VERIFICATION OF QUALITY AND COMPATIBILITY FOR THE NEWLY CALIBRATED CLEMENTINE NIR DATA SET.
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Introduction: In February 1994, the Clementine spacecraft began orbiting the Moon with a suite of instrumentation that generated millions of images of the lunar surface. This instrumentation package included an ultraviolet-visible (UVVIS) imager that collected 5 spectral wavelengths (0.415, 0.75, 0.90, 0.95, and 1.00 μm) and a near-infrared (NIR) imager that collected 6 spectral wavelengths (1.10, 1.25, 1.50, 2.00, 2.60, and 2.78 μm) of information [1]. Over the past decade, calibration of the NIR data set has been troublesome due to largely varying dark frame signals with time and orbit and uncertainties on gain and offset values [2, 3]. Several previous attempts to calibrate the Clementine NIR data set have been made [2, 4-7]. However, these calibrations were not easily automated.

Recently, the USGS, Flagstaff released these data with a near final calibration [8]. Here we show a preliminary study to verify the quality and compatibility of this data set using Earth-based telescopic data and previous calibrations of the Clementine NIR and UVVIS data sets [5, 6, 9].

Data: Newly calibrated Clementine NIR data were downloaded from the USGS Astrogeology Research Program website. These data are available in a simple cylindrical projection with a resolution of 500 meters/pixel. Previously calibrated NIR Clementine data of the Aristarchus crater region of the Moon was obtained from [5, 6] for comparison. The data from [5, 6] is characterized by a robust NIR pixel-by-pixel data calibration using Earth-based data. Currently, [5, 6] serves as the current gold standard for automated NIR Clementine data calibration. Earth-based telescopic data taken from Mauna Kea Observatory of the Hadley-Apennine region of the Moon was also obtained for comparison with space borne data [9]. For a summary on how these data sets were calibrated see [5, 6, 9].

Earth-Based Telescopic Data: Earth-based telescopic data of the Moon was implemented for use as a ground truth comparison. These data have high spectral resolution and provide an accurate shape to the continuum. A preliminary comparison was conducted using mean spectra of nine localities in the Hadley-Apennine region. The majority (8 of 12) of mean spectral comparisons shows good similarity and are within respective 1σ standard deviations. A comparison between spectra of the Aristillus central peak shows a goodness of fit of acceptable quality (**Figure 1**). Spectral comparisons outside of the 1σ standard deviation are speculated to be attributed to imprecise knowledge of the geographic positions available in the Earth-based telescopic data set.

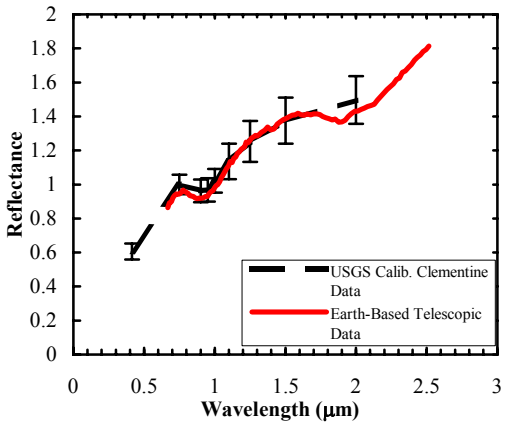

Figure 1: Comparison of Aristillus central peak telescopic and Clementine UVVIS and NIR data. Clementine error is based on a 1σ standard deviation.

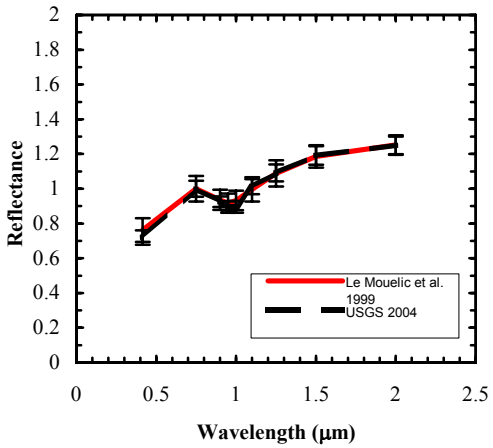

Figure 2: A comparison of two calibrations of the Clementine NIR data set. Data was collected from Aristarchus crater rim. Both data sets are within 1σ standard deviations.

Previously Calibrated Clementine Data: Of the previously calibrated Clementine NIR data sets, [5] was chosen for comparison to the USGS version because of its stout calibration and attention to Earth-based data sets. Recently calibrated USGS Clementine data shows many similarities to that of [5]. A spectra of the Aristarchus crater rim shows goodness of fit well within the standard deviations of each analysis (**Figure 2**). Good similarity was also shown with spectra taken of the Aristarchus central peak.

