Absolute spectral irradiance of the Moon as measured by the Airborne Lunar Spectral Irradiance (Air-LUSI) instrument during the March 2022 flight campaign.

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1 Introduction

In March of 2022, Air-LUSI conducted its first operational flight campaign. It flew on four out of five scheduled nights aboard the National Aeronautics and Space Administration (NASA) ER-2 high-altitude aircraft out of NASA Armstrong Flight Research Center (FRC) in Palmdale, CA and measured the lunar spectral irradiance in the visible and near infrared from approximately 21 km in altitude. On each night of the campaign Air-LUSI was calibrated in the hangar prior to flight and again following the conclusion of the campaign. NIST was involved in the design and development of the Air-LUSI instrument through the NASA Airborne Instrument Technology Transition (AITT) program.

The Air-LUSI instrument and its associated lunar tracking system have been described in several peer-reviewed publications [1–5]. Briefly, Air-LUSI consists of a 125 mm aperture telescope with an approximately 1.6° field of view that focuses into an integrating sphere. An optical fiber carries light from the integrating sphere to a spectrograph. A tracking system acquires and tracks the Moon during flight and a control system allows the instrument to be operated from four switches in the aircraft cockpit. Additionally, there is a reference light emitting diode (LED) that can inject light into the integrating sphere to measure the stability of the instrument during flight.

The Air-LUSI instrument was calibrated in hangar 703 at NASA Armstrong prior to each flight using a lamp illuminated integrating sphere (IS) source with an angular extent similar to the Moon. The irradiance of the source was measured with a transfer spectrograph (TS) that was traceable to a NIST FEL lamp irradiance standard and then the IS source was measured by the Air-LUSI instrument to transfer the calibration. A description of the data reduction and uncertainty analysis [6] has been published and the measurement equation derived was:

$$E^{TOA}_{Moon} = \frac{1}{\tau_{TOA}} \frac{S^{Moon}_{LUSI} T}{S^{IS}_{LUSI}} \left(\frac{D_1}{D_2}\right)^2 \frac{S^{IS}_{TS}}{S^{FEL}_{TS}} E_{FEL} \tag{1}$$

where E^{TOA}_{Moon} is the top-of-atmosphere (TOA) lunar irradiance, τ_{TOA} is the atmospheric transmittance along the path from the instrument to the Moon, S is the signal measured by the instrument in the subscript while observing the source in the superscript, T is the ratio between the responsivity of Air-LUSI during lunar acquisition and during ground calibration, D_1 and D_2 are the distances of the TS and air-LUSI from the IS calibration source, and E_{FEL} is the irradiance of the FEL lamp used to calibrate the TS. A schematic of the calibration setup is shown in Figure 1.

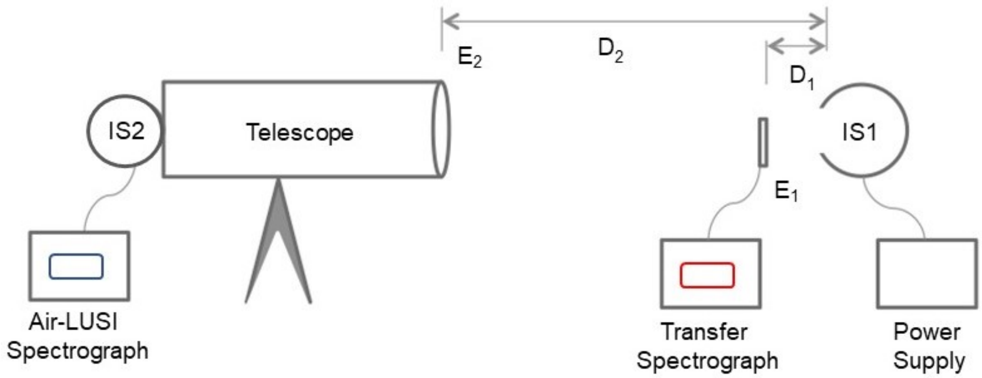

Figure 1: Schematic of the calibration of Air-LUSI. The transfer spectrograph measured the irradiance of the IS, E_1, at a distance D_1, followed by Air-LUSI measuring the irradiance E_2, at a distance D_2. Using the inverse square law, $E_2 = E_1(D_1/D_2)^2$.

2 Description of Test

The test involved several steps that led to the SI-traceable lunar spectral measurements. These included the characterization of the Air-LUSI instrument, the calibration and characterization of a transfer spectrograph, the calibration of the Air-LUSI instrument on the ER-2 aircraft, the lunar irradiance measurements, and corrections for atmospheric transmission.

2.1 Spectrograph characterization

The lunar irradiance measurements used two spectrographs: one in the Air-LUSI instrument and one as a transfer spectrograph used to calibrate Air-LUSI before each flight. Both spectrographs are commercial (Instrument Systems, CAS-140CT), fiber-fed, instruments with charge coupled device (CCD) arrays. The transfer spectrograph (SN 68914209) has a cosine-corrected fore-optic optimized for irradiance measurement at the end of the input fiber; the fiber for the Air-LUSI spectrograph (SN 332014217) collects light from the integrating sphere at the back of the telescope. Characterization of both spectrographs included, assigning wavelengths to the pixels, measuring the bandwidth, assessing the stray light, and measuring the linearity of the irradiance response.

2.1.1 Linearity correction

The linearity of the spectrographs was assessed using a beam conjoiner system. [7, 8] Light from a current-stabilized incandescent lamp was split along two paths each with a filter wheel with a set of neutral density filters, then recombined and passed through a third filter wheel with neutral density filters before illuminating the spectrographs. Spectra were acquired using every possible combination of neutral density filters in the three filter wheels in a randomized order.

2.1.2 Wavelength, bandwidth and stray light

The wavelength assignments, bandwidth measurement, and stray light correction were all assessed using spectra obtained by introducing laser light tuned in 5 nm wavelength increments across the wavelength range of the spectrograph. For the transfer spectrograph the laser illuminated the irradiance head of the spectrograph and for the Air-LUSI instrument the laser illuminated the integrating sphere. The laser was a 1 kHz pulsed OPO system (EKSPLA NT-242) and the wavelength was measured by a laser spectrum analyzer (High Finesse, LSA-UV2, sn 2017). The methodology used to produce the stray-light correction is an updated version of that used by Zong [9].

2.2 Air-LUSI characterization

Characterization of the Air-LUSI instrument was performed in the Telescope Calibration Facility (TCF) at NIST [10]. The instrument was designed to measure the irradiance of a calibration source approximately 12 m away as well as the Moon. So, the instrument response as a function of distance was measured in this range and the uniformity of the field of view was assessed.

2.2.1 Inverse square test

A 30 cm diameter integrating sphere with a 10 cm aperture was placed on a tripod on the sled in the TCF. The sphere was illuminated by a current stabilized quartz tungsten halogen (QTH) lamp. The sphere was positioned from 10.5 m to 16.5 m from the Air-LUSI telescope in 1 m intervals and at each position the telescope and sphere were aligned and the distance between the front of the telescope and a 6.2 mm thick face plate on the integrating sphere was measured with a laser range finder (Leica, Disto D2). Air-LUSI acquired spectra at each location.

2.2.2 Field of view uniformity

The air-LUSI telescope was set up on a robotic telescope mount at a distance of 14.46 m $\pm$ .05 m from a white LED diode source. The mount was configured to be controlled in az-alt mode with alt only a few degrees above horizontal, so that for plotting purposes, treating az and alt as cartesian coordinates causes only minimal distortion. Baffles made of blackened aluminum foil were placed to prevent light from the diode scattering off of the (also black) room walls and entering the telescope. A list of 625 az-alt points spanning a $3° \times 3°$ region was generated and its order randomized. The telescope was then directed to each of the points and a spectrum acquired. This test was performed with an earlier version of the sphere core.

2.3 Transfer spectrograph responsivity calibration

The transfer spectrograph was calibrated for irradiance responsivity using an FEL lamp following the methodology of NIST Special Publication SP250-89 [11]. The FEL lamp used was serial number F-747 and was calibrated for irradiance at the NIST FASCAL-2 facility [12, 13]. It has previously been demonstrated that the repeatability of the spectrograph calibration over time [14] when the instrument is undisturbed between calibrations is very good. Reproducibility before and after shipping the instrument can be somewhat more inconsistent, at the fraction of a percent level. The irradiance head of the spectrograph was mounted on a stage aligned to the optical axis of the FEL lamp and a laser beam was retroreflected to establish proper alignment. The distance between the FEL alignment jig and the irradiance head was set to 50.00 cm. The FEL lamp was ramped to a nominal current of 8.2 A over several minutes and allowed to warm up for a minimum of twenty minutes before spectra were taken. The actual current was measured by reading the voltage drop across a calibrated 100 mOhm shunt resistor (Omega Labs, RTD P1385, SN 21077) [15] using a calibrated digital voltmeter (HP 3458A, SN US28031926) [16]. Spectra were taken directly viewing the lamp and with a disc obscuring the lamp for background subtraction. Additionally, a series of ten spectra were taken at 25.4 mm intervals to verify the inverse square dependence for irradiance and to fit for the effective distance of the irradiance head from the FEL lamp. The high flux of the FEL lamp required that the spectrograph be operated with an internal neutral density filter in place during calibration. The transmission of the filter was determined by measuring the the response with and without the filter at a distance from the FEL sufficient to avoid saturation.

2.4 Air-LUSI responsivity calibration

The Air-LUSI instrument needed to be disassembled for uploading onto the ER-2 aircraft which required that it be calibrated after it was installed. When installed on the aircraft the spectrograph was in an environmental enclosure in the mid-body of the wingpod and the telescope was in the aft-body with the optical fiber running between the two. For calibration, the telescope was removed from the aft-body without disconnecting the optical fiber. A calibration was performed after uploading onto the ER-2, before each scheduled flight, and after the last flight. A checklist ensured that all steps were performed in order for each calibration. The main overhead lights in the ER-2 section of the hangar were turned off, but emergency lighting was on at all times.

To transfer the irradiance responsivity from the TS to Air-LUSI, both observed a lamp-illuminated, 30 cm diameter calibration sphere with a 10 cm aperture. The calibration sphere was placed on a tripod with a robotic telescope mount approximately 14 m from the telescope in a hut with three walls and roof that were opaque and the open side facing Air-LUSI. The sides of the hut are a black material to minimize the scatter of light into the telescope field of view. The transfer spectrograph was in a temperature controlled crate and allowed to stabilize for one hour before measurements were taken. The QTH lamp in the sphere was also allowed to stabilize for one hour. The telescope and the sphere were aligned to one another and the distance from the front of the telescope to the sphere, D_2, was measured with a laser range finder. The alignment used a laser mounted normal to the sphere aperture to align the sphere to the telescope and a computerized routine to scan the telescope vertically and horizontally to locate and center on the sphere. The distance from the front of the integrating sphere to the irradiance head of the transfer spectrograph, D_1, was measured with a Mitutoyo ruler. The transfer spectrograph measured spectra of the sphere and then ambient spectra with a disk obscuring the sphere aperture. The irradiance head was moved to the side and Air-LUSI measured the sphere spectra. The lamp was turned off and Air-LUSI measured a dark signal. The transfer spectrograph measured a Hg penlamp and Air-LUSI measured the output of an Ocean Optics Hg-1 lamp injected through the telescope. Air-LUSI measured the spectrum of the LED validation source. After calibration was complete, the telescope was reinstalled in the aft-body pod and the aircraft was towed to the runway to prepare for flight. A picture of the IS in the calibration hut is shown in Figure 2 and pictures of the Air-LUSI telescope on the stand for calibration are shown in Figure 3. MODTRAN version 6.0.2r5 is used to calculate the atmospheric transmission along the path from Air-LUSI to the calibration source to apply a small correction for the calibration[17, 18].

