OCC	01	01
L1D: NI1	02	01
L2: NMAX	N/A	N/A
L2: O2DEN	01	01
L2: ON2	01	01
L2: QEUV	N/A	N/A
L2: TDISK	01	01
L2: TLIMB	01	01
L3: TLIMB AVG	N/A	N/A
L3: QEUV AVG	N/A	N/A

Table 1-1 Version/Revision Numbers by Data Product for this Release

2 Updates with This Release:

This release combines an update to the previously released Level 1C NI1 data product with an initial partial release of Level 2 data products. The L1C NI1 observations use a variable dwell time. This difference in the observing mode was not captured properly when calculating the radiance in Rayleighs for the L1C-NI1 data products. This version fixes this error and the filenames have been updated with the new version number.

The Level 2 release includes the GOLD neutral temperature (TDISK) and O/N_2 (ON2) from dayside disk measurements, exospheric temperature (TLIMB) from limb scans, and O_2 density (O2DEN) from stellar occultations.

3 Known issues:

There are a number of known issues with the data provided in this and previous releases. This section provides a description of these issues and guidance to the user community on the use and interpretation of GOLD data products. This documentation is cumulative so that descriptions of known issues will remain until they are resolved in future releases. For the current release, Section 3.1 describes known issues with Level 1 data. Section 3.2 describes known issues and potential problems in the new Level 2 data, which is the subject of this release.

3.1 Level 1

3.1.1 Gradient in sensitivity from top to bottom of detector is not included in the calibration

In this release, we are not correcting for a change in the instrument responsivity along the slit. This is a ~10% effect from top to bottom of the slit. The top panel of Figure 3-1 shows that Near the equator, values extracted from the southern hemisphere scan (red) are ~10% larger than those from the northern hemisphere scan (black). The magnitude of the difference decreases with increasing wavelength as illustrated for LBH radiances shown in the lower panel. We plan on adding this correction in future data releases.

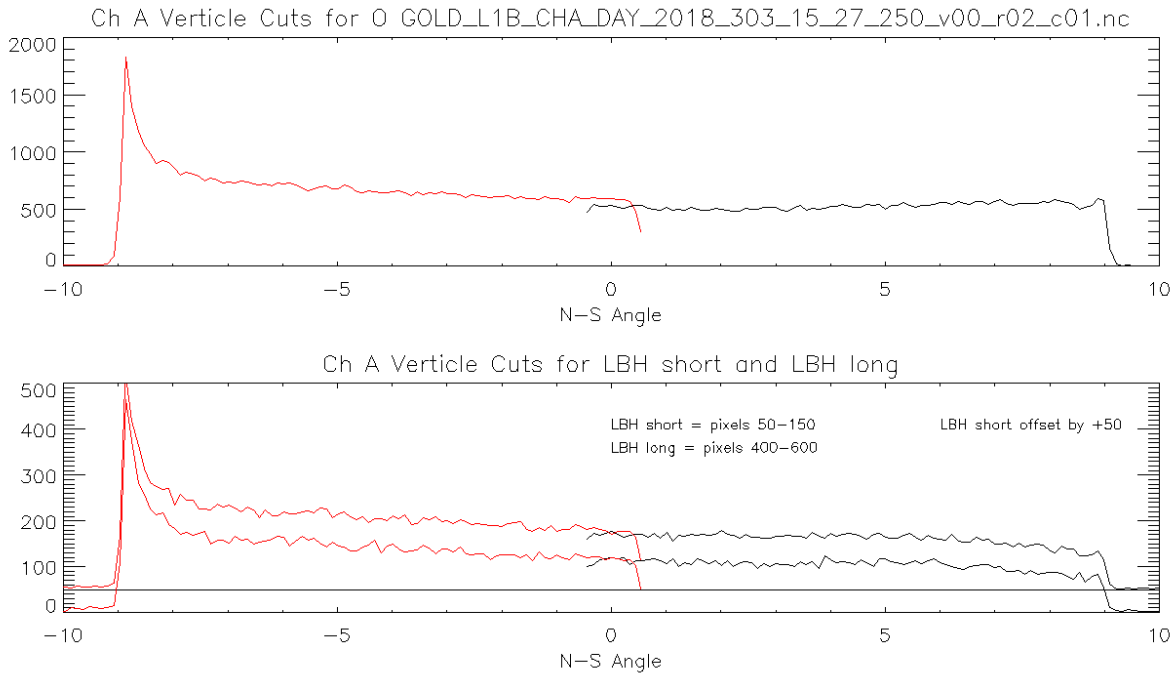

Figure 3-1 Uncorrected Vertical Sensitivity Variation

3.1.2 Time Delay of Reconstructed Full Disk Images

The projected height of the slit covers more than half the Earth, with an overlap around the equator when scanning the northern and the southern hemispheres. Full disk images made by combining northern hemisphere radiance images with those from the adjacent (in time) southern hemisphere image, will show ‘banding’ where the images overlap at the equator. This occurs because incidence and emission angles change throughout the 30 minutes during which the images are obtained. The effect is more pronounced early and late in the day. Figure 3-2 shows this effect on a DAY scan.

