MOBY Normalized Water-Leaving Radiance Time-series Uncertainty Reduction for Improved Multi-platform Satellite Sensor Vicarious Calibration (OS33A-01)


Abstract

The Marine Optical Buoy (MOBY), a remote buoy stationed in the waters off Lassen, has been the primary ocean color sensor for the vicarious calibration of satellite ocean color sensors. Since late 1996, MOBY has been the primary testbed for the on-orbit vicarious calibration of MODIS data. VICART, a field-based vicarious sensor (SeaWiFS), the Japanese Ocean Color and Temperature Sensor (OCTS), the French Plutonization Detection Environmental Radiometer (POLYS), the USA Moderate Resolution Imaging Spectrometer (MODIS), and the Indian Remote Sensing Satellite (IRS) are all included in this list. The MODIS vicariable calibration of these sensors supports this interlaboratory effort to develop a global, multi-sensor common reference ocean color data product. A longstanding goal of the Ocean Color Science Teams is to develop a satellite-derived corrected water-leaving radiance (Lw) with a combined standard uncertainty of 5%. A critical component of this approach is to reduce uncertainties in MODIS data. As has been the case for the first MODIS deployment, these improvements are achieved incrementally and form a variety of system aspects. We will discuss these efforts and present initial results relating to the radiometric calibration, instrument stability during deployments, sensitivity to temperature, stray light corrections, data acquisition protocols, and instrument self-shading.

The Need for a Vicarious Calibration

A long-standing goal of ocean color satellite Science Teams is to determine satellite-derived Lw with a combined standard uncertainty of 5%. Because water-leaving radiance contributes only 10% (at most) of the radiance measured by a satellite sensor above the atmosphere, a 5% uncertainty in Lw implies a 0.5% uncertainty in the above-atmosphere radiance measurements.

This level of uncertainty can only be addressed by using "vicarious-calibration" approaches. In practice, this means that the satellite radiance responsivity is adjusted to minimize the squared differences between an in situ radiance measurement and the radiance measured by the satellite. The result of this approach is to implicitly absorb unquantified, but systematic, errors in the atmospheric correction, incident solar flux, and satellite sensor calibration into a single correction factor to produce consistency with the in situ data.

MOBY’s role in vicarious calibration

An interdisciplinary team of scientists and engineers has been assembled who collaborated to develop, produce and maintain a high quality system. The team has paid special attention to characterizing and calibrating MOBY to reduce the uncertainty and bias within the system. The site provides the required oligotrophic waters which minimizes horizontal variability around the site. MOBY’s optical design, even though it is 15 years old, still remains state of the art. MOBY’s high spectral resolution has provided for accurate convolution of each satellite’s relative spectral response, which eliminates the spectral bias. A multi-spectral approach introduces systematic biases into the calibration process.

Corresponding author: Bryan Franz (bfranz@noaa.gov), National Institute of Standards and Technology, Optical Technology Division 100 Bureau Drive Stop 8443, Gaithersburg, MD 20899-8442, United States. MOBY has provided the only decade-long marine optical time series which is directly traceable to NIST. Pre-processing of the entire data set includes the correction of time stamps for the ancillary data, and removal of 'spikes' in the radiometric data. Multiple scans of the data are averaged together, and each average scan is processed to reduce noise in the data. A "spike" is a sub-sampling of the whole data set in the pixel that is above or below the pixel's average value. This processing step is important for reducing noise in the data.

Optical Buoy

The MOBY system consists of a series of optical components, each of which is designed to measure a specific property of the seawater. The system includes a set of optical fibers that are used to measure the light intensity at different wavelengths. The fibers are connected to a series of optical detectors, which are used to measure the intensity of the light at each wavelength. The system also includes a series of filters, which are used to block light at certain wavelengths and pass light at others. Finally, the system includes a series of calibration standards, which are used to calibrate the system and ensure that the measurements are accurate.

Stray Light Correction

Radiometric sensors do not have an ideal spectral selectivity. That is, the response at a wavelength of interest to flux at other wavelengths ("out-of-band") is small but finite. For MODIS, the out-of-band response is largely determined by the scattering properties of the grating and mirror reflections of the grating and mirror surfaces at higher orders. We refer to this as "ringing." It is a significant issue in ocean color sensors, particularly for bands like 865 nm where the out-of-band response is high. To correct for stray light, the function that describes the ringing to flux at other wavelengths is measured experimentally for each MODIS detector. This is done by blocking the light from the detector of interest with a black plateau and measuring the response at each wavelength. The out-of-band response is then calculated as the ratio of the response at each wavelength to the response at the wavelength of interest. This ratio is then used to correct the data for stray light.

The unique role of MOBY as a primary, long-term, daily reference for vicarious calibration of satellite ocean color sensors requires radiometric measurements of the highest possible quality. The extended combined standard uncertainty of MODIS radiance measurements is between 5% and 8%. This estimate is based on uncertainties of MODIS calibrations at less than 2%, changes in atmospheric conditions at less than 0.5%, and radiometric stability at less than 1% over the period of a deployment. The extended combined standard uncertainty of the MOBY data is less than 1%, and it is expected that any remaining uncertainty will be less than 5% (the estimated uncertainty of the method).