SeaWiFS long-term solar diffuser reflectance and sensor noise analyses

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The NASA Ocean Biology Processing Group's Calibration and Validation (Cal/Val) team has undertaken an analysis of the mission-long Sea-Viewing Wide Field-of-View Sensor (SeaWiFS) solar calibration time series to assess the long-term degradation of the solar diffuser reflectance over 9 years on orbit. The SeaWiFS diffuser is an aluminum plate coated with YB71 paint. The bidirectional reflectance distribution function of the diffuser was not fully characterized before launch, so the Cal/Val team has implemented a regression of the solar incidence angles and the drift in the node of the satellite's orbit against the diffuser time series to correct for solar incidence angle effects. An exponential function with a time constant of 200 days yields the best fit to the diffuser time series. The decrease in diffuser reflectance over the mission is wavelength dependent, ranging from 9% in the blue (412 nm) to 5% in the red and near infrared (670–865 nm). The Cal/Val team has developed a methodology for computing the signal-to-noise ratio (SNR) for SeaWiFS on orbit from the diffuser time series corrected for both the varying solar incidence angles and the diffuser reflectance degradation. A sensor noise model is used to compare on-orbit SNRs computed for radiances reflected from the diffuser with prelaunch SNRs measured at typical radiances specified for the instrument. To within the uncertainties in the measurements, the SNRs for SeaWiFS have not changed over the mission. The on-orbit performance of the SeaWiFS solar diffuser should offer insight into the long-term on-orbit performance of solar diffusers on other instruments, such as the Moderate-Resolution Imaging Spectrometer [currently flying on the Earth Observing System (EOS) Terra and Aqua satellites], the Visible and Infrared Radiometer Suite [scheduled to fly on the NASA National Polar-orbiting Operational Environmental Satellite System (NPOESS) and NPOESS Preparatory Project (NPP) satellites] and the Advanced Baseline Imager [scheduled to fly on the National Oceanic and Atmospheric Administration Geostationary Environmental Operational Satellite Series R (GOES-R) satellites].

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1. Introduction

The Sea-Viewing Wide Field-of-View Sensor (SeaWiFS) is an eight-band visible and near-infrared scanning radiometer designed to have high radiometric sensitivity over oceans without saturating over bright clouds. The bands are provided in Table 1. The goal of the NASA Ocean Biology Processing Group's Calibration and Validation (Cal/Val) team is to produce a long-term ocean color data set with 5% absolute and 1% relative accuracies on the water-leaving radiances and 35% accuracy on chlorophyll a concentrations in open-ocean regions.[1] To meet this goal, the Cal/Val team has implemented an on-orbit calibration strategy that uses monthly lunar calibrations to monitor the radiometric stability of the instrument over its mission lifetime and that uses daily solar calibrations to look for short-period, step-function changes in the instrument response.[2,3] The Cal/Val team has undertaken an analysis of the mission-long solar calibration time series to assess the long-term degradation in the solar diffuser reflectance over 9 years on orbit. SeaWiFS presents advantages for this analysis since the diffuser is not the primary monitor of the instrument's radiometric stability. This analysis has allowed the Cal/Val team to use the sunlight reflected from the diffuser to compute the signal-to-noise ratios (SNRs) of the instrument on orbit and to monitor changes in the SNRs over time.

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7. Discussion

Since SeaWiFS has completed the ninth year of its mission, analysis of the solar calibration data provides a unique opportunity to study long-term trends in solar diffuser reflectance on orbit. Because the primary monitor of the radiometric stability of SeaWiFS is the Moon, the diffuser trends are decoupled from trends in the instrument response.

The residual effects of the azimuth angle variations in the SeaWiFS diffuser time series (Figs. 8–11) show the necessity of accurately determining the BRDF of diffusers prior to launch and the necessity of monitoring the changes in both the BRDF of and the reflectance of diffusers on orbit. The long-term degradation of the reflectance of solar diffusers on orbit, and the monitoring and modeling of that degradation, is a critical concern for Earth remote sensing instruments that employ solar diffusers as the primary on-orbit radiometric calibration standard for reflective solar (visible, near-infrared, and shortwave infrared) bands.

The reflectance degradation trends for the SeaWiFS solar diffuser (Fig. 13) show that diffusers made from YB71-coated aluminum exhibit decreases in reflectance over time that can be fit by decaying exponentials with relatively short time constants (200 days for SeaWiFS). The degradation is wavelength dependent, with the blue bands degrading 9% while the red bands degrade 5%. For all of the bands, the degradation levels off after the first thousand days on orbit. The most likely degradation mechanism is coating of optical surfaces by photolyzed organic materials outgassed from the spacecraft. These results imply that for other instruments that use diffusers as the primary monitor of radiometric response, trends in the diffuser response that continue significantly beyond 1000 days probably arise from either continued outgassing events from the spacecraft or ongoing changes in the instrument response.

The Landsat-7 ETM+ is one remote sensing instrument, other than SeaWiFS, that uses a YB71-coated solar diffuser (the FASC). The SeaWiFS diffuser results are difficult to compare with those reported for the ETM+ FASC, since estimates of the FASC reflectance on orbit are provided for only a limited number of observations.[14]

The SeaWiFS diffuser results are qualitatively similar to those observed for the EOS Terra MODIS solar diffuser,[11] which is made from space-grade Spectralon. The complicated on-orbit history of the Terra MODIS instrument and the poor characterization of the SeaWiFS diffuser BRDF makes detailed comparisons of the SeaWiFS and MODIS diffusers difficult. However, comparisons of the long-term degradation trends of the SeaWiFS diffuser to both the EOS Terra and Aqua MODIS diffusers should provide insight into the on-orbit performance of solar diffusers on future Earth remote sensing instruments, such as the Visible and Infrared Radiometer Suite, scheduled to fly on the NPP and NPOESS satellites and the Advanced Baseline Imager, scheduled to fly on the GOES-R series satellites.

The solar calibration data analysis presented here provides a methodology for computing the SNRs for SeaWiFS on orbit from solar data that has been corrected for both the varying solar incidence angles on the diffuser and for the degradation in diffuser reflectance. Comparison of the on-orbit SNRs with noise model SNRs, prelaunch SNRs, and the instrument specifications shows that changes in the SNRs over the mission are less than 7% and are within the measurement uncertainties (Table 5). The SNR for each SeaWiFS band still exceeds the prelaunch specification. Similar diffuser data analysis methodologies can be developed to monitor the on-orbit SNRs other remote sensing instruments.