### OLI Detector Response Characterization (Solar Diffuser)

#### Background

The Primary radiometric calibration devices on OLI are solar diffusers. These Spectralon panels are rotated in position in front of the OLI aperture and the spacecraft is oriented so as to bring sunlight in the solar diffuser port so that sunlight is reflected into the OLI aperture. There are 2 solar diffusers on-board OLI, a Primary and pristine. The current plan calls for the Primary diffuser to be deployed approximately weekly during normal operations. The pristine diffuser will be deployed on a less frequent basis and used to monitor degradation of the Primary panel. The OLI diffuser data provides a valuable source for deriving radiometric gain updates for L1r processing, performing instrument characterizations and monitoring uniformity and stability requirements. Both radiance and reflectance based gains will be derived and stored.

To derive radiance gains, both bias and nonlinearity corrected OLI data (0Rc) values (in DN) and diffuser spectral radiance values (W/m2-sr m) are required. With the exception of a correction for Earth-Sun distance, the diffuser spectral radiance values are relatively static as the sun reflects off the diffuser at a fixed angle and the diffusers are expected to change slowly in reflectance characteristics. The radiance values adjusted to a reference Earth-sun distance can be stored in the CPF. (Note. there may be multiple versions of these values i.e., prelaunch, postlaunch and current that could be stored in a single CPF or as separate CPFs). The Earth-Sun distance correction will be derived from JPL ephemeris data. Gains will be generated and output as per detector relative gains, and band-averaged gains. Similar outputs for reflectance-based gains will be derived based on spectral reflectance values (unitless) in place of the spectral radiance values.

Approximately 500 frames of data with the solar diffuser illuminated will be acquired per typical collect. However, there are some less frequent acquisitions that will change the size of these data sets. These collects will be acquired at variable integration times for non-linearity characterization and only the nominal integration time portion of these collects will be processed by this algorithm. A second acquisition scenario involves 60 second long solar diffuser collects; these collects are used to evaluate the short-term stability of the OLI response.

Ephemeris and attitude data will be processed and used to confirm the solar pointing during each solar acquisition. This processing may occur in part separately prior to use in this algorithm. It is assumed that all ancillary data for verification of the acquisition will come from the wideband ancillary data. Separately, the MOC will provide the CVT a report on the solar calibration maneuver indicating whether the maneuver was executed as planned, e.g., the solar pointing was as required.

To track pristine and Primary diffuser datasets a diffuser parameter needs to be identified, associated with the appropriate inputs and output parameters and stored in the trending DB. Artifacts will be accounted for in the L0rc inputs to processing.

Assessment of algorithm outputs will be performed by comparing the “original” solar radiance and reflectance calibrated products, to “new” solar products derived with the newly derived gains. While not performed by this algorithm, these product generation steps should be considered a routine part of “solar characterization process.” The evaluation of these products and reports will be performed ‘off-line’

#### Inputs

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Descriptions | Symbol | Units | Level | Source | Type |
| L0rc1 (Bias corrected and linearized) Means | Qnet | DN | Nband x Ndet | Db (Histogram) | Float |
| L0rc Stdev1 | Qnet | DN | Nband x Ndet | Db (Histogram) | Float |
| Start time |  | GMT |  | Db | Float |
| Stop time |  | GMT |  | Db | Float |
| Number of lines used |  |  |  | Db (Histogram) | Int |
| Inoperable Detectors |  |  | Nband x Ndet | CPF | Int |
| Attitude Control System Quaternion Coefficients | Q0,Q1,Q2,Q3 |  |  | Ancillary Preprocessing | Fltarr |
| Diffuser Radiance2 @nominal SZA, E-S Distance (1A.U.) | L | W/m2 sr m | NDT x Nband x Ndet | CPF | Float |
|  |  |  |  |  |  |
| Diffuser Deployment Angle |  | degrees |  | Ancillary File | Float |
| Earth –Sun Distance 3 | des | AU |  | Auxiliary File | Float |
| Diffuser Bidirectional Reflectance Factor2 |  |  | NDT x Nband x Ndet | CPF or Ancillary | Float |
| Integration Time |  |  |  | Header or DB |  |
| Diffuser Type (DT) i.e., Pristine or Primary |  |  |  | L0R |  |
| Start\_time |  |  |  | L0R |  |
| Stop\_time |  |  |  | L0R |  |
| Collection Type |  |  |  | L0r, Metadata |  |
| Sun Zenith Angle Mean | Θs | degrees |  | Report, Db |  |
| Sun Zenith Angle Stdev | Θs | degrees |  | Report, Db | Float |
| Sun Azimuthal Angle Mean | Φs | degrees |  | Report, Db | Float |
| Sun Azimuthal Angle Stdev | Φs | degrees |  | Report, Db | Float |

Notes:

1 Mask artifacts presumed to be accounted for in the imagery, prior to generating

histogram statistics. Histogram statistics should also include the solar integration time

sweep data acquired at the nominal integration time.