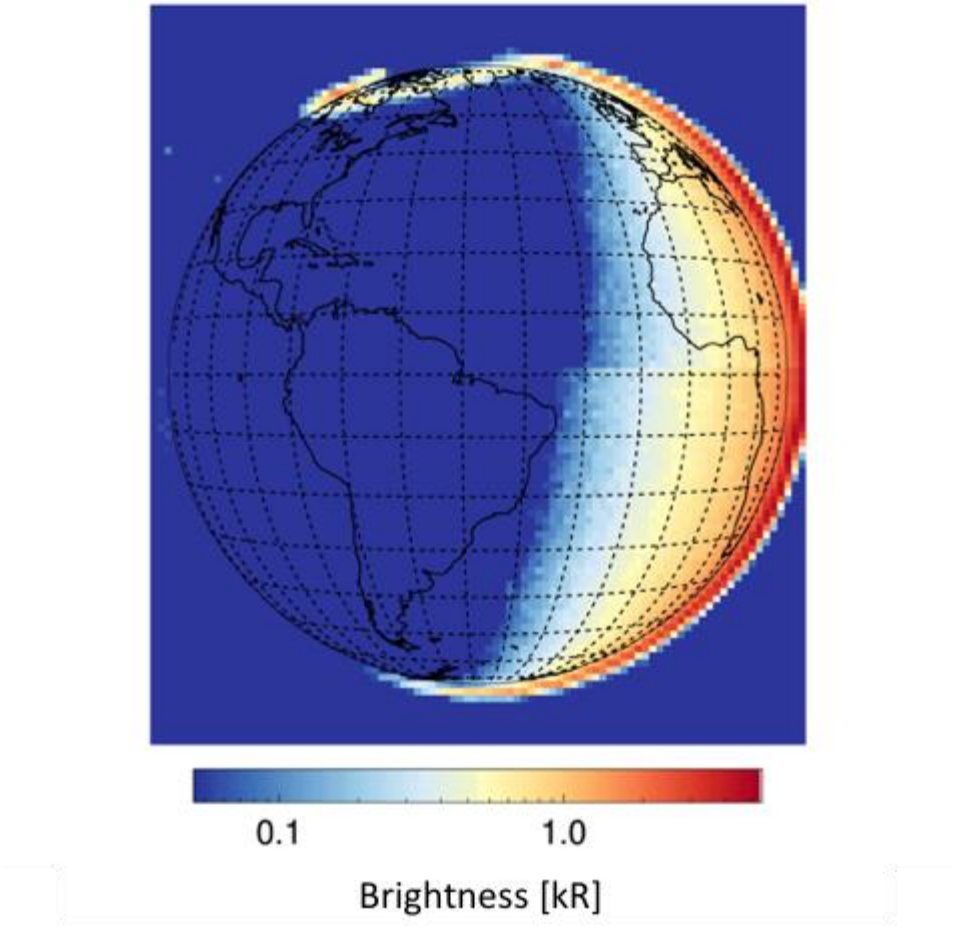

Figure 3-2 Combined scans of north and south latitudes from L1C data

3.1.3 Incomplete Scattered Light Correction

Due to the signal to noise, the first version of the background and scattered light removal algorithm assumes that there is no wavelength dependence. Though small, this is not exact and will be accounted for in later releases. Figure 3-3 below shows that there does appear to be a small slope when looking at the regions of the spectrum where we believe there should be no radiance.

