In-Band OLI-2 Relative Spectral Response

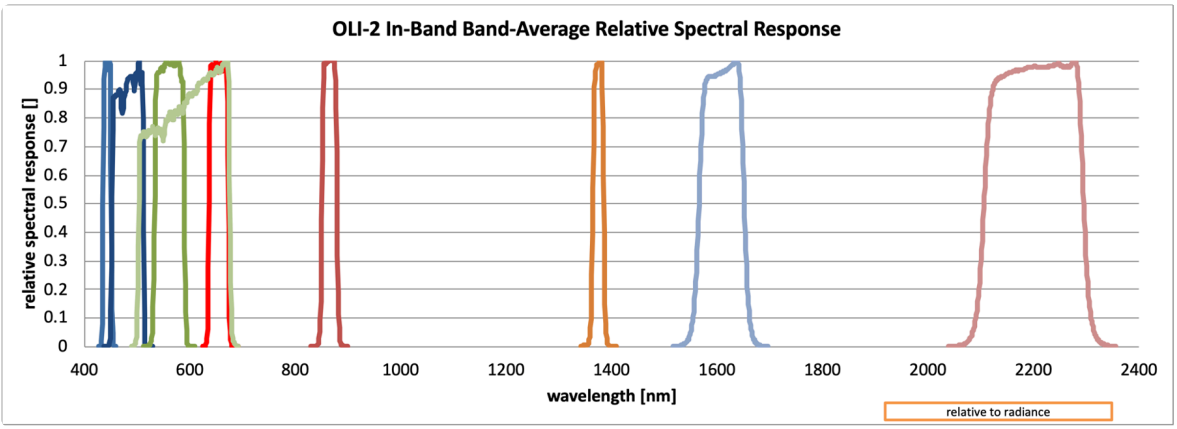

Figure 1. The band-average relative spectral radiance responses of OLI-2.

The band-average relative spectral radiance responses of the Operational Land Imager-2 (OLI-2) are provided (Figure 1). A per-band summary is provided in Table 1. The module-average in-band RSRs are provided here . These responses are based on measurements made of the fully assembled instrument under thermal vacuum (TVAC) conditions conducted at the Ball Aerospace, the instrument vendor's facility.

Band	Band Width [nm]	Lower Band Edge [nm]	Upper Band Edge [nm]	Center Wavelength [nm]
CA	15.51	435.06	450.57	442.81
Blue	59.87	451.96	511.82	481.89
Green	56.50	532.71	589.20	560.95
Red	36.88	635.88	672.76	654.32
NIR	28.77	850.26	879.03	864.64
SWIR1	86.12	1565.11	1651.23	1608.17
SWIR2	189.44	2105.44	2294.87	2200.16
Pan	172.47	503.09	675.56	589.32
Cirrus	20.90	1363.68	1384.57	1374.13

Table 1. Summary statistics of the band-average relative spectral radiance responses of the OLI-2.

The instrument level measurements of OLI-2 were made using the Goddard Laser for Absolute Measurement of Radiance (GLAMR) facility. This is a change from the Landsat-8 OLI, where a lamp and monochromator-based illumination system was used. GLAMR consists of a system of tunable lasers that are fiber coupled to an integrating sphere (Figure 2), which can provide a near full field-of-view, uniform target for instrument characterization. The radiance inside the sphere is measured by radiometers which have a NIST-traceable calibration. While GLAMR does provide a calibration of the absolute response of the instrument, only the relative responses of OLI-2 are presented here.