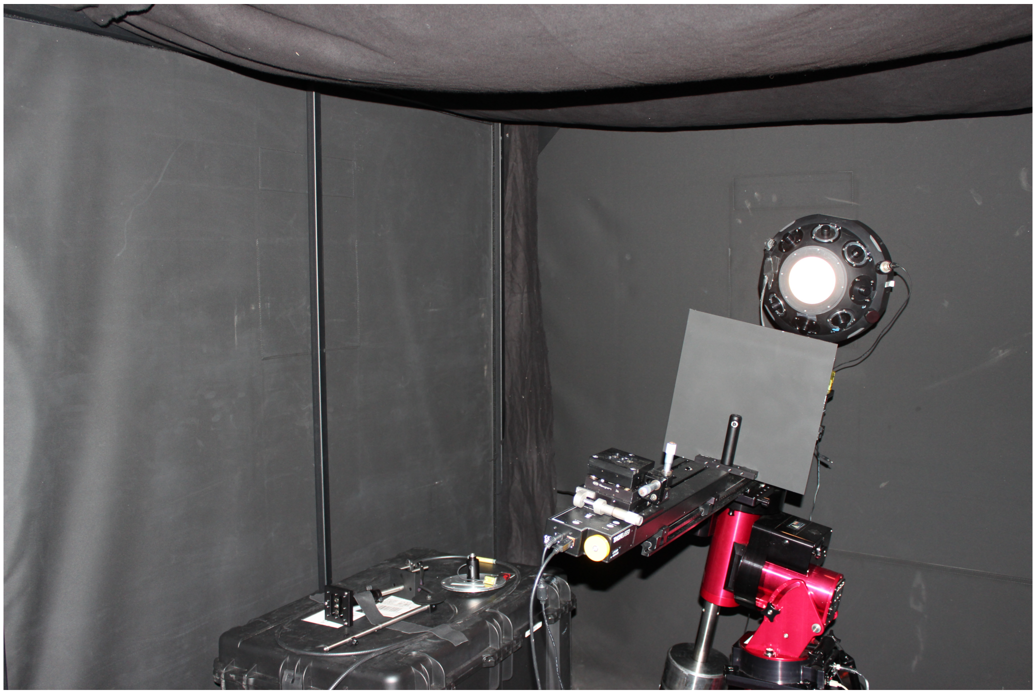

Figure 2: The calibration sphere source on a tripod in the black-walled calibration hut on the hangar floor at NASA Armstrong FRC.

Figure 3: The Air-LUSI telescope outside the wingpod of the ER-2 (left) in the NASA Armstrong Hangar. The sphere source as viewed from behind the Air-LUSI telescope (right). Photo Credit Ken Ulrich/NASA Armstrong.

2.5 Lunar irradiance measurements

During a typical flight the ER-2 requires 40 min to ascend to the acquisition altitude of 21 km then flies a flight line that keeps the Moon visible through the port in the wingpod for 40 min followed by a 40 min descent. During the ascent and descent light from the validation LED was injected into the sphere and measured both with a photodiode and the spectrograph to monitor for any changes in the sphere throughput between the ground calibration and the lunar measurements. Upon obtaining the flight line at altitude the LED was shuttered and the robotic pointing system was activated to unstow the telescope and acquire the Moon. At the end of the run, the telescope was stowed, the LED was unshuttered, and a nitrogen purge was started to reduce condensation inside the telescope. During the entire flight the spectrograph was recording files consisting of one 5.0 s dark spectrum (shutter internal to spectrograph) and three 5.0 s light spectra of either the validation LED or the Moon. While at altitude, the robotic tracking system was recording its performance which allowed us to flag when the system was locked on the Moon.

2.6 Atmospheric Transmittance

At 21 km altitude, Air-LUSI was above 95 % of the Earth's atmosphere, but the remaining 5 % still scatters or adsorbs a significant fraction of the light coming from the Moon. We again used MODTRAN6, in combination with aircraft telemetry and the lunar position to calculate the atmospheric transmittance along the path from Air-LUSI to the Moon. Ephemeris data were calculated using spiceypy, a wrapper on the NASA NAIF (Navigation and Ancillary Information Facility) SPICE (Spacecraft, Planet, Instrument, C-matrix, Events) toolkit [19, 20], with the following kernels loaded:
naif0012.tls, earth_assoc_itrf93.tf, earth_000101_230610_230317.bpc, earth_720101_070426.bpc, moon_assoc_pa.tf, moon_de440_200625.tf, moon_pa_de440_200625.bpc, de440s.bsp, pck00010.tpc.
The moon frame MOON_PA_DE440 was used with no aberration corrections and the "INTERCEPT/ELLIPSOID" method used for calculating subsolar and sublunar points.
The kernals are available from: Index of /pub/naif/generic_kernels (nasa.gov)

3 Results of Test

A data analysis pipeline was written in Python using Jupyter notebooks.

3.1 Spectrograph characterization

The characterization of the spectrographs allows for improved interpretation of the spectra that were collected and the assignment of uncertainties to the results. The data in this section was used to assign uncertainties in the upcoming sections. All spectra were collected in digital numbers (DN) per ms and converted to DN using the integration time to enable the use of the linearity correction, which is applied to DN. Spectra were then stray light corrected.

3.1.1 Linearity correction

The results of the beam conjoiner measurements, described in section2.1.1, were analyzed using a subset of pixels near the peak of the spectra where the counts varied by less than 1 %. The range of digital counts covered was from 0.003 of full scale to about 0.9 of full scale. The resulting correction factors were fit to a third order polynomial. The residuals have minimal structure and were not significantly improved with higher order fits. The standard deviation of the residuals was 0.09 % for both the transfer spectrograph and for the Air-LUSI spectrograph.

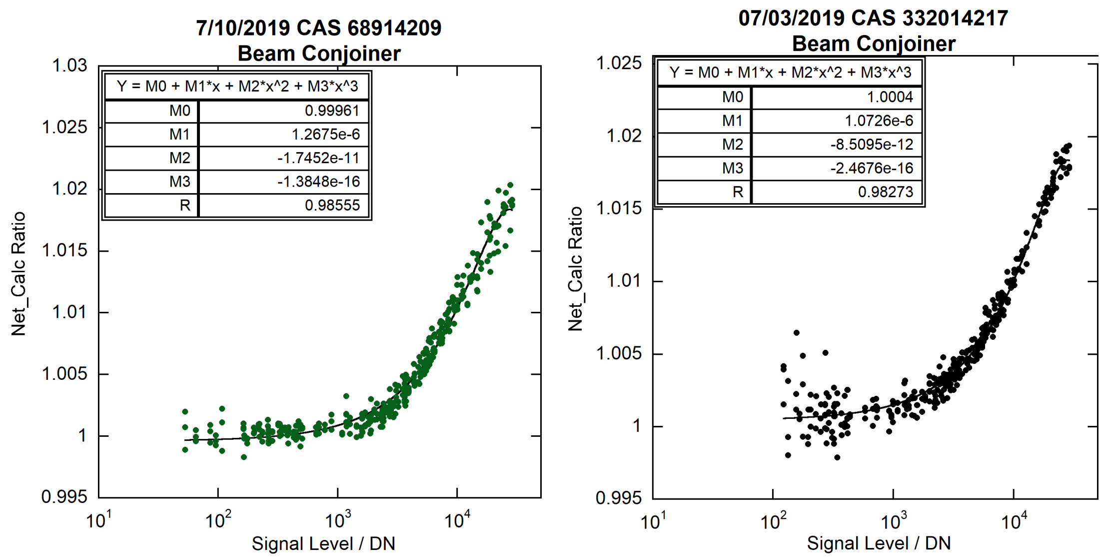

Figure 4: Linearity fits for the transfer spectrograph (left) and the Air-LUSI spectrograph (right).

3.1.2 Wavelength, linewidth and stray light

The line spread functions obtained from the laser line inputs were normalized to have a peak at unity and then multiplied by the relative spectral responsivity as seen in Figure 5. A Tikhonov Regularization was used to create a stray light correction matrix. As part of the regularization, a parameter, γ, was chosen to prevent amplification of noise. The result yields a wavelength assignment based on laser wavelengths measured by a calibrated laser spectrum analyzer and a spectral response function for each pixel of the spectrograph, the linewidth as a function of wavelength, and a stray light correction matrix.

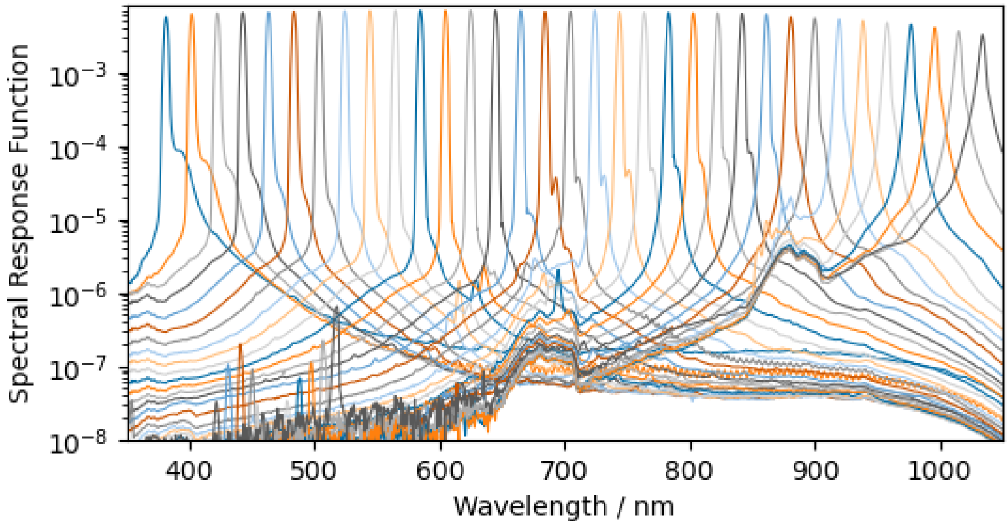

Figure 5: The responsivity-weighted, derived spectral response functions (srf) from every 25th pixel of the air-LUSI spectrograph.

3.2 Air-LUSI characterization

3.2.1 Inverse square test

To test the distance dependence of the instrument response as described in Section 2.2.1, the total counts in the spectra taken at each distance were fit to an inverse square law modified for the finite aperture size of the telescope and integrating sphere,

$$E = \frac{C}{((D - D_0)^2 + r_1^2 + r_2^2)} \tag{2}$$

where E is the irradiance, C is a constant, D is the distance from the telescope to the face plate of the integrating sphere, D_0 is the fitted offset parameter, r_1 is the radius of the telescope aperture, and r_2 is the radius of the integrating sphere aperture.

As seen in Figure 6, the resulting fit gave a value for D_0 of 4.4 mm $\pm$ 11.5 mm which is consistent with the 6.2 mm thickness of the face plate. The standard uncertainty in our measurements of D_2 was taken as 11.5 mm.

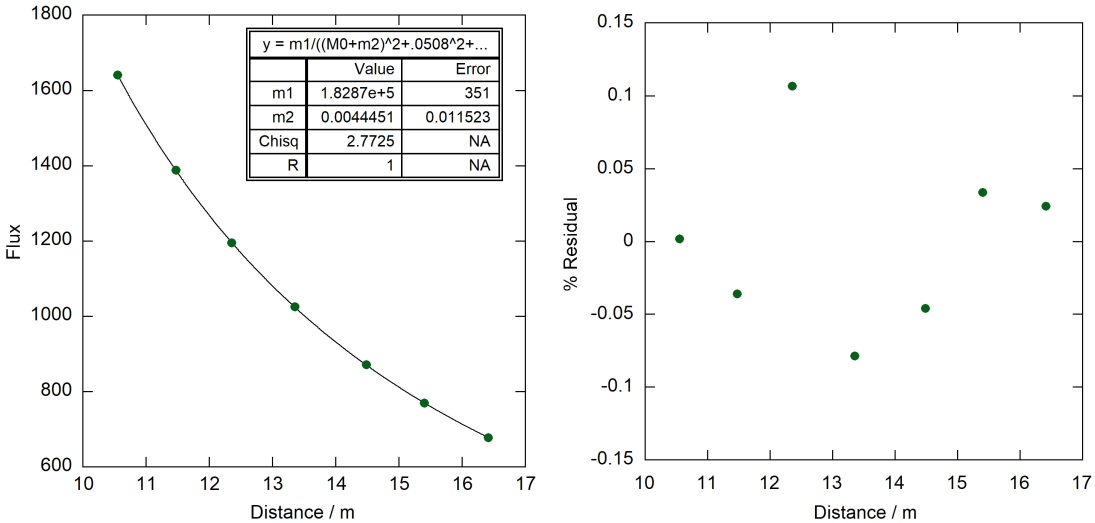

Figure 6: Results of the inverse square test of the air-LUSI telescope. Plot of flux vs. distance with fit to eqn. 2 (left). Points are integrated flux at given distance and line is least squares fit to modified inverse square law. Plot of % residuals vs. distance (right).

3.2.2 Field of view uniformity

Data from the spectra taken at the different pointings of the telescope were band averaged, and a contour plot generated. The gradient seen in Figure 7 is 1.15 % per degree offset from center at a 30°angle to the vertical axis. The data were found to have no significant spectral dependence when the entire lunar image is within the sphere, which can be expected due to the integrating sphere's high reflectivity across the visible spectrum. The co-alignment of the center of the tracking camera to the center of the calibration position is 1 camera pixel which corresponds to 0.053 degrees. This yields a 0.06 % $k = 1$ uncertainty from the field of view uniformity effect on the tracking alignment.