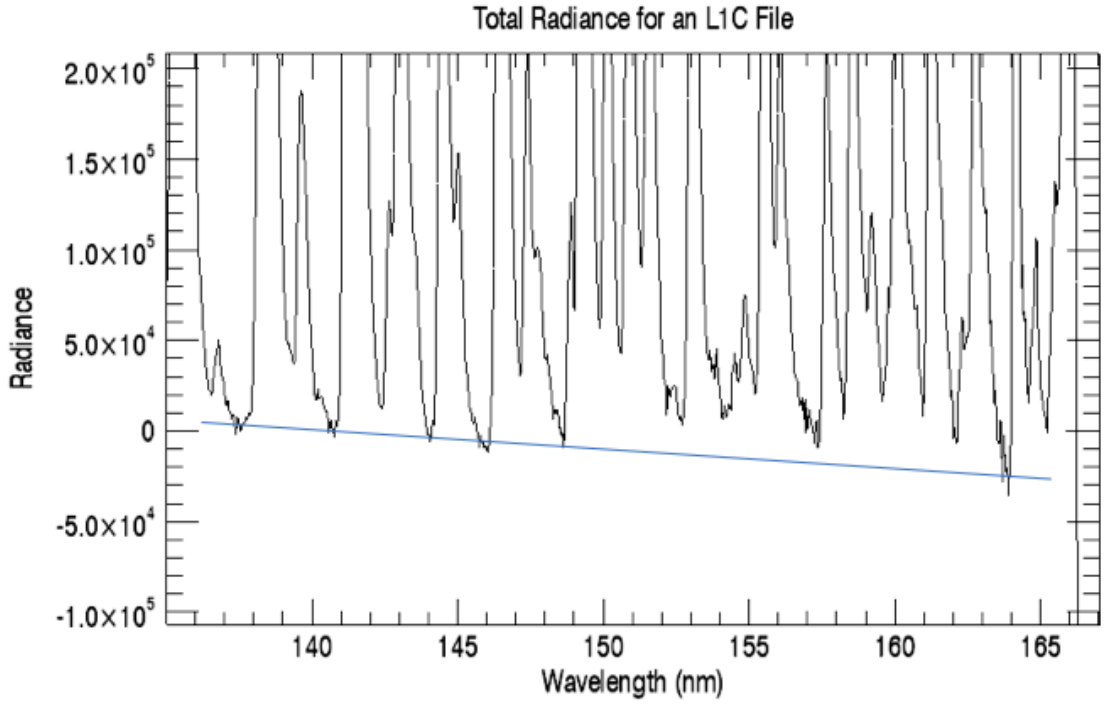

Figure 3-3 Wavelength Dependence Scattered Light

3.1.4 No Flatfield Correction

No flatfield correction is currently being applied in this release. See section 3.1.6.2 in the Public Science Data Products Guide

3.1.5 No Channel B Data

Channel B data is not being released due to uncertainty in the detector sensitivity. These data will be released after the detector sensitivity characterization is complete.

3.1.6 Slit Movement due to Thermal Changes

The projected image of the slit on the detector moves slightly with changing temperature. We are currently using the “nominal” slit position on the detector to assign a latitude to every corresponding Y-pixel along the slit and are not correcting for any movement of the image of the slit. This effectively adds additional uncertainties in the assigned latitude. Figure 3-4 shows that for a 26°C change, we see a maximum shift of about 3 L1B pixels which corresponds to ±20 km at nadir. This instrument effect will be corrected in a future release.

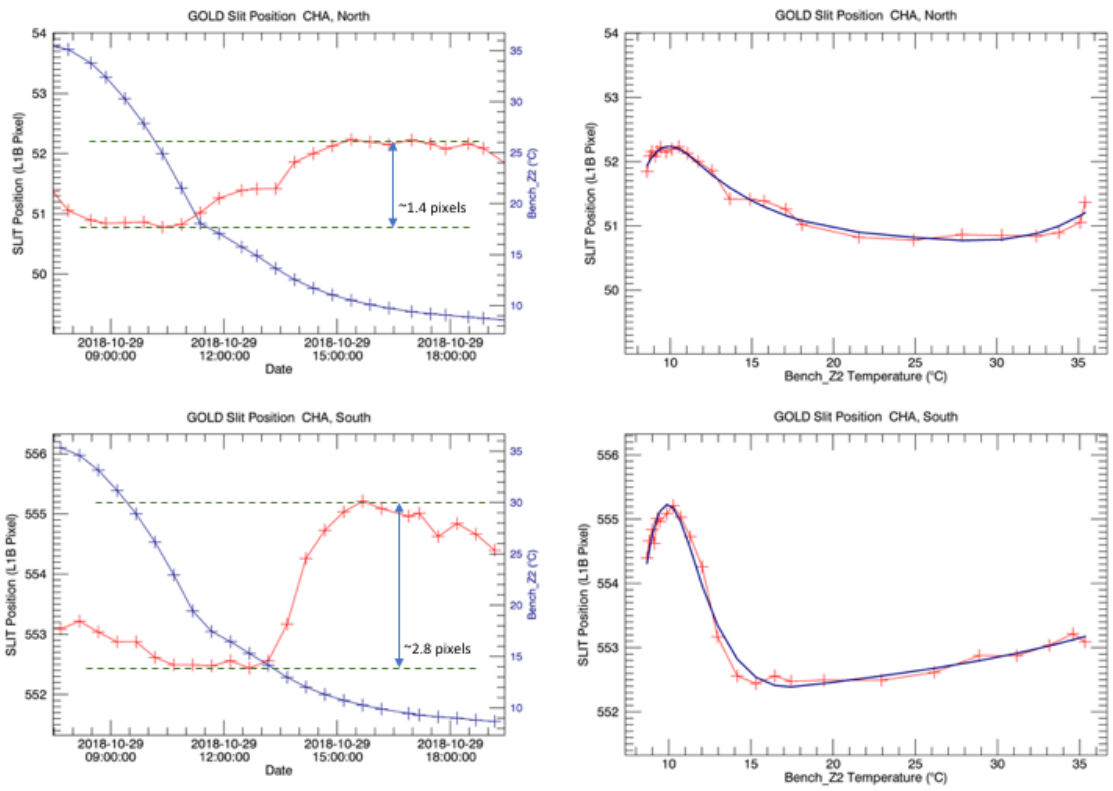

Figure 3-4 Vertical Slit Motion With Temperature

3.1.7 Occasional Incorrect Stellar Occultation Background Subtraction

Occasionally an additional star appears in the occultation window and corrupts the background subtraction. This is shown in Figure 3-5 below for 152nm. In future releases, these stars will be flagged.