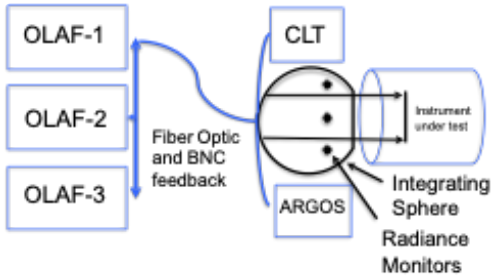

Figure 2. Schematic of the GLAMR configuration. The output of a tunable laser is fiber coupled to an integrating sphere in front of the instrument under test. GLAMR has five laser tables in this configuration: three custom built OPO Laser Alignment Facilities (OLAFs) and two commercial systems (CLT and ARGOS). The three radiance monitors are measuring the monochromatic energy inside the integrating sphere at the same time as the instrument under test is viewing it.

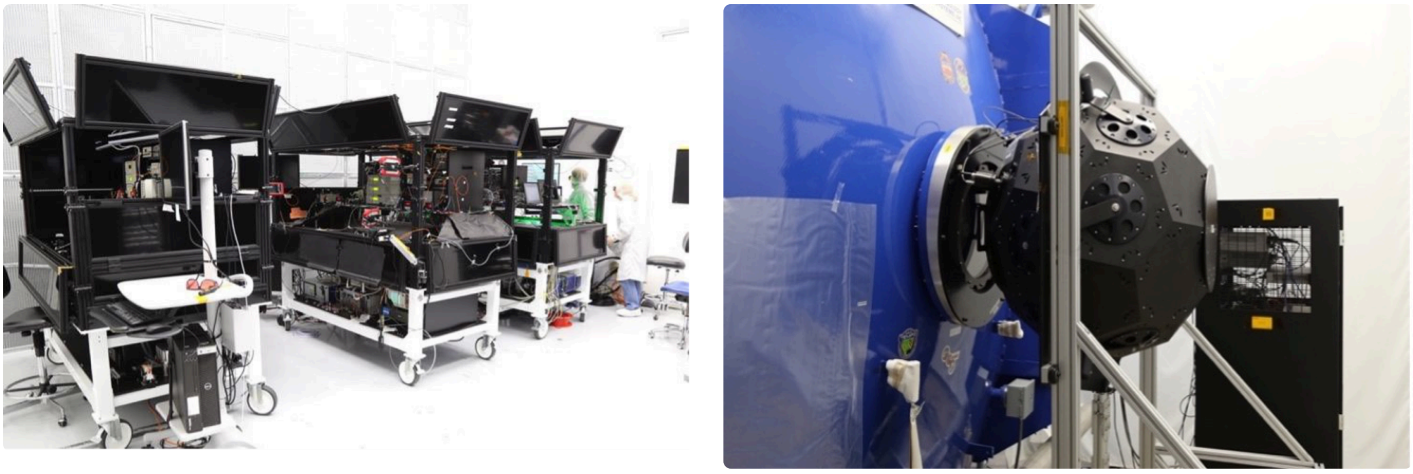

Figure 3. The GLAMR set up at Ball. On the left, the three laser tables are located in a room adjacent to the TVAC chamber. The integrating sphere and the TVAC chamber are shown on the right before covering the sphere and chamber window with a light-tight shroud. OLI-2 sits inside the chamber looking directly at the port of

The GLAMR provided light between 350 and 2500nm; at 1 or 2nm intervals for the in-band response regions and 10 or 20 nm intervals for the out-of-band response regions (Table 2). The in-band region for each spectral band was defined as the wavelengths between the 0.005 relative spectral response points. To compute the relative spectral response, the absolute spectral responsivity was calculated for every detector of every band:

$$ASR_i(\lambda) = \frac{Q_{\lambda,i}}{L(\lambda)}$$

where ASRi(λ) is the absolute spectral responsivity [DN/w/cm2 sr] of detector i, Qλ,i is the dark-subtracted, linearized digital response [DN] of an OLI-2 detector to the GLAMR signal and L(λ) is the radiance [W/cm2 sr] leaving the GLAMR integrating sphere. The relative spectral response of detector i (RSRi) is the peak-normalized ASR for each band.

$$RSR_i(\lambda) = \frac{ASR_i(\lambda)}{\max\left(ASR(\lambda)\right)}$$

The spectral response analysis was performed by both Ball and NASA/GSFC independently on these data. The results presented here are from the Ball analysis.