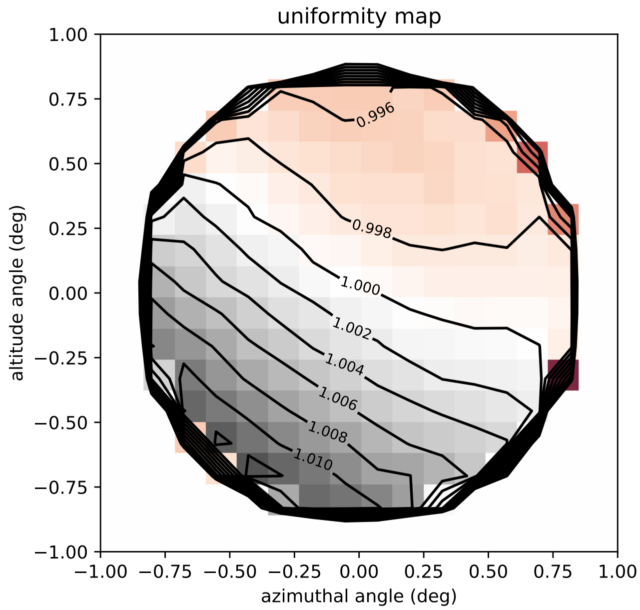

Figure 7: Contour plot of the Air-LUSI response uniformity.

3.3 Transfer spectrograph responsivity calibration

The irradiance responsivity of the transfer spectrograph was calibrated before and after the flight campaign. The two calibrations were averaged and the standard deviation was included as a repeatability term in the uncertainty budget. A distance uncertainty was derived from a fit to the inverse square law. Additional uncertainty terms derive from the uncertainty in the FEL irradiance calibration, the lamp current (both absolute measurement and drift) and the spectrograph measurement noise. The dominant uncertainty is from the calibration of the FEL irradiance. All the terms are combined to yield the TS irradiance responsivity uncertainty.

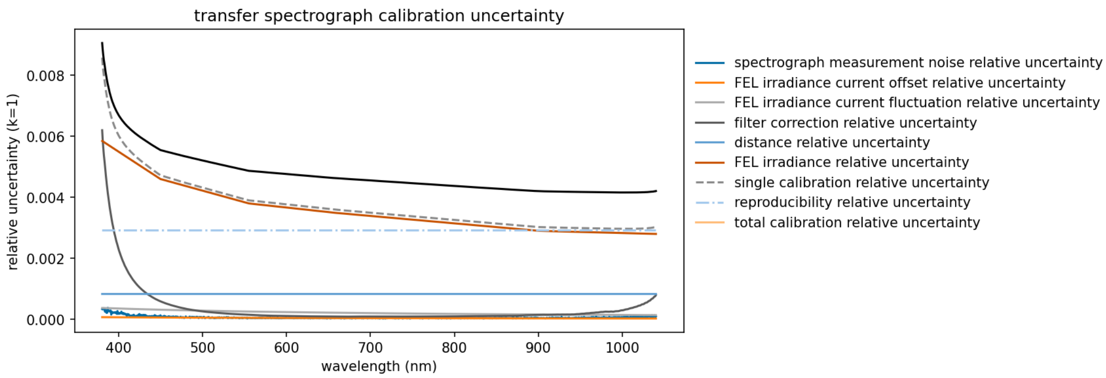

Figure 8: Contributions to the uncertainty in the calibration of the transfer spectrograph spectral irradiance responsivity as a function of wavelength. The dot-dashed line represents the reproducibility of the calibration before and after deployment. The dashed line is the uncertainty in a single calibration and is the root sum square (RSS) of all the uncertainty terms other than repeatability. The total TS irradiance responsivity uncertainty (solid black) is the RSS of the single calibration uncertainty and the reproducibility.

3.4 Air-LUSI responsivity calibration

Air-LUSI was calibrated in the hangar after upload onto the ER-2, prior to each of the five scheduled flights, and again after the final flight. There were no significant changes in the calibration while installed on the aircraft outside of the water absorption region around 930 nm. So, the seven calibrations were averaged to yield a single calibration used for all the flight data. The standard deviation of these measurements was included as the calibration coefficient repeatability uncertainty.

Each calibration proceeded in two steps, first the irradiance of the calibration sphere was measured with the TS and then Air-LUSI measured the calibration sphere. In calculating the the uncertainty of the calibration sphere irradiance it is noted that uncertainties due to wavelength assignment, linearity, and stray light correction were correlated with measurements made to calibrate the TS irradiance responsivity. The net uncertainties were entered here as seen in Figure 9. The uncertainty in the sphere irradiance was dominated by the uncertainty in the TS responsivity with some additional contribution from the distance measurement.

In Figure 10 we see that the uncertainty in the Air-LUSI irradiance responsivity is dominated by the uncertainty in the sphere irradiance with additional contributions from the repeatability of the seven calibrations and from the distance measurement. A contribution derived from a MODTRAN6 calculation of the atmospheric transmission along the path from the sphere to the telescope was included. This component is only significant in the water absorption region.

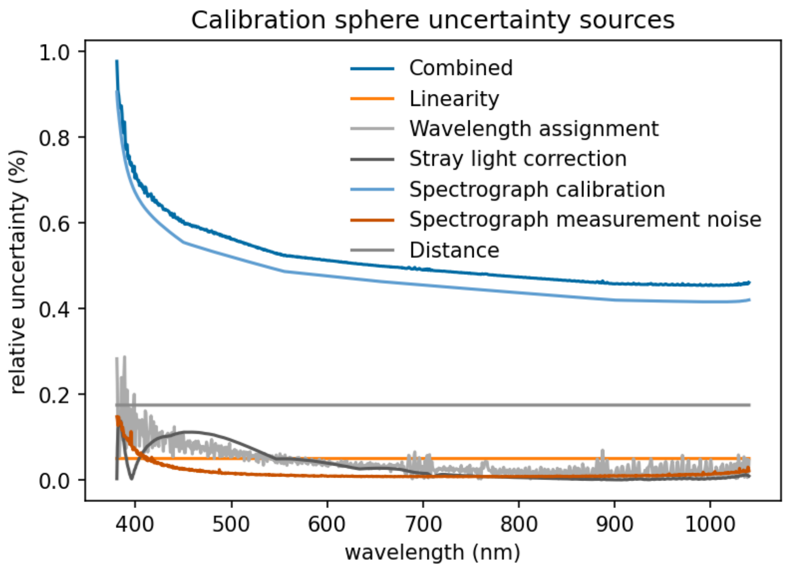

Figure 9: Contributions to the uncertainty in the measurement of the spectral irradiance of the calibration sphere by the transfer spectrograph as a function of wavelength.

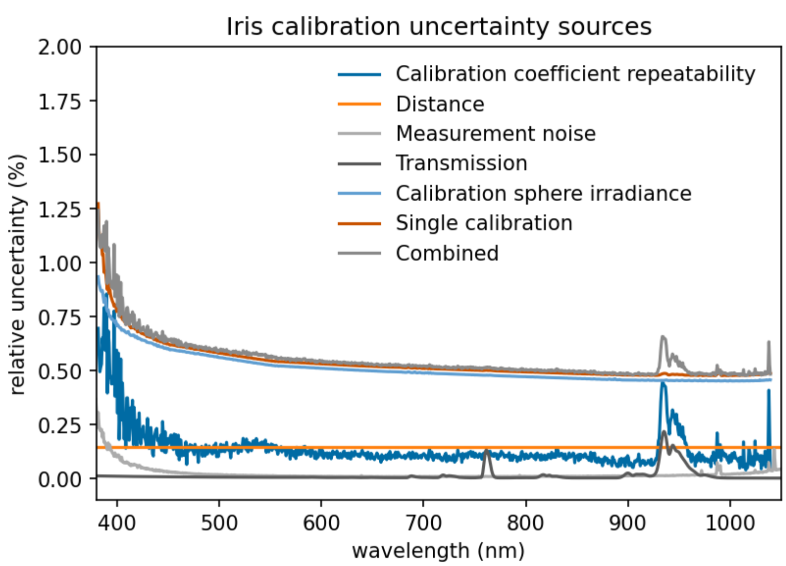

Figure 10: Contributions to the uncertainty in the calibration of Air-LUSI as a function of wavelength.

3.5 Lunar irradiance measurements

Upon reaching altitude and heading on the flight track the autonomous, robotic telescope mount instrument subsystem (ARTEMIS) lunar tracking system deployed the telescope. Data from the ARTEMIS system was used to flag which spectra were acquired while the telescope was aligned to the Moon during the flights. Flights 1, 3 and 4 maintained alignment with relatively few drop outs. Turbulence during Flight 5 prevented tracking for much of the flight with only intermittent lunar acquisitions, resulting in higher statistical uncertainty on that flight. The data collection from each flight lasted forty minutes during which time it can observe the change in lunar irradiance due to the change in position of the Sun, Moon and instrument. The instrument recorded a large number of cosmic ray events in the flight data and a filtering process to remove them was developed. Because a cosmic ray does not scatter energy in the spectrograph the way that light does (typically it affects only a few neighboring pixels) the cosmic ray events were removed prior to performing a stray light correction. The spectra were processed as follows to yield the at-sensor lunar irradiance with more details below:

1. Spectra taken while the tracking system was not on target were eliminated.
2. The data were linearity corrected.
3. Outliers (primarily cosmic rays) were eliminated.
4. The spectra were stray light corrected.
5. The instrument responsivity data were applied to the spectra.

To eliminate the outliers the change in irradiance during each flight was approximated as linear and a linear fit as a function of time was applied to the data from each pixel and the standard deviation of each data point calculated. The data point with the highest residual was removed, and the data were refit. This process was repeated until the change in standard deviation of the residuals was below a threshold that was determined experimentally. As seen in Figure 11, this process removed about 1.5% of the data, although it could remove up to 5%. The fraction of data removed was consistent with the fraction we have determined is necessary to remove using other methods. The data points that were removed were then replaced by the value predicted by the linear fit so that the stray light algorithm, which requires a complete spectrum, could run. A mask indicating which points were removed was stored for later use in data reduction. The stray light correction algorithm was applied to each spectrum and then the instrument irradiance responsivity was applied to yield the at-sensor lunar irradiance.

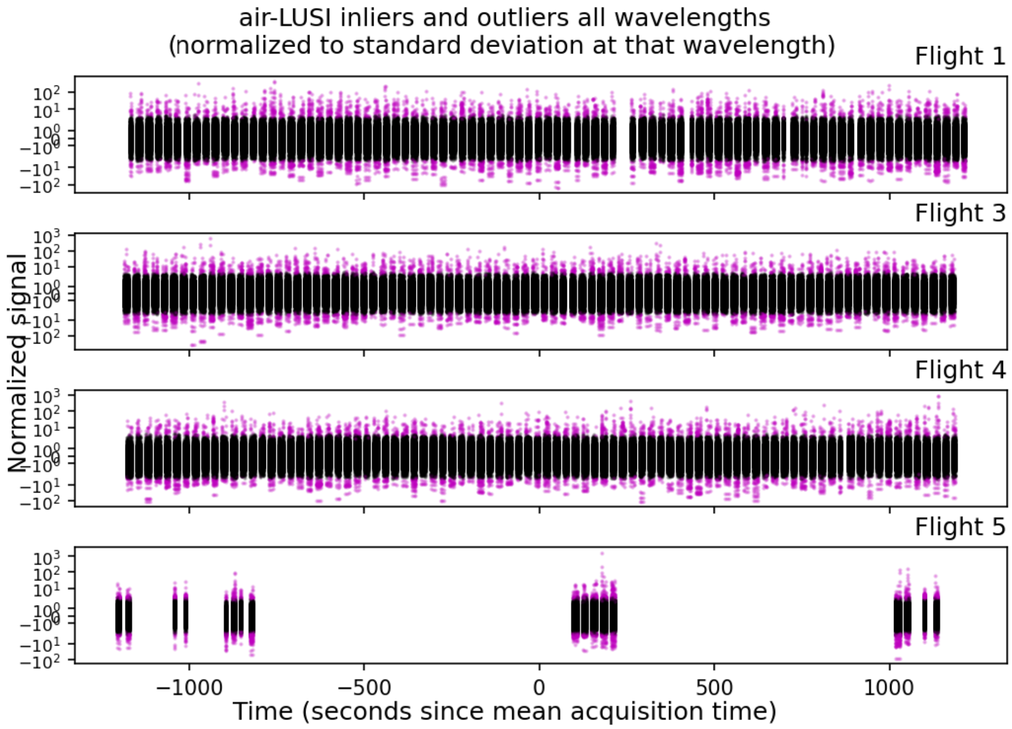

Figure 11: Plots of the inlier (black) and outlier (purple) data points for the four flights. The y-scale is a symlog scale of the normalized data and the x-scale is the flight time relative to the mean acquisition time. Each point in time shows the data from the entire spectrum. Sometimes the quantity here is known as the "z-score."