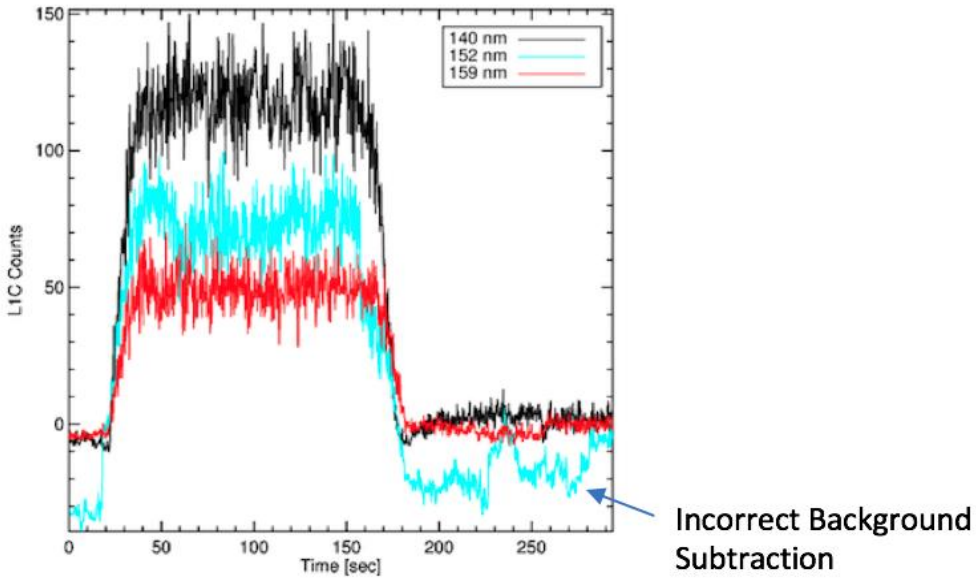

Figure 3-5 Incorrect Occultation Background Subtraction

3.1.8 Stellar Occultation Wavelength Feature

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.

3.1.9 Incorrect Background Subtraction at Limb in Day Scans

The sharp transition in the background between On and Off Limb is not accurately captured, so the background is over corrected as seen in Figure 3-6. This will be addressed in future releases.

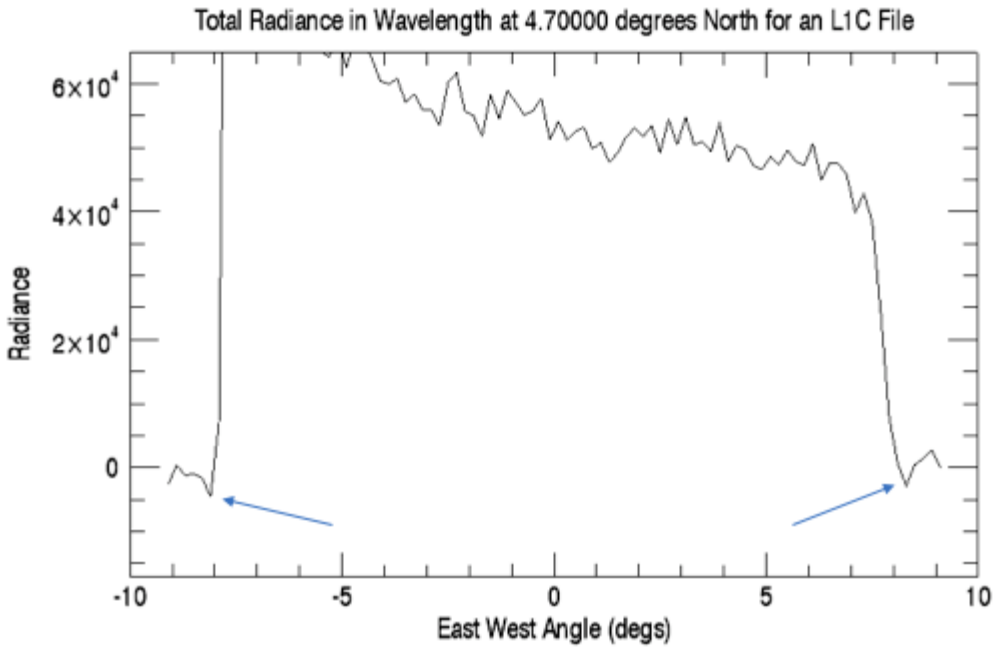

Figure 3-6 Over Corrected Background Subtraction at Limb

3.1.10 No local dead-time Correction for Occultations

Local dead-time correction, which affects the Occultations, has not been applied. The magnitude of the effect varies with the brightness of the star. A sample correction is shown in Figure 3-7.