The band-average and module-average spectral responses are provided here for each band. The largest spectral differences across the focal plane are the result of filter-to-filter variations. All OLI-2 bands include spectral filters from different production lots across the 14 modules; OLI had two bands where all filters were from the same lot. The extent of the module-to-module variation depends on how well the spectral transmission of the production lots matched. In the NIR, the filters from the multiple lots were well matched, so there is little spectral difference across the modules due to filter transmission; however, in SWIR1, the lots are less well matched, though are well within requirements, and spectral differences between the modules are apparent (Figure 4).

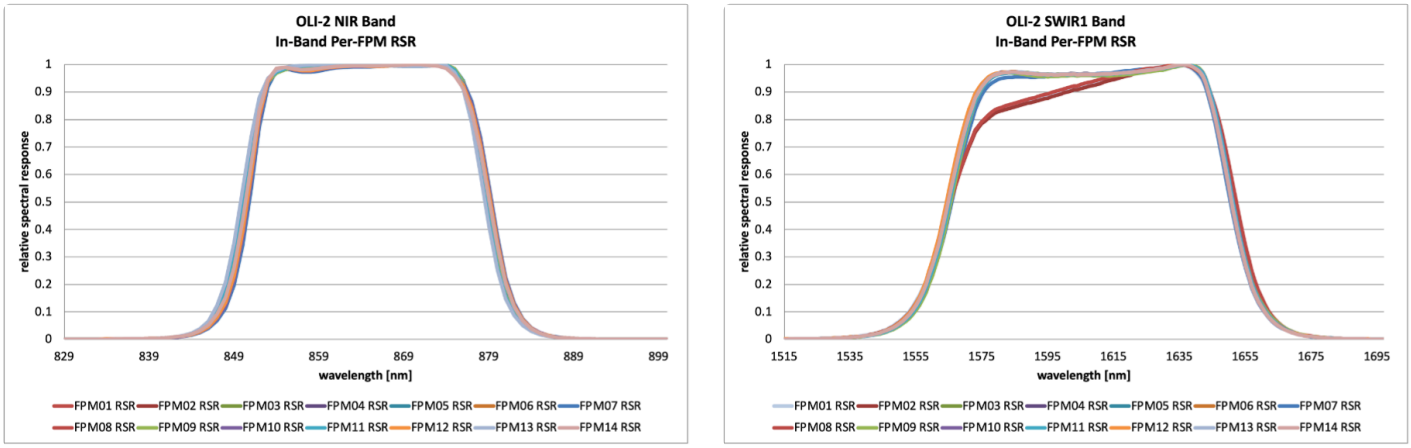

Figure 4. Two examples of within-band variation in relative spectral response. For the NIR band (Band 5), eight of the modules have filters from the first wafer and six modules have filters from the second wafer; differences are small. In the case of the SWIR1 band (Band 6), filters from three production lots were used; ten from one lot, three from a second lot and one from a third lot. The transmission of the filters from the second lot is the most different of the three.

The GLAMR measurements allowed for the characterization of non-uniformities across filters that had not previously been detected. In CA FPM7 and SWIR1 FPM9, there are regions where the responses drop by as much as 9% at certain wavelengths for some detectors (Figure 5). These regions likely indicate small defects in the filters.