3.6 Atmospheric transmittance

The atmospheric transmittance between the aircraft and the Moon was calculated for each spectrum using MODTRAN6. Inputs to MODTRAN6 included the aircraft location using the altitude as measured by pressure, the instrument bandpasses, and the angle to the Moon. At these altitudes, the primary contributions in the instrument's wavelength range were from Rayleigh scattering, and O_2 and O_3 absorption. Figure 12 shows a plot of transmittance vs. wavelength from Flight 1. We estimated that the uncertainty in the transmittance was 10 % of the loss for poorly-mixed gases such as O_3 and 1 % for well-mixed gases such as O_2 and scattering losses.

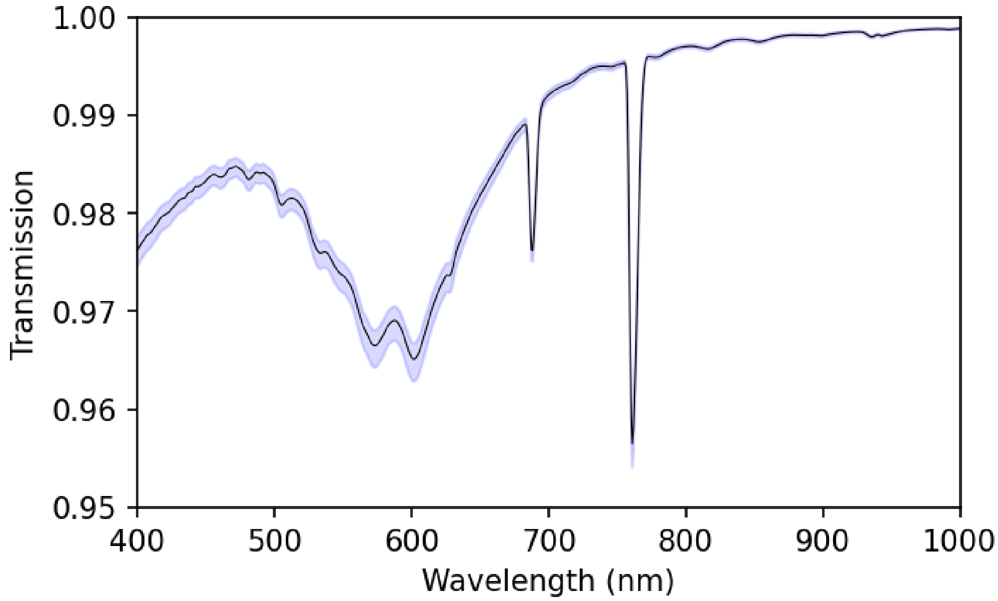

Figure 12: MODTRAN6 calculation of the atmospheric transmittance during Flight 1 as a function of wavelength. The black line is the value at the midpoint of the flight and the shading represents the range of values during data acquisition. The broad peak around 600 nm is ozone absorption and the narrow peaks near 690 nm and 760 nm are molecular oxygen.

3.7 Top-of-atmosphere lunar irradiance

The at-sensor lunar irradiance spectra were divided by the corresponding atmospheric transmittance to yield the top-of-atmosphere lunar irradiance spectra. For each flight, a linear fit was performed at each wavelength to account for the changing irradiance during the flight and the data were normalized to the time at the midpoint of the flight. The statistical uncertainty is reported by the linear fitting algorithm. The result is a top-of-the-atmosphere (TOA) lunar irradiance spectrum for a time and location corresponding to the midpoint of each flight. Figure 13 shows the TOA lunar irradiances for each of the four flights. The numerical data, showing time and location information as well as spectra, are in the data tables at the end of this report. Data reported have been corrected to the top of the atmosphere and standardized to a moon-observer distance of 384 400 km and a sun-moon distance of 1 astronomical unit (1.495978707 $\times 10^8$ km).

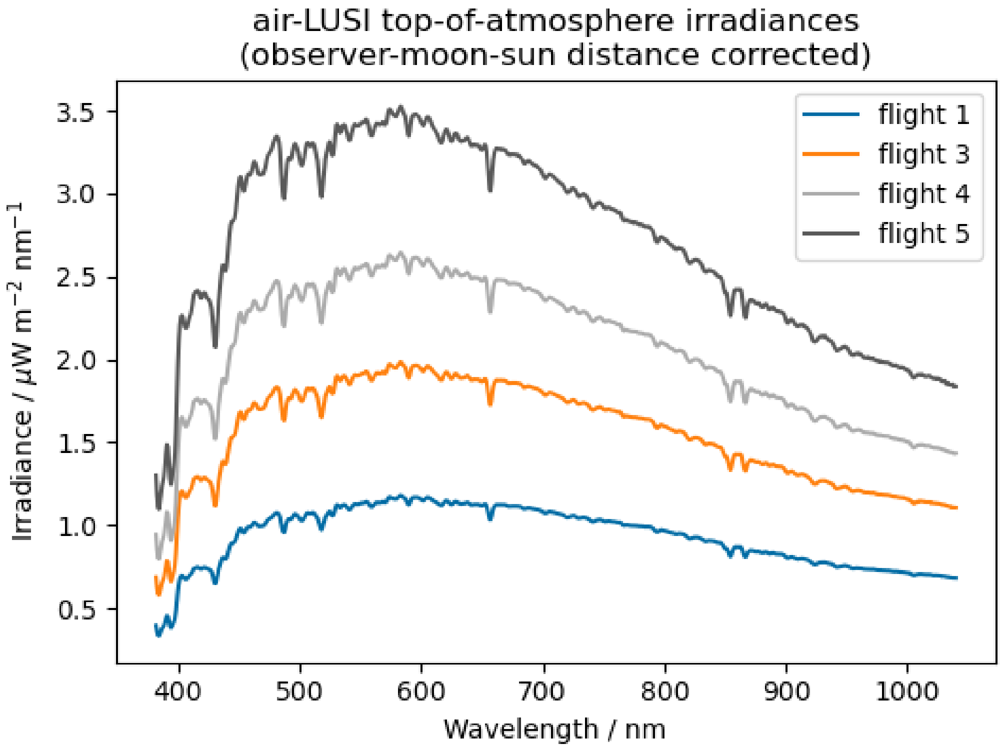

Figure 13: Top-of-atmosphere lunar irradiances for the 2022 Flight Campaign. These have been corrected to a standard observer-moon and sun-moon distance.

3.8 Uncertainty

In compiling the uncertainty budget we use standard methods as outlined in the Guide to Uncertainty in Measurement.[21] In several cases our uncertainties are correlated and the rest are treated as uncorrelated. In particular the spectrograph measurements are taken in pairs, the transfer spectrograph measures the FEL irradiance and the calibration sphere irradiance, and the air-LUSI spectrograph measures the calibration sphere and the Moon, and thus the linearity, wavelength and stray light uncertainties in each pair of measurements are correlated and treated as such.

For the wavelength uncertainty there is an uncertainty due to the wavelength assignment (wavelength uncertainty relative error) which is correlated and an uncertainty due to thermal drift (wavelength thermal uncertainty relative error) which is not.

Figure 14 shows the component uncertainty budget for Flight 1. The uncertainty is similar for all of the flights as the majority of the components are common to each flight.

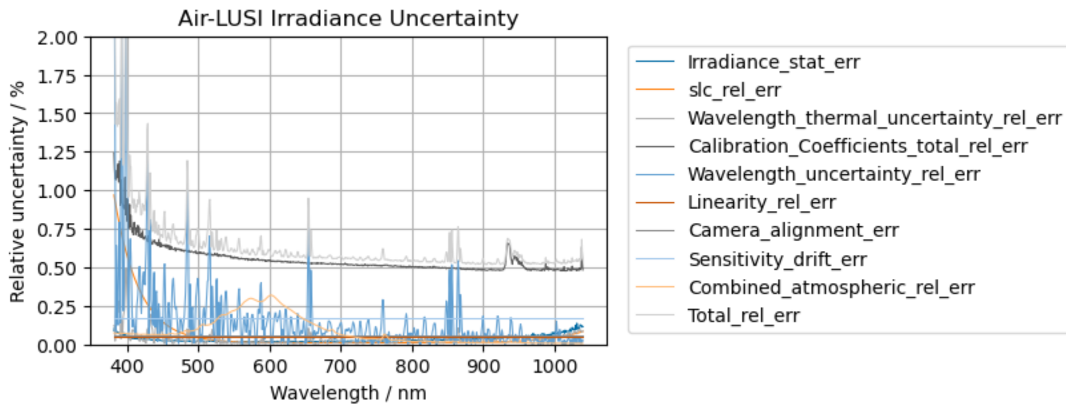

Figure 14: Uncertainty budget for Flight 1 showing the the different components as a function of wavelength.

4 General Information

4.1 Data analysis

The data analysis pipeline was written in Python using Jupyter notebooks. The input data files and pipeline code are archived at NIST at `https://gitlab.nist.gov/gitlab/air-lusi/air-lusi-pipeline/-/releases/release_for_calibration_report_20240930` and available upon request.

The code in pipeline uses the following dependencies: bokeh ≥ 3.5.1, pandas ≥ 2.2.2, polars ≥ 1.5.0, spiceypy ≥ 6.0.0, pyarrow ≥ 17.0.0, holoviews ≥ 1.14.9, hvplot ≥ 0.8.1, ruff ≥ 0.6.1, matplotlib ≥ 3.9.2, isort ≥ 5.13.2, jupyterlab ≥ 4.2.4, netcdf4 ≥ 1.7.1.post2, numpy ≥ 2.0.1, scipy ≥ 1.14.1, xarray ≥ 2024.7.0, seaborn ≥ 0.13.2, numba ≥ 0.60.0, datashader ≥ 0.16.3, ipywidgets ≥ 8.1.5, dask ≥ 2024.8.1, papermill ≥ 2.6.0, tomlkit ≥ 0.13.2, openpyxl ≥ 3.1.5, toml ≥ 0.10.2, jupyter-bokeh ≥ 4.0.5, altair ≥ 5.4.1, astropy ≥ 6.1.3, jplephem ≥ 2.22,

4.2 Data location

A GitHub repository was established for the sharing of data at `https://github.com/usnistgov/air-lusi`, and access is provided upon request.

4.3 Disclaimer

Certain commercial equipment, instruments, or software are identified in this report to foster understanding. Such identification does not imply recommendation or endorsement by the National Institute of Standards and Technology, nor does it imply that the materials or equipment identified are necessarily the best available for the purpose.

References

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5 Data Tables

Table 1: Acquisition times and locations in the WGS84 coordinate system.

Flight Number	Lunar Phase	Time (UTC)	Latitude	Longitude	Altitude (km)
1	-60.3	2022-03-13 06:10:13	35.012805	-117.860992	21.103513
3	-37.0	2022-03-15 03:55:38	36.748616	-118.315774	21.147951
4	-25.0	2022-03-16 07:25:16	35.911559	-116.324433	21.289029
5	-12.9	2022-03-17 06:49:06	34.700888	-116.878799	21.059663

Table 2: Lunar Spectral Irradiance.