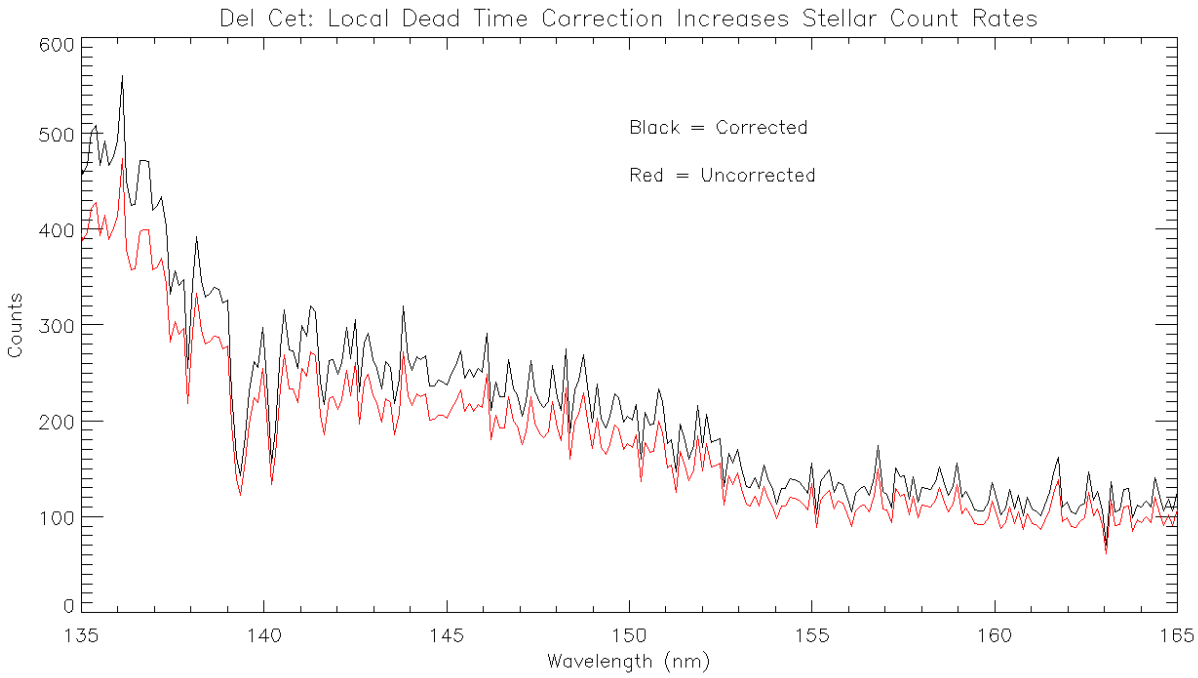

Figure 3-7 Counts Comparison with Dead-Time Correction

3.1.11 No Moon Flag

The presence of the Moon in the field of view is currently not being flagged during processing. This could affect the Limb and Occultation measurements. This issue will be addressed in future releases.

3.2 Level 2

This release contains data from a limited portion of the GOLD mission for the four GOLD Level 2 data products described in Section 2. Two additional Level 2 data products, the EUV solar irradiance proxy (QEUV) and the nightside peak electron density (NMAX) are being held back for a subsequent release pending resolution of some of the L1C issues. The time ranges available in this release for the Level 2 data products are:

TLIMB, TDISK & O2DEN: Oct 6 2018 – March 15 2019

ON2: Oct 6 2018 – Dec 31 2018

The ON2 release is more restricted in time due to concern about its higher sensitivity to the effects of instrument degradation and flat field gradients in the short wavelength region of the GOLD detectors (specifically the oxygen 135.6 nm emission).

This release contains no Level 2 data from Channel B, since the underlying Level 1 Channel B data is being held back pending resolution of the detector sensitivity characterization (see section 3.1.5). Level 2 Channel B data will be released after the corresponding Level 1 data is vetted and released.

All GOLD Level 2 files contain arrays for three separate components of the total error in retrieved geophysical parameters – random, systematic and model errors. In general, the error characterization for the Level 2 data products in this release is preliminary. Specifics for each data product are described in the sections that follow.

Each Level 2 data product file contains a list of data quality indices (DQI) specific to that data product. These DQI are defined at both the file and individual pixel level and are described in detail in the "***GOLD Public Data Product Guide***". That document also contains a description of each Level 2 data product, including a summary of the algorithm theoretical basis and a complete description of the contents of each Level 2 daily NetCDF file.

3.2.1 Issues with O2DEN data

3.2.1.1 Preliminary error analysis.

A comprehensive error analysis and retrieval characterization for the O2DEN product is in progress but has not yet been implemented in this release. Currently only the random error array is populated in the O2DEN files. These errors should be considered preliminary until the detailed error analysis is implemented.