Clementine UVVIS-NIR Compatibility: A globally average spectrum was calculated to examine inconsistencies between data from the UVVIS and NIR cameras and to look for pervasive artifacts or "kinks" in the NIR spectrum (**Figure 3**). All pixels within 60S and 60N were averaged for each wavelength, which amounted to almost 32 million data points (1 km pixels). These data are summarized in **Table 1**. These data show that there are no evident discontinuities between the two data sets.

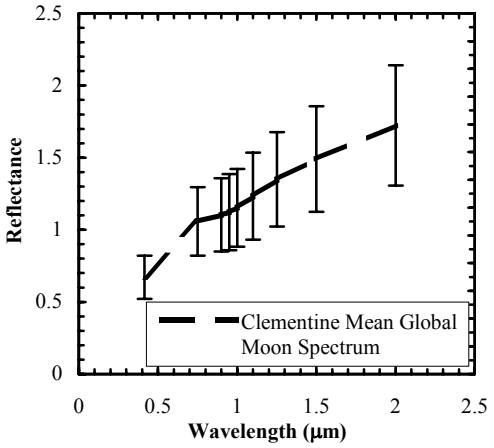

Figure 3: Mean global Moon spectrum of 11-band Clementine data set. Bands 2.6 and 2.78 μm are omitted because of contamination due to thermal emission. Error is defined by a 1σ standard deviation.

Table 1: Clementine derived statistics of an average global Moon spectrum.

λ (μm)	Mean Refl.	Norm. Mean Refl.*	Std. Dev.	Norm Std. Dev.*
0.415	0.108	0.598	0.028	0.155
0.75	0.181	1.000	0.045	0.247
0.9	0.190	1.048	0.048	0.265
0.95	0.194	1.068	0.050	0.274
1	0.199	1.099	0.051	0.280
1.1	0.214	1.183	0.057	0.313
1.25	0.236	1.303	0.062	0.340
1.5	0.263	1.450	0.069	0.381
2	0.307	1.692	0.079	0.433

* Normalized with 0.75 μm mean reflectance value.

Data Quality: The quality of the data in terms of noise and calibration is important to understanding the limits of its utility. We measured the noise from the data by scaling and differencing adjacent bands in uniform regions, and computing the residual noise, adjusting for the noise increase due to differencing. The results are given in **Table 2**. For UVVIS data alone, at 500-m sampling noise is on the order of 0.5%, while noise in data combining UVVIS and NIR, or NIR alone is closer to 1%. This performance places the ultimate limits on the ability to use the data to discriminate subtle spectral features, but does not address any systematic calibration error.

Table 2: Noise levels for specified lunar localities and wavelengths.

Locale	Wavelength (μm)		
	0.95 - 0.10	1.00 - 1.10	1.10 - 1.25
Mare Crisium	0.45*	2.45	1.09
Mare Procellarum	0.63	1.51	0.95
Farside Highlands	0.38	0.47	1.31
Mean	0.49	1.48	1.12
1σ Std. Dev.	0.13	0.99	0.18

*Values are percentages.

Summary: The newly calibrated Clementine NIR data set was used to extract spectra from a 12 lunar localities. Comparison of these spectra with ground truth telescopic data indicates that the USGS calibrated Clementine NIR data set provides reliable spectral information of the lunar surface. This data set was also compared to a previously calibrated NIR Clementine data set from [5]. Preliminary comparisons between these data sets show excellent agreement. These new data were also used to construct a global 11-band UVVIS and NIR mean spectrum of the Moon. This spectrum shows no artifacts along the continuum of the UVVIS and NIR spectral regions.

Our initial assessment of USGS calibrated NIR Clementine data set is that it is a reliable representation of the lunar surface with noise levels typically around 0.5% in the UVVIS and 1% in the NIR. These data are also compatible with previously calibrated Clementine UVVIS data and show no artifacts [10].

References: [1] Nozette S., et al. (1994) *Sci.*, 266, 1835-1839. [2] Lucey P.G., et al. (1998) *LPS XXIX*, #1576. [3] Priest R.E., et al. (1995) *PISOE*, 2475, 393-404. [4] Eliason E.M., et al. (2003) *LPS XXXIV*, #2093. [5] Le Mouelic S., et al. (1999) *JGR*, 104, 3833-3843. [6] Le Mouelic S., et al. (1999) *GRL*, 26, 1195-1198. [7] Lucey P.G., et al. (2000) *LPS XXXI*, #1273. [8] Staid M.I., et al. (2003) *USGS ARP*, http://astrogeology.usgs.gov/Projects/ClementineNIR/. [9] Blewett D.T. and Hawke B.R. (2001) *MaPS*, 36, 701-730. [10] Pieters C.M., et al. (1994) *Sci.*, 266, 1844-1848.