	Irradiance / ($Wm^{-2}nm^{-1}$)			
Wavelength / nm	Flight 1	Flight 3	Flight 4	Flight 5
381.464	0.3945	0.6866	0.9437	1.2998
382.289	0.3607	0.6268	0.8615	1.1868
383.106	0.3398	0.5906	0.8108	1.1198
383.919	0.3334	0.5790	0.7965	1.0969
384.734	0.3475	0.6028	0.8294	1.1431
385.551	0.3645	0.6312	0.8690	1.1968
386.367	0.3772	0.6540	0.8986	1.2368
387.183	0.3840	0.6661	0.9164	1.2610
387.997	0.3934	0.6824	0.9375	1.2920
388.810	0.4132	0.7167	0.9843	1.3558
389.626	0.4379	0.7579	1.0413	1.4354
390.445	0.4528	0.7856	1.0790	1.4858
391.263	0.4495	0.7800	1.0706	1.4731
392.083	0.4237	0.7360	1.0077	1.3847
392.902	0.3940	0.6821	0.9354	1.2856
393.722	0.3817	0.6613	0.9074	1.2464
394.543	0.3895	0.6736	0.9240	1.2706
395.363	0.4027	0.6979	0.9575	1.3166
396.187	0.4169	0.7218	0.9909	1.3611
397.016	0.4403	0.7617	1.0448	1.4353
397.849	0.4803	0.8316	1.1406	1.5657
398.678	0.5424	0.9393	1.2884	1.7720
399.499	0.6043	1.0476	1.4349	1.9708
400.318	0.6496	1.1244	1.5412	2.1187
401.138	0.6787	1.1747	1.6101	2.2097
401.960	0.6938	1.2018	1.6456	2.2578
402.778	0.6969	1.2061	1.6518	2.2657
403.594	0.6937	1.2011	1.6432	2.2556
404.409	0.6847	1.1860	1.6230	2.2282

Irradiance / $(Wm^{-2}nm^{-1})$				
Wavelength / nm	Flight 1	Flight 3	Flight 4	Flight 5
405.225	0.6760	1.1708	1.6022	2.1960
406.042	0.6744	1.1664	1.5962	2.1893
406.860	0.6759	1.1701	1.6008	2.1929
407.680	0.6850	1.1851	1.6204	2.2198
408.500	0.6917	1.1963	1.6346	2.2415
409.319	0.6969	1.2058	1.6473	2.2612
410.138	0.7033	1.2163	1.6621	2.2773
410.959	0.7128	1.2326	1.6839	2.3073
411.778	0.7239	1.2524	1.7110	2.3453
412.597	0.7384	1.2776	1.7444	2.3888
413.415	0.7414	1.2823	1.7510	2.3977
414.235	0.7455	1.2881	1.7579	2.4089
415.054	0.7465	1.2900	1.7606	2.4101
415.872	0.7481	1.2923	1.7632	2.4147
416.691	0.7451	1.2885	1.7579	2.4062
417.511	0.7411	1.2805	1.7467	2.3877
418.331	0.7360	1.2700	1.7336	2.3708
419.150	0.7367	1.2717	1.7351	2.3701
419.968	0.7422	1.2817	1.7488	2.3919
420.788	0.7458	1.2872	1.7553	2.3997
421.607	0.7456	1.2867	1.7536	2.3991
422.424	0.7438	1.2835	1.7494	2.3915
423.241	0.7397	1.2757	1.7390	2.3732
424.058	0.7361	1.2702	1.7305	2.3646
424.876	0.7366	1.2699	1.7298	2.3639
425.693	0.7331	1.2633	1.7210	2.3497
426.511	0.7273	1.2535	1.7074	2.3313
427.329	0.7172	1.2367	1.6839	2.2988
428.147	0.6984	1.2037	1.6383	2.2354
428.965	0.6704	1.1570	1.5739	2.1486
429.783	0.6492	1.1183	1.5225	2.0788
430.600	0.6496	1.1176	1.5221	2.0748
431.416	0.6693	1.1512	1.5684	2.1407
432.232	0.7042	1.2120	1.6505	2.2533
433.049	0.7353	1.2658	1.7232	2.3501
433.865	0.7560	1.3008	1.7694	2.4141
434.682	0.7742	1.3328	1.8128	2.4727
435.499	0.7924	1.3633	1.8549	2.5279
436.316	0.8045	1.3852	1.8828	2.5669
437.133	0.8043	1.3839	1.8810	2.5644
437.952	0.7996	1.3759	1.8704	2.5512
438.770	0.7954	1.3671	1.8582	2.5332
439.588	0.8029	1.3795	1.8766	2.5579
440.405	0.8222	1.4133	1.9218	2.6173

Irradiance / $(Wm^{-2}nm^{-1})$				
Wavelength / nm	Flight 1	Flight 3	Flight 4	Flight 5
441.223	0.8460	1.4533	1.9757	2.6920
442.041	0.8670	1.4893	2.0240	2.7582
442.858	0.8832	1.5182	2.0623	2.8087
443.674	0.8904	1.5314	2.0784	2.8297
444.492	0.8923	1.5329	2.0813	2.8325
445.310	0.8940	1.5362	2.0857	2.8379
446.127	0.8991	1.5439	2.0966	2.8505
446.944	0.9106	1.5621	2.1214	2.8848
447.761	0.9284	1.5932	2.1633	2.9418
448.577	0.9467	1.6241	2.2058	2.9963
449.394	0.9640	1.6535	2.2450	3.0511
450.211	0.9769	1.6756	2.2734	3.0879
451.027	0.9800	1.6821	2.2813	3.1013
451.844	0.9735	1.6698	2.2648	3.0799
452.660	0.9617	1.6504	2.2375	3.0398
453.476	0.9547	1.6367	2.2191	3.0151
454.292	0.9561	1.6389	2.2219	3.0197
455.107	0.9674	1.6584	2.2486	3.0539
455.924	0.9782	1.6756	2.2721	3.0825
456.739	0.9859	1.6896	2.2904	3.1070
457.553	0.9893	1.6955	2.2966	3.1172
458.368	0.9886	1.6938	2.2945	3.1147
459.183	0.9892	1.6950	2.2945	3.1142
459.999	0.9938	1.7019	2.3048	3.1272
460.815	1.0039	1.7176	2.3267	3.1550
461.632	1.0117	1.7318	2.3451	3.1800
462.448	1.0163	1.7390	2.3535	3.1910
463.264	1.0128	1.7335	2.3470	3.1832
464.081	1.0080	1.7248	2.3345	3.1641
464.896	1.0001	1.7110	2.3160	3.1379
465.711	0.9943	1.7010	2.3025	3.1189
466.525	0.9932	1.6992	2.2990	3.1155
467.339	0.9934	1.6988	2.2981	3.1130
468.152	0.9947	1.7014	2.3001	3.1168
468.965	0.9955	1.7016	2.3008	3.1173
469.779	0.9962	1.7039	2.3036	3.1182
470.592	1.0012	1.7113	2.3131	3.1357
471.406	1.0080	1.7230	2.3292	3.1547
472.220	1.0183	1.7404	2.3525	3.1843
473.034	1.0284	1.7568	2.3749	3.2143
473.848	1.0345	1.7673	2.3880	3.2335
474.663	1.0383	1.7728	2.3949	3.2405
475.477	1.0418	1.7791	2.4027	3.2508
476.292	1.0455	1.7845	2.4113	3.2620

Irradiance / $(Wm^{-2}nm^{-1})$				
Wavelength / nm	Flight 1	Flight 3	Flight 4	Flight 5
477.108	1.0501	1.7930	2.4220	3.2775
477.922	1.0578	1.8056	2.4387	3.2977
478.735	1.0648	1.8175	2.4540	3.3184
479.549	1.0688	1.8242	2.4624	3.3298
480.364	1.0744	1.8322	2.4734	3.3437
481.179	1.0742	1.8324	2.4733	3.3440
481.993	1.0721	1.8291	2.4686	3.3351
482.806	1.0645	1.8159	2.4496	3.3111
483.619	1.0489	1.7894	2.4135	3.2605
484.433	1.0180	1.7370	2.3417	3.1628
485.246	0.9856	1.6800	2.2661	3.0613
486.060	0.9633	1.6426	2.2150	2.9900
486.873	0.9567	1.6309	2.1992	2.9691
487.686	0.9734	1.6586	2.2387	3.0245
488.498	1.0017	1.7063	2.3018	3.1069
489.310	1.0236	1.7435	2.3512	3.1754
490.122	1.0352	1.7627	2.3770	3.2094
490.934	1.0376	1.7678	2.3823	3.2159
491.747	1.0353	1.7641	2.3775	3.2070
492.558	1.0360	1.7637	2.3773	3.2064
493.370	1.0437	1.7766	2.3944	3.2297
494.182	1.0544	1.7952	2.4184	3.2627
494.994	1.0625	1.8090	2.4369	3.2864
495.807	1.0678	1.8177	2.4487	3.3007
496.620	1.0654	1.8135	2.4420	3.2918
497.433	1.0607	1.8059	2.4311	3.2785
498.246	1.0554	1.7967	2.4183	3.2597
499.061	1.0462	1.7802	2.3963	3.2302
499.874	1.0372	1.7637	2.3747	3.1994
500.688	1.0303	1.7516	2.3580	3.1774
501.501	1.0279	1.7486	2.3528	3.1703
502.313	1.0310	1.7528	2.3594	3.1776
503.126	1.0382	1.7662	2.3766	3.2038
503.938	1.0510	1.7871	2.4043	3.2393
504.750	1.0621	1.8057	2.4292	3.2738
505.563	1.0704	1.8196	2.4477	3.2984
506.374	1.0743	1.8258	2.4546	3.3070
507.186	1.0726	1.8230	2.4513	3.3006
507.998	1.0712	1.8188	2.4459	3.2916
508.809	1.0694	1.8157	2.4417	3.2851
509.620	1.0730	1.8217	2.4490	3.2965
510.432	1.0760	1.8263	2.4553	3.3049
511.243	1.0737	1.8231	2.4517	3.2993
512.055	1.0693	1.8156	2.4406	3.2848

Irradiance / $(Wm^{-2}nm^{-1})$				
Wavelength / nm	Flight 1	Flight 3	Flight 4	Flight 5
512.866	1.0606	1.8003	2.4192	3.2542
513.677	1.0516	1.7856	2.3992	3.2290
514.489	1.0416	1.7671	2.3747	3.1944
515.300	1.0222	1.7346	2.3305	3.1358
516.111	1.0010	1.6987	2.2825	3.0682
516.922	0.9811	1.6648	2.2359	3.0054
517.733	0.9730	1.6496	2.2168	2.9791
518.544	0.9855	1.6711	2.2447	3.0176
519.355	1.0065	1.7078	2.2939	3.0840
520.165	1.0319	1.7501	2.3500	3.1602
520.976	1.0489	1.7784	2.3877	3.2111
521.786	1.0582	1.7939	2.4093	3.2386
522.597	1.0685	1.8113	2.4318	3.2668
523.406	1.0767	1.8250	2.4505	3.2924
524.216	1.0833	1.8357	2.4641	3.3119
525.025	1.0779	1.8264	2.4515	3.2932
525.834	1.0655	1.8052	2.4222	3.2525
526.642	1.0580	1.7924	2.4046	3.2302
527.451	1.0613	1.7976	2.4117	3.2395
528.260	1.0784	1.8260	2.4499	3.2911
529.069	1.1008	1.8656	2.5022	3.3587
529.879	1.1194	1.8956	2.5420	3.4124
530.689	1.1226	1.9013	2.5483	3.4188
531.499	1.1180	1.8933	2.5381	3.4078
532.309	1.1108	1.8807	2.5220	3.3836
533.119	1.1053	1.8712	2.5080	3.3658
533.929	1.1089	1.8769	2.5162	3.3771
534.739	1.1169	1.8911	2.5342	3.4005
535.548	1.1213	1.8979	2.5431	3.4105
536.357	1.1232	1.9015	2.5480	3.4158
537.166	1.1206	1.8964	2.5402	3.4057
537.976	1.1140	1.8843	2.5239	3.3843
538.785	1.1066	1.8713	2.5073	3.3610
539.594	1.0984	1.8577	2.4886	3.3363
540.402	1.0942	1.8506	2.4789	3.3228
541.210	1.0942	1.8508	2.4793	3.3225
542.019	1.1015	1.8626	2.4951	3.3431
542.827	1.1116	1.8796	2.5165	3.3730
543.636	1.1189	1.8917	2.5326	3.3933
544.444	1.1252	1.9014	2.5452	3.4123
545.252	1.1290	1.9069	2.5534	3.4205
546.060	1.1273	1.9053	2.5501	3.4159
546.867	1.1256	1.9010	2.5448	3.4080
547.675	1.1265	1.9021	2.5459	3.4079

Irradiance / $(Wm^{-2}nm^{-1})$				
Wavelength / nm	Flight 1	Flight 3	Flight 4	Flight 5
548.483	1.1260	1.9028	2.5461	3.4087
549.291	1.1293	1.9069	2.5519	3.4144
550.098	1.1326	1.9121	2.5578	3.4251
550.905	1.1337	1.9140	2.5608	3.4284
551.713	1.1332	1.9143	2.5604	3.4273
552.520	1.1355	1.9170	2.5643	3.4302
553.328	1.1382	1.9221	2.5707	3.4389
554.136	1.1413	1.9263	2.5761	3.4463
554.943	1.1417	1.9269	2.5770	3.4457
555.751	1.1375	1.9193	2.5668	3.4314
556.559	1.1307	1.9085	2.5504	3.4089
557.367	1.1203	1.8902	2.5265	3.3786
558.175	1.1118	1.8762	2.5078	3.3529
558.982	1.1102	1.8730	2.5040	3.3489
559.788	1.1128	1.8772	2.5088	3.3540
560.594	1.1192	1.8876	2.5227	3.3734
561.400	1.1279	1.9027	2.5420	3.3992
562.207	1.1332	1.9110	2.5536	3.4118
563.013	1.1366	1.9173	2.5620	3.4233
563.818	1.1380	1.9193	2.5632	3.4236
564.624	1.1353	1.9142	2.5574	3.4164
565.429	1.1356	1.9139	2.5565	3.4152
566.234	1.1367	1.9164	2.5582	3.4161
567.039	1.1383	1.9185	2.5617	3.4212
567.843	1.1425	1.9251	2.5702	3.4321
568.647	1.1418	1.9245	2.5688	3.4303
569.452	1.1378	1.9170	2.5591	3.4156
570.256	1.1374	1.9160	2.5577	3.4147
571.060	1.1424	1.9242	2.5682	3.4281
571.865	1.1509	1.9389	2.5870	3.4534
572.670	1.1633	1.9595	2.6144	3.4907
573.476	1.1698	1.9704	2.6288	3.5071
574.282	1.1690	1.9686	2.6271	3.5052
575.088	1.1668	1.9655	2.6220	3.4991
575.894	1.1638	1.9598	2.6142	3.4886
576.700	1.1610	1.9537	2.6066	3.4770
577.505	1.1595	1.9512	2.6026	3.4729
578.311	1.1588	1.9496	2.6003	3.4673
579.117	1.1582	1.9488	2.5997	3.4649
579.923	1.1618	1.9551	2.6076	3.4748
580.728	1.1676	1.9649	2.6192	3.4926
581.533	1.1729	1.9733	2.6315	3.5073
582.337	1.1775	1.9807	2.6407	3.5202
583.142	1.1794	1.9838	2.6447	3.5265

