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SeaWiFS On-Orbit Calibration Change Derived from Four Years of Lunar Measurements

Robert E. Eplee, Jr.[1], Frederick S. Patt[1], Robert A. Barnes[1], and Charles R. McClain[2]

[1] Science Applications International Corporation, Beltsville, MD
[2] NASA Goddard Space Flight Center, Greenbelt, MD

Introduction

The SeaWiFS Project Calibration and Validation Team (CVT) uses monthly lunar calibrations to track the long-term stability of the radiometric calibration of SeaWiFS. This time series is used to compute the temporal correction factors for the SeaWiFS ocean and land data. Lunar calibrations are performed once per month when the moon is at a phase angle of approximately 7 degrees (chosen to maximize the illuminated surface of the moon while minimizing the opposition effect).

Figure 1

The first lunar calibration image is shown in Fig. 1. The pitch rate of the spacecraft during the calibration causes SeaWiFS to oversample the moon in the along-track direction, resulting in lunar images that are typically 26 scan lines by 7 pixels in size.

Calibration Time Series

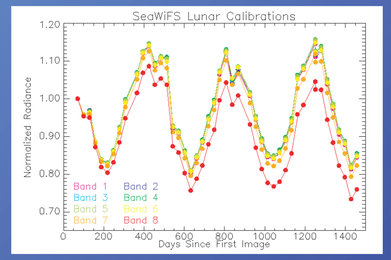

Figure 2

Disk-integrated radiances are computed for each band from the lunar images by summing the radiances over all pixels whose brightness is greater than 1% of the peak brightness. The time series of disk-integrated radiances for the first 46 lunar calibrations (spanning 1388 days from 14 November 1997 through 2 September 2001) are plotted in Fig. 2. The radiances in each band have been normalized by the value at the first calibration to show the relative changes in the instrument response as functions of time. Much of the variation in these time series is due to the changing observing geometry from calibration to calibration.

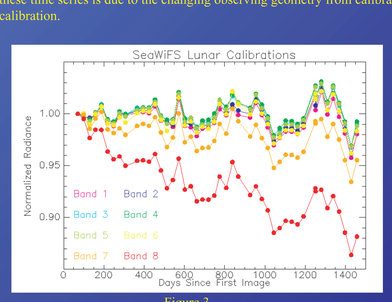

Figure 3

The disk-integrated radiances are normalized to a common viewing geometry for incorporation into the lunar calibration time series. These normalizing factors are the sun–moon distance, spacecraft–moon distance, illuminated fraction of the lunar surface, number of scan lines in the lunar image, and phase angle. The time series are plotted in Fig. 3. Two trends are apparent in these plots: a systematic variation in the data from one calibration to the next that arises from an incomplete normalization to the common viewing geometry, and a decrease in the radiometric responses of bands 7 and 8 with time.

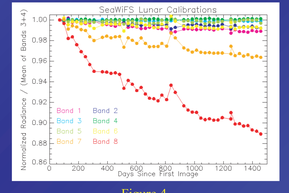

Figure 4

The time series can be corrected for the incomplete normalization over viewing geometry by a second normalization based on a subset of the SeaWiFS bands. Bands 3 and 4 are changing the least among the bands, so the mean value of these bands at each calibration is used as the second normalization. The time series with the second normalization is plotted inFig. 4. The radiometric responses for bands 1-6 have changed slightly over the course of the mission, while the response for band 7 is down approximately 3.5% and the response for band 8 is down approximately 11%. Calibrations 3, 9, and 15 occurred at phase angles of less than 6 degrees and calibrations 19, 26, 27, and 39 occurred at phase angles of 8 degrees or more.

Phase Angle Corrections

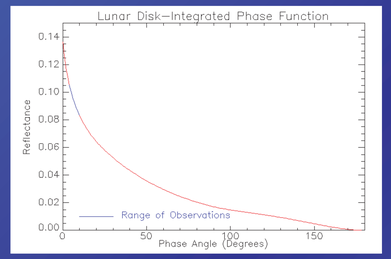

Figure 5

The change in lunar reflectance with phase angle is shown in Fig. 5. The SeaWiFS observations span a range phase angles of 4 to 10 degrees. This monochromatic function is the first-order phase angle correction applied to the lunar time series. The deviations of the low and high phase angle calibrations in the time series shown in Fig. 4 vary in magnitude as a function of wavelength, indicating that wavelength-dependent phase angle effects are still present in the data.