2 Parameters must be stored separately identifiable by the Diffuser Type (DT i.e.

Pristine or Primary).

3 From JPL data

#### Outputs

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Descriptions** | **Symbol** | **Units** | **Level** | **Target** | **Type** |
| Start time |  |  |  | Report, Db | Float |
| Stop time |  |  |  | Report, Db | Float |
| Lines averaged |  |  |  | Report, Db | Int |
| Relative Gains Mean 2 | Grel |  | Nband x Ndet | Db | Float |
| Relative Gain Stdev2 | G rel |  | Nband xNdet | Db | Float |
| Radiance-Band Avg Gains Mean 2 | G | DN/  W-m2-sr-m | Nband | Report, Db | Float |
| Radiance-Band Avg Gains Stdev 2 | G | DN | Nband | Report, Db | Float |
| Reflectance-Band Avg Gains Mean 2 | G | DN | Nband | Report, Db | Float |
| Reflectance-Band Avg Gains Stdev 2 | G | DN | Nband | Report, Db | Float |
| Diffuser Type | DT |  |  | Report, Db | Int |
| Deployment Angle |  | degrees |  | Report, Db | Float |
| View Sun Zenith Angle Mean3 | Θv | degrees |  | Report, Db | Float |
| View Sun Zenith Angle Stdev3 | Θv | degrees | Nband | Report, Db | Float |
| View Sun Relative Azimuthal Angle Mean3 | Φv | degrees | Nband | Report, Db | Float |
| View Sun Relative Azimuthal Angle Stdev3 | Φv | degrees |  | Report, Db | Float |
| Incident Sun Zenith Angle3 | Θs | degrees |  | Report,Db | Float |
| Incident Sun Zenith Angle Stdev3 | Θs | degrees |  | Report,Db | Float |

#### Options

Summary report to be generated with every solar processing run.

#### Procedure

Note, while all procedure steps will be identical for both Diffuser Types (DT) Primary panel (both nominal and Time Sweep acquisitions) and the Pristine panel, certain inputs (as identified by the input table) needs to be identified/processed by its Diffuser Type (DT).

1.0 Verify solar acquisition:

* 1. Read in ancillary data and verify/output solar collect information e.g.

Diffuser Deployment Resolver Position

Collect Sequence

Integration Time

Verify the integration time is nominal.

IF not verified THEN stop processing ELSE

* 1. Derive Solar Angles:

Sun angles are calculated in the Landsat 8/9 Solar Calibration Frame of Reference system (LSCF). In the solar calibration mode the spacecraft is aligned to the LSCF i.e., the pitch axis is aligned to the sun (-Y), and the yaw axis to the projected nadir vector (+Z). *Angle(s) should be constant over the entire acquisition with pointing control..* Fig 1 illustrates the vectors and angles wrt to a diffuser panel (small oval), mounted within the rotating calibration assembly (large oval).

s = incident angle between diffuser normal and sun vector direction

v = view (scatter) angle between diffuser normal and sensor line-of

sight vector.

Both theta angles should be about 45 degrees wrt prelaunch

alignment of the diffuser prelaunch that should remain

constant throughout the mission.

ϕv = view (scatter) relative azimuthal angle between diffuser normal

and sensor line-of sight

+x (sc velocity)

+y

Sensor view (-z) +z (nadir)

Θ**sun** Φ**view Spacecraft Frame of Reference**

Diffuser Normal

Figure 6‑108. Diffuser Solar Angles Defined wrt Diffuser Normal Component

1.2.1 Process S/C Attitude: Extract spacecraft (ACS) quaternion coefficients from ancillary data preprocessing, corresponding to calibration interval.

* + 1. Retrieve JPL Solar Ephemeris i.e., sx,sy,sz

For all Attitude quaternion values in solar cal acquisition

* + 1. Transform sun vectors from Earth-centered to LSCF for all ephemeris points in acquisition.

Xs,Ys,Zs = TR \* sx,sy,sz using values from 1.2.1 and 1.2.2

Where:

TRansform Matrix =

TR(0,0) = 1-2\*(q2(i)^2+q3(i)^2)

TR(1,0) = 2\*(q1(i)\*q2(i)+q0(i)\*q3(i))

TR(2,0) = 2\*(q1(i)\*q3(i)-q0(i)\*q2(i))

TR(0,1) = 2\*(q1(i)\*q2(i)-q0(i)\*q3(i))

TR(1,1) = 1-2\*(q1(i)^2+q3(i)^2)

TR(2,1) = 2\*(q0(i)\*q1(i)+q2(i)\*q3(i))

TR(0,2) = 2\*(q0(i)\*q2(i)+q1(i)\*q3(i))

TR(1,2) = 2\*(q2(i)\*q3(i)-q0(i)\*q1(i))

TR(2,2) = 1-2\*(q1(i)^2+q2(i)^2)

* + 1. Derive array of sun angles using transformed sun components i.e.,

Xs, Ys, Zs,

panel orientation components i.e.,

Xn = 0.