Irradiance / $(Wm^{-2}nm^{-1})$				
Wavelength / nm	Flight 1	Flight 3	Flight 4	Flight 5
583.946	1.1761	1.9771	2.6363	3.5131
584.750	1.1702	1.9677	2.6229	3.4943
585.555	1.1663	1.9611	2.6137	3.4807
586.358	1.1624	1.9543	2.6042	3.4693
587.161	1.1528	1.9387	2.5828	3.4409
587.963	1.1391	1.9152	2.5511	3.3985
588.766	1.1276	1.8957	2.5260	3.3624
589.568	1.1230	1.8873	2.5144	3.3469
590.370	1.1303	1.8993	2.5307	3.3696
591.172	1.1462	1.9262	2.5663	3.4165
591.974	1.1588	1.9468	2.5930	3.4519
592.777	1.1654	1.9588	2.6074	3.4699
593.580	1.1679	1.9610	2.6117	3.4750
594.385	1.1680	1.9622	2.6125	3.4747
595.189	1.1689	1.9630	2.6139	3.4788
595.994	1.1686	1.9628	2.6124	3.4744
596.799	1.1678	1.9615	2.6113	3.4706
597.604	1.1660	1.9584	2.6065	3.4654
598.409	1.1627	1.9527	2.5994	3.4541
599.213	1.1583	1.9447	2.5877	3.4407
600.017	1.1546	1.9378	2.5787	3.4286
600.820	1.1500	1.9306	2.5690	3.4168
601.622	1.1487	1.9277	2.5649	3.4097
602.424	1.1524	1.9339	2.5731	3.4200
603.226	1.1583	1.9445	2.5865	3.4351
604.027	1.1643	1.9535	2.5988	3.4527
604.829	1.1674	1.9585	2.6054	3.4606
605.631	1.1676	1.9592	2.6055	3.4610
606.433	1.1654	1.9548	2.6005	3.4535
607.234	1.1613	1.9479	2.5913	3.4419
608.036	1.1570	1.9409	2.5807	3.4285
608.837	1.1516	1.9322	2.5684	3.4104
609.639	1.1475	1.9254	2.5602	3.3993
610.442	1.1453	1.9211	2.5544	3.3916
611.244	1.1428	1.9164	2.5474	3.3823
612.046	1.1398	1.9112	2.5407	3.3700
612.848	1.1358	1.9043	2.5309	3.3579
613.650	1.1326	1.8985	2.5227	3.3467
614.451	1.1265	1.8883	2.5091	3.3301
615.253	1.1218	1.8795	2.4973	3.3137
616.054	1.1194	1.8755	2.4924	3.3055
616.855	1.1200	1.8771	2.4942	3.3095
617.654	1.1257	1.8864	2.5062	3.3244
618.454	1.1356	1.9034	2.5279	3.3529

Irradiance / ($Wm^{-2}nm^{-1}$)				
Wavelength / nm	Flight 1	Flight 3	Flight 4	Flight 5
619.254	1.1433	1.9159	2.5445	3.3749
620.054	1.1467	1.9210	2.5517	3.3848
620.854	1.1474	1.9230	2.5535	3.3860
621.654	1.1441	1.9168	2.5457	3.3729
622.455	1.1380	1.9062	2.5316	3.3543
623.255	1.1315	1.8950	2.5165	3.3355
624.056	1.1257	1.8853	2.5040	3.3185
624.857	1.1245	1.8831	2.4996	3.3146
625.658	1.1270	1.8874	2.5050	3.3199
626.459	1.1325	1.8966	2.5174	3.3346
627.259	1.1398	1.9087	2.5333	3.3550
628.060	1.1431	1.9142	2.5399	3.3638
628.860	1.1420	1.9119	2.5371	3.3605
629.662	1.1387	1.9061	2.5297	3.3516
630.463	1.1335	1.8971	2.5170	3.3329
631.265	1.1303	1.8915	2.5105	3.3232
632.066	1.1284	1.8880	2.5054	3.3162
632.868	1.1280	1.8874	2.5044	3.3137
633.670	1.1297	1.8894	2.5071	3.3183
634.471	1.1294	1.8894	2.5071	3.3180
635.272	1.1302	1.8906	2.5083	3.3195
636.071	1.1330	1.8951	2.5141	3.3267
636.871	1.1356	1.8991	2.5189	3.3317
637.671	1.1374	1.9029	2.5235	3.3374
638.470	1.1362	1.9007	2.5201	3.3341
639.269	1.1314	1.8925	2.5087	3.3180
640.068	1.1259	1.8828	2.4964	3.3013
640.866	1.1222	1.8765	2.4877	3.2901
641.664	1.1218	1.8755	2.4862	3.2879
642.464	1.1232	1.8768	2.4889	3.2911
643.263	1.1247	1.8802	2.4929	3.2958
644.062	1.1247	1.8796	2.4929	3.2939
644.860	1.1243	1.8787	2.4900	3.2892
645.658	1.1243	1.8790	2.4902	3.2904
646.456	1.1249	1.8797	2.4910	3.2918
647.253	1.1246	1.8795	2.4897	3.2898
648.051	1.1204	1.8729	2.4813	3.2775
648.849	1.1183	1.8685	2.4750	3.2688
649.648	1.1169	1.8661	2.4722	3.2639
650.448	1.1180	1.8677	2.4736	3.2670
651.248	1.1235	1.8762	2.4850	3.2838
652.047	1.1269	1.8825	2.4936	3.2942
652.847	1.1261	1.8807	2.4909	3.2881
653.646	1.1160	1.8643	2.4679	3.2566

Irradiance / ($Wm^{-2}nm^{-1}$)				
Wavelength / nm	Flight 1	Flight 3	Flight 4	Flight 5
654.445	1.0878	1.8177	2.4061	3.1766
655.243	1.0569	1.7648	2.3369	3.0828
656.042	1.0370	1.7314	2.2934	3.0266
656.841	1.0337	1.7258	2.2847	3.0159
657.640	1.0530	1.7570	2.3269	3.0709
658.439	1.0806	1.8030	2.3878	3.1500
659.236	1.1004	1.8362	2.4299	3.2069
660.033	1.1118	1.8560	2.4566	3.2387
660.828	1.1196	1.8685	2.4729	3.2624
661.622	1.1228	1.8744	2.4803	3.2735
662.417	1.1233	1.8747	2.4808	3.2728
663.214	1.1233	1.8740	2.4802	3.2712
664.011	1.1223	1.8729	2.4785	3.2682
664.806	1.1225	1.8734	2.4780	3.2659
665.597	1.1235	1.8741	2.4793	3.2695
666.387	1.1229	1.8728	2.4774	3.2666
667.180	1.1225	1.8721	2.4765	3.2633
667.975	1.1231	1.8729	2.4777	3.2656
668.771	1.1228	1.8720	2.4763	3.2630
669.563	1.1211	1.8694	2.4728	3.2581
670.348	1.1173	1.8637	2.4646	3.2471
671.130	1.1150	1.8601	2.4592	3.2401
671.912	1.1135	1.8562	2.4548	3.2353
672.700	1.1134	1.8571	2.4549	3.2331
673.493	1.1140	1.8575	2.4569	3.2372
674.290	1.1148	1.8585	2.4573	3.2365
675.084	1.1147	1.8586	2.4576	3.2372
675.874	1.1148	1.8583	2.4574	3.2367
676.659	1.1153	1.8592	2.4576	3.2364
677.442	1.1153	1.8585	2.4563	3.2367
678.225	1.1153	1.8584	2.4563	3.2350
679.012	1.1146	1.8573	2.4545	3.2297
679.803	1.1137	1.8558	2.4518	3.2309
680.595	1.1128	1.8555	2.4517	3.2254
681.385	1.1120	1.8526	2.4481	3.2217
682.170	1.1094	1.8484	2.4420	3.2137
682.952	1.1048	1.8423	2.4332	3.2041
683.733	1.1014	1.8352	2.4247	3.1908
684.517	1.0993	1.8304	2.4195	3.1825
685.307	1.0995	1.8312	2.4187	3.1802
686.105	1.1013	1.8343	2.4229	3.1877
686.910	1.1036	1.8375	2.4270	3.1919
687.719	1.1045	1.8393	2.4291	3.1967
688.527	1.1044	1.8384	2.4283	3.1969

Irradiance / $(Wm^{-2}nm^{-1})$				
Wavelength / nm	Flight 1	Flight 3	Flight 4	Flight 5
689.329	1.1032	1.8364	2.4262	3.1907
690.127	1.1016	1.8341	2.4218	3.1868
690.921	1.0995	1.8313	2.4179	3.1800
691.712	1.0993	1.8303	2.4167	3.1776
692.499	1.0983	1.8281	2.4139	3.1745
693.287	1.0970	1.8263	2.4120	3.1693
694.079	1.0964	1.8249	2.4104	3.1679
694.873	1.0963	1.8231	2.4081	3.1665
695.669	1.0944	1.8209	2.4050	3.1587
696.466	1.0930	1.8186	2.4000	3.1557
697.263	1.0913	1.8153	2.3967	3.1474
698.062	1.0891	1.8116	2.3923	3.1441
698.862	1.0859	1.8064	2.3842	3.1328
699.664	1.0821	1.8004	2.3767	3.1215
700.466	1.0786	1.7941	2.3675	3.1102
701.272	1.0742	1.7864	2.3575	3.0960
702.088	1.0725	1.7838	2.3544	3.0909
702.902	1.0745	1.7874	2.3584	3.0969
703.702	1.0772	1.7912	2.3622	3.1033
704.487	1.0802	1.7961	2.3703	3.1115
705.261	1.0824	1.7999	2.3746	3.1161
706.023	1.0820	1.7990	2.3731	3.1140
706.770	1.0817	1.7982	2.3724	3.1123
707.493	1.0801	1.7963	2.3692	3.1081
708.208	1.0793	1.7939	2.3660	3.1057
708.938	1.0776	1.7902	2.3611	3.0991
709.687	1.0761	1.7884	2.3589	3.0939
710.461	1.0747	1.7863	2.3553	3.0888
711.260	1.0729	1.7837	2.3513	3.0841
712.089	1.0705	1.7796	2.3464	3.0774
712.940	1.0684	1.7768	2.3428	3.0713
713.793	1.0679	1.7747	2.3392	3.0675
714.641	1.0664	1.7714	2.3357	3.0618
715.482	1.0647	1.7686	2.3317	3.0577
716.320	1.0631	1.7655	2.3275	3.0520
717.156	1.0590	1.7594	2.3187	3.0408
717.987	1.0550	1.7538	2.3107	3.0303
718.807	1.0516	1.7471	2.3015	3.0171
719.616	1.0486	1.7416	2.2947	3.0082
720.414	1.0476	1.7397	2.2923	3.0045
721.199	1.0483	1.7409	2.2947	3.0074
721.971	1.0503	1.7447	2.2983	3.0110
722.731	1.0540	1.7497	2.3053	3.0206
723.490	1.0555	1.7534	2.3101	3.0256