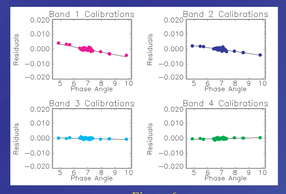

Figure 6

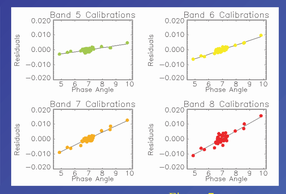

Figure 7

Second-order, wavelength-dependent phase angle corrections have been computed for SeaWiFS by fitting a quadratic function to the time series in Fig. 4, excluding the low and high phase angle data. The differences between the fits and the observations for all of the calibrations are plotted as functions of the phase angle in Figs. 6 and 7. The slopes of linear fits to the data are the wavelength-dependent phase angle correction factors.

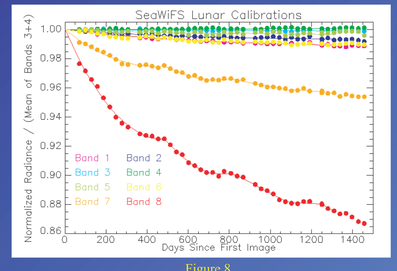

Figure 8

The lunar time series, with the wavelength-dependent phase angle corrections applied, are plotted in Fig. 8. The CVT has fit these data with a set of functions of time. Single linear fits have been applied to bands 1–6. Three quadratic fits and a linear fit have been applied to bands 7 and 8. These fits provide the time corrections for the SeaWiFS operational processing. The duration of each of the quadratic fits for bands 7 and 8 is approximately one year, indicating that a seasonal effect is giving rise to the inflection points in the time series.

Focal Plane Temperature Effects

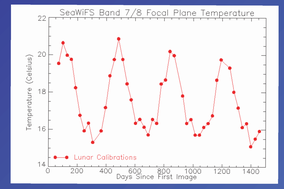

Figure 9

The ambient temperatures at which the SeaWiFS focal planes operate are affected by the solar insolation on the spacecraft. The temperature of the focal plane for bands 7 and 8 is plotted at the times of the lunar calibrations in Fig. 9. This plot shows a seasonal cycle as the Earth – sun distance varies. The SeaWiFS counts-to-radiance conversion incorporates corrections for variations in the radiometric response of the instrument with focal plane temperature. Comparison of Figs. 8 and 9 shows that the periodicities in the time series for bands 7 and 8 correspond to periodicities in the focal plane temperatures. This correlation indicates that the prelaunch focal plane temperature corrections do not fully account for the variation in radiometric response with changing focal plane temperatures observed over the course of a year.

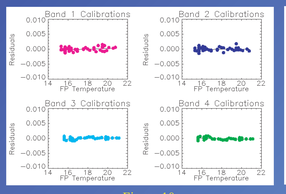

Figure 10

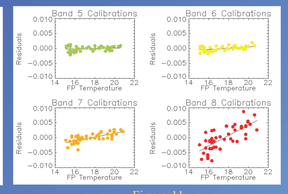

Figure 11

The CVT has fit single quadratic functions to the lunar time series for all eight bands. The residuals of these fits are plotted as functions of focal plane temperature in Figs. 10 and 11, along with linear fits to the data. These plots shows negligible slopes for bands 1–5 and increasing slopes for bands 6–8. The CVT has used the slopes of these plots to revise the focal plane temperature correction factors for the SeaWiFS counts-to-radiance conversion. These revised temperature correction factors have been used to reprocess all of the lunar calibration data.

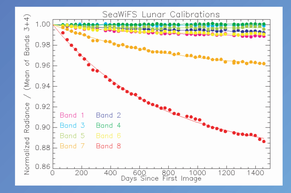

Figure 12

The lunar time series, with the revised focal plane temperature correction applied, are plotted in Fig. 12. The revised temperature corrections allow a single function to be fit to each band. The CVT has fit each band with a decaying exponential function of time. These fits will provide the time corrections for the next (fourth) reprocessing of the SeaWiFS mission data set.