Yn = -cos(45.)

Zn = -sin(45.)

and view direction components i.e.

Xv = 0.

Yv = 0.

Zv = 1

Incident Solar Zenith Angle

cosi = Xn\*Xs + Yn\*Ys+Zn\*Zs

sini = sqrt (1-cosi^2)

ϑs= atan(sini/cosi)

View Solar Zenith Angle

cosi = atan ( Xn\*Xv + Yn\*Yv+Zn\*Zv)

sini = sqrt (1-cosi^2)

ϑv = atan(sini/cosi)

View Solar Relative Azimuthal Angle

cosa = Xns\*Xnv+Yns\*Ynv+Zns\*Znv

sina = sqrt(1-cosa^2)

ϕv = atan (sina/cosa)

Where Xns,Yns,Zns = sun normal , the cross product of

XnYnZn with XsYs,Zs i.e.

Xnv,Ynv,Znv = view normal , the cross product of

XnYnZn with XYZ-view direction

components i.e., the only non-zero view

component (zv=1) along the sensor view axis.

End Attitude loop

* + 1. Derive sun angle means and standard deviations

Θs = mean(ϑs) & Θs = Stdev(ϑs)

Θv = mean(ϑv) & Θv = Stdev(ϑv)

Φv =mean(ϕv) & Φv = Stdev(ϕv)

##### 2.0 DERIVE RADIANCE GAINS:

FOR each Band

2.1 Read per detector spectral radiances - L (b,d)

2.2 For date of acquisition, read in appropriate value of Earth-Sun distance, des

FOR each detector

2.3 Read in L0rc means (<Qnet (b,d)>) and standard deviations (Qnet (b,d)) derived from histogram statistics

2.4 Derive absolute per detector gain mean and standard deviation, i.e.

G(b,d) = des 2 \* <Qnet (b,d)>/ L(b,d) (3)

G(b,d) = des 2 \* Qnet (b,d)/ L(b,d) (3a)

END detector loop

* 1. Generate/output the band mean gain and standard deviation (over all operable

detectors)

GaBands(b) = < G(b,\*)> & GaBands(b) = Stdev(G(b,\*)) (4)

2.6 Generate/output the per detector mean relative gain and standard deviation , wrt to the per band average.

Grel (b,d) = G(b,d)/GaBands(b) &

G rel (b,d)= G(b,d) /GaBands(b) (5)

END band loop

##### 3.0 DERIVE REFLECTANCE GAINS:

For each bands

For each detector:

3.1 Read per detector bidirectional reflectance factors (b,d)

3.2 Derive absolute per detector average reflectance gains G(b,d),

and per detector reflectance gain standard deviations G(b,d) = i.e.

G(b,d) = (Qnet (b,d) \* des 2 )/((b,d) \* cos (Θs)) (6)

G(b,d) = (Qnet (b,d) \* des 2 )/((b,d) \* cos (Θs)) (6a)

Where Qnet (b,d) = per detector diffuser corrected response

(b,d) = diffuser reflectance factors

Θs = solar zenith diffuser angle (nominally 45°)

des = Earth-Sun distance

End detector loop

3.3 Generate/output the band mean gain and standard deviation (over all operable detectors)

GaBands(b) = < G(b,\*)> and GaBands(b) = Stdev (G(b,\*)) (7)

End bands

4.0 Generate summary report for every processing run with hardcoded

formats. (Example format)

SOLAR CALIBRATION SUMMARY REPORT

Report Date

Start Acq Time

Stop Acq Time

Total Acq Time

Diffuser Type: (i.e., Pristine, Primary )

Collect Sequence Type: (i.e., Nominal, Integration Time Sweep)

Integration Time:

Solar Distance and Diffuser Angles:

E-S Distance (AU)

Deployment Angle (degs)

Solar Zenith Angle (Theta-i, degs)

View Zenith Angle (Theta-v, degs)

Sun Azimuth Angle (Phi-v, degs)

Ephem Outliers:

Image Stats (Bias Corrected & Linearized)

BandID Avg Stdev

Diffuser Radiance & Diffuser Gains

BandID Avg Avg Stdev

Diffuser Reflectance & Reflectance Gains

BandID Avg Avg Stdev

Total Frames Processed:

#### Maturity

- This algorithm can be adapted to process actual scene data for alternative relative gain derivation method.

Issues:

- Assessments of CPF spectral radiance values based upon

prelaunch measurements, could lead to in-line derivation of

radiance for each acquisition.

- Hardcoded report format.