Irradiance / $(Wm^{-2}nm^{-1})$				
Wavelength / nm	Flight 1	Flight 3	Flight 4	Flight 5
724.255	1.0571	1.7557	2.3135	3.0323
725.026	1.0576	1.7562	2.3143	3.0296
725.802	1.0573	1.7550	2.3116	3.0274
726.584	1.0549	1.7511	2.3061	3.0217
727.374	1.0501	1.7437	2.2963	3.0096
728.168	1.0464	1.7370	2.2869	2.9959
728.962	1.0435	1.7326	2.2809	2.9875
729.755	1.0427	1.7304	2.2782	2.9820
730.547	1.0442	1.7326	2.2809	2.9847
731.337	1.0450	1.7340	2.2833	2.9893
732.126	1.0465	1.7368	2.2856	2.9916
732.913	1.0477	1.7375	2.2879	2.9953
733.700	1.0476	1.7386	2.2883	2.9972
734.489	1.0470	1.7368	2.2865	2.9925
735.278	1.0458	1.7346	2.2834	2.9890
736.069	1.0439	1.7313	2.2792	2.9822
736.860	1.0405	1.7266	2.2718	2.9727
737.652	1.0369	1.7200	2.2628	2.9612
738.445	1.0325	1.7130	2.2542	2.9497
739.236	1.0276	1.7038	2.2422	2.9328
740.027	1.0235	1.6974	2.2337	2.9211
740.818	1.0217	1.6940	2.2299	2.9148
741.606	1.0217	1.6943	2.2291	2.9133
742.394	1.0232	1.6975	2.2326	2.9201
743.181	1.0267	1.7025	2.2390	2.9262
743.968	1.0295	1.7066	2.2454	2.9356
744.754	1.0308	1.7085	2.2480	2.9401
745.541	1.0327	1.7116	2.2509	2.9444
746.327	1.0337	1.7136	2.2537	2.9453
747.115	1.0336	1.7138	2.2534	2.9449
747.902	1.0325	1.7107	2.2506	2.9398
748.690	1.0299	1.7062	2.2440	2.9340
749.477	1.0272	1.7028	2.2388	2.9265
750.265	1.0241	1.6969	2.2311	2.9163
751.053	1.0223	1.6949	2.2280	2.9124
751.841	1.0223	1.6937	2.2271	2.9100
752.629	1.0240	1.6966	2.2311	2.9134
753.418	1.0251	1.6984	2.2328	2.9159
754.207	1.0255	1.6990	2.2333	2.9164
754.995	1.0253	1.6976	2.2322	2.9150
755.783	1.0237	1.6958	2.2290	2.9111
756.568	1.0221	1.6926	2.2256	2.9064
757.352	1.0220	1.6922	2.2243	2.9048
758.133	1.0213	1.6912	2.2238	2.9042

Irradiance / $(Wm^{-2}nm^{-1})$				
Wavelength / nm	Flight 1	Flight 3	Flight 4	Flight 5
758.917	1.0208	1.6907	2.2219	2.9002
759.704	1.0197	1.6888	2.2189	2.8981
760.494	1.0173	1.6851	2.2137	2.8906
761.284	1.0157	1.6818	2.2103	2.8872
762.074	1.0164	1.6828	2.2106	2.8861
762.863	1.0176	1.6848	2.2135	2.8875
763.651	1.0166	1.6833	2.2113	2.8865
764.438	1.0121	1.6756	2.2003	2.8726
765.226	1.0056	1.6652	2.1870	2.8551
766.013	1.0008	1.6574	2.1772	2.8426
766.798	0.9993	1.6537	2.1724	2.8365
767.582	1.0005	1.6559	2.1752	2.8364
768.367	1.0025	1.6596	2.1794	2.8432
769.151	1.0024	1.6589	2.1794	2.8417
769.936	1.0010	1.6567	2.1747	2.8373
770.721	0.9998	1.6543	2.1724	2.8336
771.506	0.9994	1.6548	2.1721	2.8314
772.292	0.9982	1.6531	2.1691	2.8283
773.078	0.9981	1.6519	2.1690	2.8282
773.865	0.9976	1.6509	2.1680	2.8271
774.652	0.9978	1.6505	2.1671	2.8221
775.439	0.9980	1.6503	2.1668	2.8259
776.224	0.9978	1.6511	2.1667	2.8261
777.011	0.9975	1.6506	2.1669	2.8241
777.796	0.9965	1.6481	2.1632	2.8207
778.581	0.9948	1.6461	2.1602	2.8172
779.364	0.9947	1.6450	2.1591	2.8122
780.147	0.9944	1.6448	2.1581	2.8155
780.929	0.9953	1.6451	2.1592	2.8137
781.711	0.9938	1.6439	2.1572	2.8101
782.493	0.9929	1.6420	2.1546	2.8082
783.274	0.9913	1.6398	2.1519	2.8024
784.056	0.9903	1.6382	2.1493	2.8001
784.841	0.9911	1.6397	2.1509	2.8013
785.626	0.9913	1.6381	2.1500	2.7998
786.413	0.9913	1.6386	2.1506	2.7984
787.200	0.9908	1.6380	2.1478	2.8003
787.987	0.9900	1.6362	2.1458	2.7956
788.775	0.9893	1.6349	2.1444	2.7915
789.565	0.9866	1.6301	2.1381	2.7849
790.353	0.9829	1.6249	2.1311	2.7754
791.140	0.9784	1.6176	2.1210	2.7616
791.926	0.9719	1.6061	2.1065	2.7425
792.711	0.9656	1.5957	2.0921	2.7221

Irradiance / $(Wm^{-2}nm^{-1})$				
Wavelength / nm	Flight 1	Flight 3	Flight 4	Flight 5
793.497	0.9611	1.5885	2.0822	2.7102
794.283	0.9595	1.5856	2.0794	2.7068
795.068	0.9628	1.5907	2.0847	2.7137
795.852	0.9671	1.5974	2.0941	2.7276
796.635	0.9706	1.6039	2.1026	2.7358
797.418	0.9723	1.6061	2.1051	2.7387
798.202	0.9709	1.6043	2.1022	2.7358
798.986	0.9690	1.6005	2.0985	2.7318
799.768	0.9680	1.5985	2.0952	2.7278
800.550	0.9657	1.5949	2.0903	2.7209
801.333	0.9655	1.5943	2.0886	2.7174
802.117	0.9641	1.5922	2.0862	2.7176
802.901	0.9617	1.5874	2.0804	2.7069
803.684	0.9586	1.5835	2.0746	2.7000
804.467	0.9573	1.5809	2.0705	2.6980
805.249	0.9558	1.5779	2.0677	2.6899
806.032	0.9554	1.5765	2.0655	2.6853
806.816	0.9542	1.5755	2.0640	2.6860
807.599	0.9524	1.5710	2.0593	2.6792
808.381	0.9493	1.5666	2.0527	2.6675
809.162	0.9473	1.5636	2.0490	2.6655
809.943	0.9469	1.5631	2.0482	2.6639
810.726	0.9483	1.5644	2.0506	2.6663
811.509	0.9502	1.5685	2.0541	2.6724
812.291	0.9507	1.5687	2.0551	2.6710
813.069	0.9501	1.5680	2.0542	2.6695
813.849	0.9496	1.5665	2.0527	2.6687
814.632	0.9483	1.5643	2.0502	2.6654
815.416	0.9473	1.5626	2.0462	2.6615
816.201	0.9448	1.5571	2.0403	2.6525
816.985	0.9396	1.5503	2.0307	2.6391
817.768	0.9338	1.5411	2.0176	2.6214
818.552	0.9284	1.5312	2.0051	2.6074
819.338	0.9241	1.5230	1.9950	2.5937
820.124	0.9201	1.5161	1.9863	2.5830
820.908	0.9192	1.5164	1.9854	2.5797
821.688	0.9196	1.5162	1.9859	2.5807
822.468	0.9217	1.5193	1.9891	2.5850
823.248	0.9240	1.5228	1.9939	2.5907
824.029	0.9264	1.5258	1.9985	2.5975
824.812	0.9274	1.5289	2.0011	2.6006
825.593	0.9274	1.5292	2.0011	2.6011
826.371	0.9272	1.5286	2.0020	2.6020
827.148	0.9273	1.5283	2.0004	2.5992

Irradiance / ($Wm^{-2}nm^{-1}$)				
Wavelength / nm	Flight 1	Flight 3	Flight 4	Flight 5
827.926	0.9268	1.5265	1.9989	2.5981
828.707	0.9245	1.5236	1.9942	2.5919
829.489	0.9221	1.5195	1.9888	2.5840
830.270	0.9186	1.5153	1.9831	2.5753
831.050	0.9145	1.5083	1.9738	2.5642
831.828	0.9109	1.5013	1.9649	2.5487
832.609	0.9067	1.4931	1.9542	2.5389
833.392	0.9030	1.4872	1.9471	2.5284
834.176	0.9019	1.4853	1.9439	2.5260
834.958	0.9038	1.4878	1.9468	2.5281
835.739	0.9059	1.4915	1.9513	2.5360
836.520	0.9069	1.4939	1.9546	2.5376
837.303	0.9063	1.4918	1.9529	2.5372
838.088	0.9058	1.4922	1.9518	2.5356
838.873	0.9058	1.4909	1.9514	2.5332
839.654	0.9046	1.4895	1.9500	2.5298
840.431	0.9049	1.4897	1.9480	2.5281
841.208	0.9038	1.4877	1.9465	2.5279
841.987	0.9012	1.4834	1.9399	2.5193
842.770	0.8977	1.4773	1.9327	2.5091
843.552	0.8959	1.4747	1.9292	2.5031
844.330	0.8955	1.4730	1.9270	2.5015
845.105	0.8944	1.4710	1.9247	2.4974
845.879	0.8940	1.4702	1.9244	2.4964
846.656	0.8928	1.4694	1.9216	2.4933
847.435	0.8876	1.4609	1.9109	2.4802
848.215	0.8789	1.4456	1.8918	2.4539
848.994	0.8698	1.4315	1.8727	2.4294
849.768	0.8624	1.4183	1.8565	2.4080
850.542	0.8588	1.4126	1.8487	2.3989
851.318	0.8589	1.4124	1.8480	2.3988
852.099	0.8493	1.3965	1.8268	2.3694
852.881	0.8326	1.3689	1.7904	2.3217
853.663	0.8193	1.3467	1.7623	2.2865
854.443	0.8117	1.3337	1.7451	2.2623
855.221	0.8195	1.3460	1.7610	2.2851
856.000	0.8372	1.3759	1.8004	2.3334
856.780	0.8540	1.4030	1.8352	2.3811
857.563	0.8639	1.4200	1.8569	2.4073
858.347	0.8683	1.4278	1.8667	2.4205
859.126	0.8698	1.4288	1.8687	2.4223
859.902	0.8686	1.4274	1.8660	2.4201
860.678	0.8680	1.4254	1.8649	2.4209
861.457	0.8681	1.4267	1.8651	2.4209

Irradiance / $(Wm^{-2}nm^{-1})$				
Wavelength / nm	Flight 1	Flight 3	Flight 4	Flight 5
862.241	0.8696	1.4284	1.8678	2.4221
863.026	0.8689	1.4276	1.8661	2.4202
863.808	0.8602	1.4135	1.8486	2.3959
864.584	0.8432	1.3849	1.8095	2.3477
865.358	0.8251	1.3552	1.7712	2.2960
866.132	0.8121	1.3347	1.7434	2.2623
866.912	0.8091	1.3291	1.7375	2.2507
867.694	0.8190	1.3447	1.7577	2.2787
868.473	0.8312	1.3655	1.7855	2.3149
869.245	0.8397	1.3793	1.8033	2.3388
870.015	0.8445	1.3866	1.8126	2.3516
870.786	0.8473	1.3921	1.8194	2.3597
871.562	0.8483	1.3929	1.8211	2.3585
872.341	0.8477	1.3920	1.8190	2.3590
873.115	0.8460	1.3889	1.8151	2.3532
873.882	0.8445	1.3856	1.8108	2.3468
874.644	0.8415	1.3818	1.8059	2.3428
875.409	0.8413	1.3808	1.8041	2.3372
876.177	0.8408	1.3803	1.8038	2.3385
876.945	0.8426	1.3822	1.8053	2.3370
877.710	0.8422	1.3820	1.8053	2.3404
878.472	0.8393	1.3780	1.8016	2.3359
879.228	0.8372	1.3736	1.7947	2.3223
879.984	0.8347	1.3694	1.7880	2.3170
880.743	0.8337	1.3671	1.7862	2.3148
881.510	0.8338	1.3685	1.7882	2.3156
882.284	0.8366	1.3726	1.7940	2.3267
883.061	0.8394	1.3755	1.7983	2.3319
883.837	0.8387	1.3763	1.7983	2.3342
884.608	0.8369	1.3727	1.7926	2.3252
885.373	0.8331	1.3660	1.7853	2.3121
886.136	0.8298	1.3604	1.7775	2.3020
886.899	0.8282	1.3589	1.7745	2.3022
887.665	0.8305	1.3617	1.7784	2.3055
888.438	0.8328	1.3652	1.7825	2.3107
889.215	0.8336	1.3665	1.7848	2.3135
889.991	0.8329	1.3650	1.7828	2.3111
890.762	0.8299	1.3605	1.7764	2.3008
891.527	0.8278	1.3566	1.7723	2.2966
892.292	0.8272	1.3557	1.7709	2.2932
893.061	0.8261	1.3543	1.7694	2.2910
893.836	0.8265	1.3547	1.7680	2.2914
894.610	0.8263	1.3547	1.7681	2.2888
895.384	0.8260	1.3536	1.7662	2.2867