3.2.1.2 Valid altitude range in retrieved O_2 profile.

The O2DEN data product – density profile of molecular oxygen (O_2) retrieved from stellar occultation (OCC) measurements – is retrieved on a fixed geometric altitude grid. However, the altitude range of the retrieved profile varies for each event (altitudes above and below the valid retrieval range for each event are populated by fill values). This is because the algorithm truncates the input measured atmospheric slant path transmission profiles to a fixed transmission range before input to the optimal estimation routine. A given transmission value will correspond to different tangent altitude levels as the absolute O_2 number density varies with geophysical conditions.

Pending a more complete retrieval characterization analysis to accompany the error analysis in a future release, a preliminary sensitivity study has been performed to characterize the degree of *a priori* bias in the O_2 retrievals. Figure 3-8 summarizes the results of this analysis. It shows the relative difference, in %, between the retrieved O_2 profile and the *a priori* profile for a random sample of ~500 occultations over 60 days. Difference profiles for the individual occultation events are shown in the left panel and daily averages are on the right. These plots clearly illustrate the behavior described above, with the retrieved O_2 converging to the *a priori* at both

high and low altitudes. Based on this analysis it is recommended that users assign the highest confidence to the altitude region between 130 and 190 km, which contains the most independent information on the absolute O_2 density profile. This range is denoted by the dashed horizontal lines in Figure 38. Currently the error bars and DQI reported in the O2DEN data files do not capture this data quality metric.

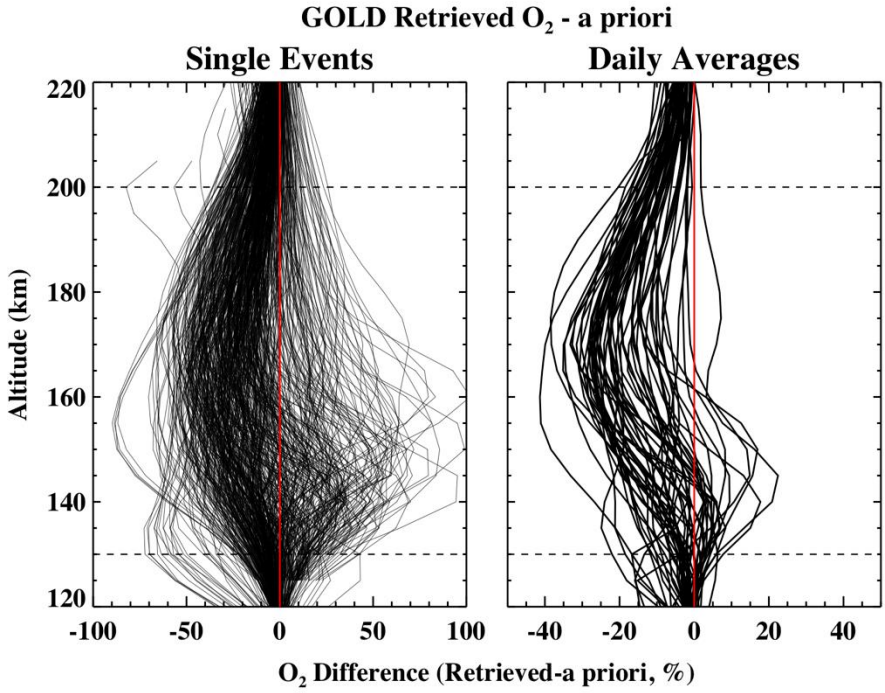

Figure 3-8 Variance between retrieved O2 profile and retrieval a priori.

3.2.1.3 Possible residual background bias in dayside O2DEN data.

GOLD performs occultation measurements on both limbs at all times during the day. Therefore, on average approximately half of the O2DEN retrievals are obtained on the sunlit limb. Under these conditions it is particularly important that the atmospheric airglow background be accurately removed from the data in the L1C processing (see Section 3.1.7 above). As noted above there are still some unresolved issues with the background removal, which can result in occasional artifacts (biases and/or negative spikes) in the OCC L1C data for these dayside events. These artifacts can propagate into the O2DEN retrievals. The most noticeable effect is an overall increase in noise level in the O_2 profiles for dayside events, particularly for events using the dimmer stars in the GOLD target star list. Both dayside and nightside data (Channel A only) are contained in this release. While users are not discouraged from using the dayside retrievals, for a more conservative screening of the data users can easily identify these events using the "dayside" flag in the event level DQI array, or by simply paying attention to the measurement solar zenith angle (an approximate flag for dayside events is SZA < 100 degrees).

3.2.1.4 O2DEN data gap.

There is a gap of approximately one month in the O2DEN data set, between the dates of December 17, 2018 and January 13, 2019. During this time period a glitch in the GOLD operational planning caused errors in the instrument pointing and timing which resulted in missed occultations. This data will not be recoverable in the future since no underlying L1C data are available.

3.2.2 Issues with TLIMB data

The primary issues with TLIMB data are degraded performance at large SZA and failure of the algorithm to converge to a physical solution.