The linked spreadsheets contain the band-averaged or FPM-averaged in-band relative spectral response, sampled at 1nm intervals. The FPM-averaged file also includes the spectral responses for two individual detectors each on CA FPM7 and SWIR1 FPM9. More details on the measurement of the OLI-2 spectral responses can be found in [Barsi, 2019]

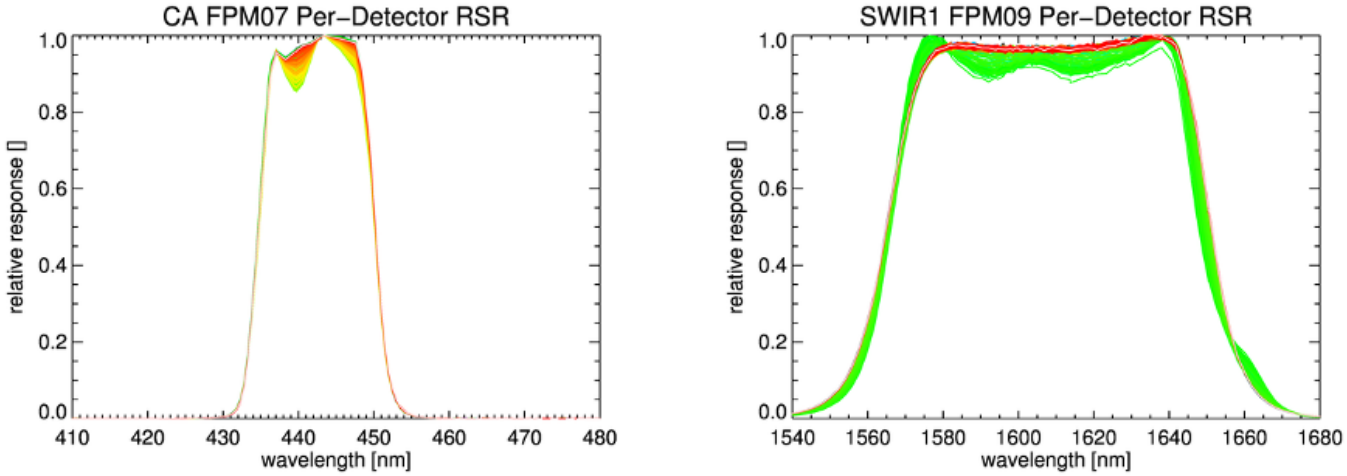

Figure 5. Per-detector RSR variation for the CA FPM7 and SWIR1 FPM9 detectors. Each figure shows the spectral responses for all 494 detectors on the module. On the CA module, about 170 detectors are affected likely by a defect in the filter, with the response dropping from about 0.955 to as low as 0.86. On the SWIR1 module, about 100 detectors are affected, where the response drops from about 0.965 to as low as 0.90.

Spectral Band Region	Spectral range [nm]	GLAMR wavelength step size [nm]	GLAMR linewidth (approximate) [nm]
OOB	350-430	10	0.05
CA, Blue, Green	428-600	1	0.10
Pan	600-630	2	0.15
Red, Pan	630-684	1	0.15
OOB	680-840	10	0.10
NIR	836-894	1	0.10
OOB	890-1100	10	0.20
OOB	1100-1350	20	0.20
Cirrus	1346-1404	1	0.20
OOB	1404-1514	20	0.20
SWIR1	1514-1698	2	0.20
OOB	1690-2050	20	0.20
SWIR2	2038-2365	2	1.00
OOB	2365-2500	20	1.00

Table 2. Sampling specifications during instrument-level spectral testing of OLI-2. The out-of-band (OOB) regions are defined as regions where the response is less than 0.005 in all bands.

References:

https://landsat.gsfc.nasa.gov/satellites/landsat-9/landsat-9-instruments/oli-2-design/

https://glamr.gsfc.nasa.gov

https://landsat.gsfc.nasa.gov/landsat-8/spectral-response-operational-land-imager-band-band-average-relative-spectral-response

Julia A. Barsi, Brian L. Markham, Joel McCorkel, Brendan McAndrew, Eric Donley, Eric Morland, James Pharr, Michael Rodriguez, Tim Shuman, Andrei Sushkov, Barbara Zukowski, “The Operational Land Imager-2: prelaunch spectral characterization,” Proc. SPIE 11127, Earth Observing Systems XXIV, 111270B (9 September 2019);https://doi.org/10.1117/12.2529776