Irradiance / $(Wm^{-2}nm^{-1})$				
Wavelength / nm	Flight 1	Flight 3	Flight 4	Flight 5
896.156	0.8257	1.3530	1.7657	2.2858
896.928	0.8256	1.3523	1.7643	2.2839
897.702	0.8229	1.3482	1.7605	2.2800
898.475	0.8206	1.3439	1.7534	2.2744
899.251	0.8158	1.3361	1.7441	2.2586
900.029	0.8094	1.3253	1.7308	2.2414
900.806	0.8046	1.3167	1.7197	2.2258
901.580	0.8025	1.3136	1.7148	2.2174
902.352	0.8034	1.3148	1.7173	2.2227
903.126	0.8063	1.3208	1.7246	2.2323
903.903	0.8087	1.3239	1.7288	2.2395
904.684	0.8097	1.3255	1.7294	2.2399
905.464	0.8090	1.3247	1.7289	2.2385
906.240	0.8064	1.3192	1.7225	2.2310
907.011	0.8034	1.3148	1.7153	2.2214
907.779	0.8005	1.3101	1.7101	2.2111
908.548	0.7985	1.3056	1.7041	2.2054
909.320	0.7964	1.3026	1.7009	2.2006
910.094	0.7958	1.3020	1.6999	2.1999
910.870	0.7976	1.3041	1.7030	2.2037
911.646	0.7984	1.3059	1.7047	2.2083
912.421	0.7985	1.3071	1.7046	2.2074
913.193	0.8000	1.3082	1.7063	2.2066
913.963	0.7992	1.3068	1.7051	2.2095
914.732	0.7985	1.3060	1.7029	2.2054
915.502	0.7960	1.3027	1.7004	2.1980
916.272	0.7958	1.3004	1.6960	2.1951
917.044	0.7932	1.2965	1.6932	2.1920
917.814	0.7919	1.2938	1.6881	2.1855
918.585	0.7893	1.2909	1.6842	2.1781
919.355	0.7861	1.2851	1.6764	2.1723
920.122	0.7820	1.2786	1.6675	2.1579
920.888	0.7770	1.2707	1.6559	2.1474
921.655	0.7725	1.2618	1.6460	2.1289
922.424	0.7680	1.2545	1.6363	2.1140
923.197	0.7651	1.2501	1.6311	2.1080
923.971	0.7634	1.2484	1.6280	2.1055
924.743	0.7650	1.2497	1.6303	2.1098
925.513	0.7672	1.2531	1.6346	2.1152
926.282	0.7703	1.2579	1.6399	2.1210
927.049	0.7730	1.2626	1.6455	2.1316
927.819	0.7748	1.2644	1.6496	2.1354
928.591	0.7755	1.2679	1.6526	2.1376
929.364	0.7760	1.2685	1.6536	2.1397

Irradiance / $(Wm^{-2}nm^{-1})$				
Wavelength / nm	Flight 1	Flight 3	Flight 4	Flight 5
930.138	0.7760	1.2680	1.6536	2.1356
930.911	0.7762	1.2686	1.6538	2.1382
931.683	0.7765	1.2671	1.6534	2.1381
932.460	0.7761	1.2684	1.6541	2.1416
933.242	0.7750	1.2656	1.6506	2.1322
934.019	0.7730	1.2620	1.6483	2.1274
934.790	0.7719	1.2590	1.6422	2.1235
935.562	0.7698	1.2563	1.6388	2.1172
936.333	0.7691	1.2551	1.6357	2.1128
937.104	0.7678	1.2529	1.6329	2.1109
937.872	0.7665	1.2502	1.6302	2.1067
938.634	0.7624	1.2469	1.6230	2.0968
939.391	0.7581	1.2385	1.6139	2.0863
940.145	0.7538	1.2313	1.6036	2.0742
940.903	0.7494	1.2242	1.5946	2.0596
941.670	0.7474	1.2198	1.5896	2.0527
942.437	0.7474	1.2210	1.5900	2.0528
943.203	0.7490	1.2214	1.5921	2.0552
943.972	0.7503	1.2234	1.5934	2.0608
944.742	0.7508	1.2255	1.5963	2.0613
945.510	0.7522	1.2279	1.5991	2.0640
946.279	0.7542	1.2305	1.6032	2.0710
947.049	0.7549	1.2322	1.6040	2.0746
947.821	0.7561	1.2337	1.6069	2.0754
948.594	0.7571	1.2353	1.6075	2.0783
949.374	0.7559	1.2335	1.6073	2.0729
950.157	0.7554	1.2324	1.6041	2.0721
950.932	0.7530	1.2283	1.5999	2.0660
951.696	0.7502	1.2235	1.5932	2.0553
952.453	0.7465	1.2171	1.5854	2.0473
953.216	0.7432	1.2118	1.5775	2.0352
953.985	0.7407	1.2079	1.5727	2.0300
954.756	0.7396	1.2049	1.5691	2.0265
955.528	0.7397	1.2042	1.5681	2.0268
956.303	0.7398	1.2060	1.5701	2.0265
957.081	0.7406	1.2084	1.5727	2.0314
957.855	0.7427	1.2104	1.5749	2.0336
958.624	0.7424	1.2111	1.5751	2.0341
959.391	0.7426	1.2106	1.5758	2.0369
960.159	0.7430	1.2114	1.5763	2.0345
960.928	0.7420	1.2087	1.5746	2.0291
961.691	0.7414	1.2082	1.5729	2.0304
962.453	0.7401	1.2042	1.5683	2.0258
963.224	0.7384	1.2035	1.5643	2.0196

Irradiance / $(Wm^{-2}nm^{-1})$				
Wavelength / nm	Flight 1	Flight 3	Flight 4	Flight 5
963.994	0.7369	1.2001	1.5619	2.0131
964.761	0.7362	1.1983	1.5598	2.0104
965.527	0.7358	1.1979	1.5587	2.0093
966.293	0.7352	1.1977	1.5592	2.0098
967.061	0.7352	1.1964	1.5577	2.0078
967.834	0.7350	1.1980	1.5579	2.0123
968.608	0.7342	1.1968	1.5559	2.0106
969.377	0.7334	1.1945	1.5548	2.0036
970.141	0.7336	1.1940	1.5550	2.0066
970.907	0.7339	1.1949	1.5553	2.0029
971.666	0.7354	1.1959	1.5553	2.0079
972.423	0.7340	1.1954	1.5537	2.0038
973.192	0.7319	1.1926	1.5510	1.9983
973.964	0.7309	1.1896	1.5468	1.9933
974.731	0.7296	1.1877	1.5445	1.9951
975.497	0.7296	1.1880	1.5448	1.9891
976.262	0.7286	1.1853	1.5418	1.9882
977.032	0.7286	1.1850	1.5419	1.9852
977.807	0.7298	1.1868	1.5435	1.9904
978.579	0.7286	1.1851	1.5418	1.9839
979.346	0.7275	1.1845	1.5400	1.9842
980.107	0.7281	1.1836	1.5384	1.9846
980.862	0.7276	1.1832	1.5383	1.9819
981.622	0.7269	1.1828	1.5370	1.9815
982.386	0.7272	1.1831	1.5369	1.9800
983.150	0.7260	1.1824	1.5367	1.9803
983.912	0.7256	1.1817	1.5354	1.9804
984.675	0.7266	1.1809	1.5356	1.9775
985.440	0.7257	1.1801	1.5338	1.9749
986.205	0.7254	1.1779	1.5291	1.9726
986.971	0.7228	1.1761	1.5259	1.9669
987.729	0.7226	1.1745	1.5265	1.9646
988.482	0.7217	1.1729	1.5239	1.9603
989.241	0.7201	1.1712	1.5211	1.9614
990.005	0.7219	1.1733	1.5241	1.9614
990.767	0.7211	1.1727	1.5229	1.9644
991.530	0.7217	1.1710	1.5209	1.9573
992.294	0.7199	1.1688	1.5182	1.9567
993.061	0.7201	1.1687	1.5179	1.9540
993.829	0.7177	1.1674	1.5142	1.9490
994.586	0.7183	1.1667	1.5154	1.9524
995.339	0.7178	1.1653	1.5143	1.9509
996.099	0.7170	1.1665	1.5132	1.9529
996.862	0.7174	1.1661	1.5128	1.9489

Irradiance / $(Wm^{-2}nm^{-1})$				
Wavelength / nm	Flight 1	Flight 3	Flight 4	Flight 5
997.625	0.7160	1.1635	1.5103	1.9458
998.387	0.7146	1.1611	1.5079	1.9419
999.150	0.7139	1.1592	1.5043	1.9361
999.914	0.7136	1.1578	1.5044	1.9366
1000.672	0.7127	1.1585	1.5032	1.9347
1001.423	0.7118	1.1541	1.5008	1.9288
1002.178	0.7106	1.1522	1.4949	1.9234
1002.940	0.7054	1.1469	1.4896	1.9130
1003.699	0.7021	1.1404	1.4788	1.9024
1004.457	0.6998	1.1360	1.4727	1.8936
1005.214	0.6976	1.1306	1.4671	1.8892
1005.972	0.6975	1.1330	1.4699	1.8921
1006.725	0.6990	1.1331	1.4726	1.8949
1007.473	0.7016	1.1394	1.4778	1.9014
1008.227	0.7034	1.1414	1.4820	1.9058
1008.987	0.7038	1.1410	1.4832	1.9095
1009.745	0.7053	1.1455	1.4836	1.9076
1010.502	0.7043	1.1430	1.4829	1.9064
1011.258	0.7052	1.1450	1.4856	1.9066
1012.013	0.7043	1.1440	1.4836	1.9108
1012.771	0.7039	1.1437	1.4853	1.9059
1013.529	0.7038	1.1424	1.4833	1.9045
1014.287	0.7028	1.1427	1.4814	1.8992
1015.045	0.7023	1.1397	1.4775	1.8971
1015.803	0.7015	1.1397	1.4784	1.8964
1016.561	0.7029	1.1404	1.4798	1.8998
1017.319	0.7011	1.1396	1.4797	1.9014
1018.075	0.7021	1.1408	1.4783	1.9018
1018.830	0.7017	1.1398	1.4766	1.8980
1019.584	0.6999	1.1328	1.4716	1.8940
1020.337	0.6985	1.1356	1.4714	1.8885
1021.090	0.6980	1.1346	1.4694	1.8871
1021.843	0.6979	1.1335	1.4671	1.8842
1022.597	0.6963	1.1332	1.4666	1.8867
1023.354	0.6977	1.1312	1.4678	1.8848
1024.111	0.6974	1.1329	1.4666	1.8807
1024.865	0.6973	1.1306	1.4669	1.8858
1025.617	0.6957	1.1302	1.4641	1.8825
1026.368	0.6961	1.1294	1.4641	1.8833
1027.118	0.6961	1.1286	1.4632	1.8764
1027.868	0.6949	1.1271	1.4600	1.8763
1028.618	0.6916	1.1243	1.4559	1.8685
1029.370	0.6924	1.1224	1.4550	1.8680
1030.122	0.6926	1.1237	1.4564	1.8687

	Irradiance / ($Wm^{-2}nm^{-1}$)			
Wavelength / nm	Flight 1	Flight 3	Flight 4	Flight 5
1030.874	0.6920	1.1222	1.4537	1.8710
1031.624	0.6896	1.1204	1.4505	1.8612
1032.374	0.6878	1.1162	1.4459	1.8509
1033.123	0.6887	1.1161	1.4457	1.8531
1033.867	0.6863	1.1137	1.4424	1.8588
1034.611	0.6878	1.1136	1.4436	1.8486
1035.356	0.6854	1.1115	1.4402	1.8459
1036.102	0.6845	1.1065	1.4395	1.8452
1036.851	0.6842	1.1101	1.4384	1.8473
1037.601	0.6835	1.1075	1.4366	1.8491
1038.346	0.6824	1.1055	1.4321	1.8350
1039.090	0.6830	1.1073	1.4316	1.8371
1039.833	0.6823	1.1064	1.4334	1.8369

6 Signatures

JOHN WOODWARD

Digitally signed by JOHN WOODWARD
Date: 2024.10.11 10:00:57 -04'00'

John T. Woodward

Date

Stephen E Maxwell

Digitally signed by STEPHEN MAXWELL
Date: 2024.10.11 10:19:18 -04'00'

Stephen E. Maxwell

Date

JOSEPH RICE

Digitally signed by JOSEPH RICE
Date: 2024.10.11 14:24:35 -04'00'

Joseph P. Rice, Group Leader

Date