3.2.2.1 Preliminary error analysis

A comprehensive error analysis and retrieval characterization for the TLIMB product is in progress but has not yet been implemented in this data release. Currently only the random error array is populated with non-fill values in the Level 2 files. These errors should be considered preliminary until a more detailed error analysis is performed.

3.2.2.2 Stars in the field of view

It is common for stars to be observed within the field-of-view of the detector during limb scans. An example showing multiple stars within the field-of-view can be seen in Figure 3-9. When a star appears in the field-of-view it can alter the shape of the N_2 LBH limb profile producing systematic biases in retrieved exospheric temperatures. Therefore, the TLIMB algorithm code implements a star detection algorithm that utilizes the difference between stellar and airglow spectra. When a star is detected in the field-of-view the TLIMB algorithm is not run and the corresponding DQI is set to a non-zero value. Note that the star detection algorithm is not 100% reliable, thus false positive and negative detections may occur. Users are advised to independently review the Level 1C data for stars in the field-of-view when working with the TLIMB data.

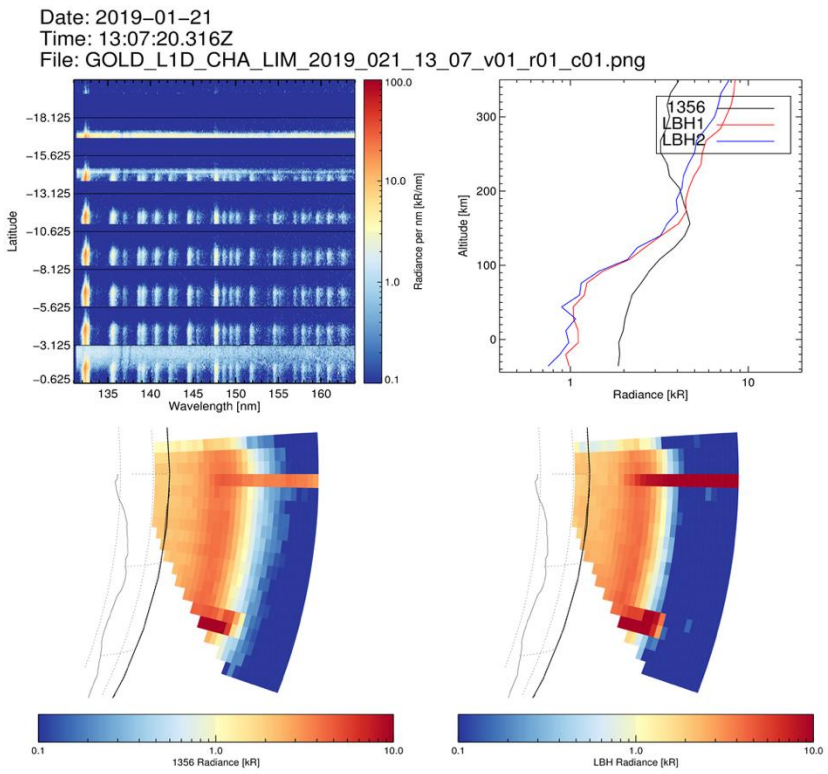

Figure 3-9 Level 1D plot showing observation of multiple stars in the field-of-view during a limb scan.

3.2.2.3 Latitude constraints

The signal-to-noise ratio at the edge of the detector is typically low during southern hemisphere scans, which can produce systematic biases in retrieved temperatures. Therefore, the TLIMB algorithm is not run (TLIMB is set to fill value and DQI set to non-zero value) when the latitude of southern hemisphere limb scan data is greater than 2.5 degrees. Note that northern hemisphere scans may also be affected by low signal-to-noise at the edge of the detector, though no latitude constraint is currently imposed for northern scans (i.e. the TLIMB algorithm is run in this case). Users are advised to use caution when working with TLIMB data derived from the edges of the detector.

3.2.2.4 Tangent altitude constraints

The TLIMB algorithm is only run if the tangent altitudes span the range from 250 km (or higher) to 160 km (or lower) and there are no NaNs in the corresponding Level 1C LIM brightnesses or uncertainties. If this condition is not met then the TLIMB value is set to a fill value and the corresponding DQI is set to a non-zero value.

3.2.2.5 Degraded performance at large SZA

When the SZA is between 60 and 90 degrees the TLIMB algorithm is run but a corresponding DQI is set to a non-zero value indicating degraded algorithm performance. The algorithm is not

run when the SZA > 90 degrees. Users should apply extra caution when working with TLIMB data products when algorithm performance is degraded.

3.2.2.6 Algorithm failure

Occasionally the TLIMB algorithm will fail to converge when fitting an observed N_2 LBH limb profile. If the algorithm fails to retrieve an exospheric temperature the TLIMB value is set to a fill value and the corresponding DQI is set to a non-zero value.

3.2.2.7 Possible residual background bias

As noted above there are unresolved issues with the removal of background in Level 1C data. Residual background in the LIM L1C data can produce an apparent increase in the slope of the N_2 LBH limb profile. This is most likely to occur during periods of enhanced particle background. These Level 1C artifacts can subsequently propagate into the TLIMB temperature retrievals. The most noticeable effect is an apparent (but false) increase in the exospheric temperature. At present, there is no check for residual background in the TLIMB algorithm code, thus users are advised to monitor environmental conditions at the spacecraft and to apply extra caution when working with TLIMB data products during periods of enhanced particle background.

3.2.3 Issues with TDISK data

The primary issue with TDISK data is marginal signal-to-noise.

3.2.3.1 Preliminary error analysis

A comprehensive error analysis and retrieval characterization for the TDISK product is in progress but has not yet been implemented in this data release. Currently only the random error array is populated with non-fill values in the Level 2 files. These errors should be considered preliminary until a more detailed error analysis is performed.

3.2.3.2 Signal-to-noise ratio

The TDISK algorithm uses the shape of measured spectra to infer the effective temperature of the neutral atmosphere (for each Level 1C DAY pixel). Thus, high signal-to-noise ratio data are necessary for retrieving statistically significant temperatures. Due to the high spatial resolution of current Level 1C DAY data, the corresponding spectral signal-to-noise is low, resulting in relatively large uncertainties in retrieved TDISK temperatures. Improvements in the signal-to-noise of Level 1C DAY data through spatial binning and/or improvements in the TDISK algorithm code are planned for future releases.

3.2.3.3 SZA and EMA constraints

The TDISK algorithm code is not run when the SZA > 80 degrees and/or the EMA > 75 degrees.

3.2.3.4 Effective altitude.

GOLD day disk observations sample a height range of approximately 150 to 200 km, but observed temperatures are weighted by the peak volume emission rate at altitudes where there is a significant temperature gradient. Since the GOLD disk observations represent a column integration of the weighting function (i.e. there is no altitude information), the effective height of derived temperatures must be determined with the aid of forward modeling. This work has not yet been completed, thus we report a fixed altitude of 150 km for the effective disk temperature in the present release.

3.2.3.5 Algorithm failure

Occasionally the TDISK algorithm will fail to converge when fitting an observed spectrum. If the algorithm fails to retrieve an effective neutral temperature the TDISK value is set to a fill value and the corresponding DQI is set to a non-zero value.

3.2.3.6 Sources of contamination

The two primary sources of contamination that may produce artifacts in the TDISK retrieved temperatures are residual background and energetic particles. The former is not expected to produce significant artifacts; however users are advised to monitor environmental conditions at the spacecraft and to apply extra caution when working with TDISK data products during periods of enhanced particle background. Energetic particles, particularly in the polar regions, are more likely to result in TDISK artifacts. At present, there is no auroral boundary detection algorithm implemented in the Level 2 operational pipeline, therefore users are advised to use caution when working with TDISK data when the geomagnetic latitude > 60 degrees.

3.2.4 Issues with ON2 data

The primary issue with ON2 data is marginal signal to noise, particularly with N_2 LBH intensities.

3.2.4.1 Preliminary error analysis.

A comprehensive review of errors associated with ON2 is in progress. Uncertainty values in ON2 files should be considered preliminary.

3.2.4.2 Contamination of ON2

The O/N_2 algorithm is only valid when the source of O I 135.6 nm and N_2 LBH emission is photoelectrons generated by solar EUV flux. Other sources of these emissions are considered contaminants and will result in erroneous derived O/N_2 values. The main sources of the contaminant emissions for the O/N_2 algorithm are energetic particle precipitation in the polar regions (affecting both 135.6 nm and LBH) and radiative recombination of O^+ in the equatorial ionization anomalies (affecting only 135.6 nm). At present, there is no auroral boundary

detection algorithm implemented in the Level 2 operational pipeline, therefore users are advised to use caution when working with ON2 data where the geomagnetic latitude > 60 degrees. Similarly, users are advised to use caution when working with ON2 data during geomagnetically active periods that may produce enhanced radiative recombination emission in the equatorial ionization anomalies.

3.2.4.3 Limits of the algorithm

The O/N_2 values are not derived where the solar zenith angle is greater than 80 or emission angles greater than 75. DQI flags not set bitwise.

4 Upcoming Work / Plan for Upcoming Releases

4.1 Level 1

Updated sensitivity

Updated scattered light correction

Flatfield correction

Updated geolocation correction (slit image movement)

Updated occultation background correction

Channel B data release

Quality flags for stars and moon in field of view

4.2 Level 2

Release of additional TDISK, TLIMB, ON2 and O2DEN data past the cutoff dates in the current release.

Release of NMAX and QEUV data.

Release of Channel B data.

Better characterization of error components on retrieved geophysical parameters.

Improve signal to noise for dayside disk products – TDISK and possibly ON2. For TDISK, possible ways to stabilize the retrieval include fixing the vibrational populations. For TDISK and/or ON2, explore increased spatial binning – results in decreased resolution.

More complete retrieval characterization and error analysis for O2DEN data.

Auroral boundary detection algorithm.

4.3 Level 3

N/A for this release