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Comparison of spectral radiance calibrations at oceanographic and atmospheric research laboratories

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Abstract
This report describes the first Sensor Intercomparison and Merger for Biological and Interdisciplinary Oceanic Studies (SIMBIOS) Radiometric Intercomparison (SIMRIC-1). The purpose of the SIMRIC-1 is to ensure a common radiometric scale among the calibration facilities that are engaged in calibrating *in situ* radiometers used for ocean colour-related research and to document the calibration procedures and protocols. SIMBIOS staff visited the seven participating laboratories for at least two days each. The SeaWiFS Transfer Radiometer (SXR-II) measured the calibration radiances produced in the laboratories. The measured radiances were compared with the radiances expected by the laboratories. Typically, the measured radiances were higher than the expected radiances by 0 to 2%. This level of agreement is satisfactory. Several issues were identified where the calibration protocols need to be improved, especially the reflectance calibration of the reference plaques and the distance correction when using the irradiance standards at distances greater than 50 cm. The responsivity of the SXR-II changed from 0.3% (channel 6) to 1.6% (channel 2) from December 2000 to December 2001. Monitoring the SXR-II with a portable light source showed a linear drift of the calibration, except for channel 1, where a 2% drop occurred in summer.

1. Introduction

The Sensor Intercomparison and Merger for Biological and Interdisciplinary Oceanic Studies (SIMBIOS) Project [1] has a worldwide, ongoing, ocean colour data collection program, plus an operational data processing and analysis capability. The goal of the SIMBIOS Program is to assist the international ocean colour community in developing a multi-year time-series of calibrated radiances which transcends the spatial and temporal boundaries of individual satellite missions.

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The specific objectives of the SIMBIOS Program are: (1) to quantify the relative accuracies of the ocean colour products from each mission, (2) to work with each project to improve the level of confidence and compatibility among the products, and (3) to develop methodologies for generating merged level-3 products.

The quality of the calibrated satellite data can be checked with match-up analyses from *in situ* ocean colour measurements taken during ship cruises. The Sea-viewing Wide Field-of-view Sensor (SeaWiFS) and SIMBIOS Projects jointly maintain a database called SeaWiFS Bio-optical Archive and Storage System (SeaBASS, http://seabass.gsfc.nasa.gov), which contains *in situ* data from more than 600 cruises from all over the world. The quality of this database is obviously directly related to the quality and comparability of the stored *in situ* data. Two kinds of activities are performed by the SIMBIOS Project to ensure an adequate quality of the SeaBASS database: first, measurement protocols are developed [2], and their usage by the science community is encouraged. Second, calibration round-robin intercomparison experiments are conducted by the SIMBIOS Project. The participating laboratories include academic institutions, government agencies, and instrument manufacturers that either directly or indirectly contribute to SeaBASS. The purposes of these round robins are to

(a) verify that all laboratories are on the same radiometric scale,
(b) detect and correct problems at any individual laboratory in a timely fashion,
(c) encourage the common use of calibration protocols,
(d) identify areas where the calibration protocols need to be improved, and
(e) document the calibration procedures specific to each laboratory.

This report documents the results from the first SIMBIOS Radiometric Intercomparison, the Sensor Intercomparison and Merger for Radiometric Intercomparison (SIMRIC-1). The SIMRIC series was started by the SIMBIOS Project as a successor to the SeaWiFS Intercalibration Round-Robin Experiment (SIRREX) series [3]. For SIMRIC-1, SIMBIOS staff visited seven laboratories (Naval Research Laboratories, District of Columbia; Scripps Institute of Oceanography, University of California, San Diego; Biospherical Instruments Inc., California; ICESS at the University of California, Santa Barbara; HOBI Labs, California; NASA Code 920.1, Goddard Space Flight Center, Maryland; Satlantic Inc., Canada), with a radiometer designed and calibrated by the National Institute for Standards and Technology (NIST)—the SeaWiFS Transfer Radiometer II (SXR-II). The radiances produced by the laboratories for calibration were measured in the six SXR-II channels from 411 to 777 nm and were compared to the radiances expected by the laboratories. This article summarizes the comparison results and discusses areas where the calibration protocols should be improved. A full report has been published [4] as well.

4. Discussion

The differences between the SXR-II measured radiances and the radiances expected by the laboratories are typically about 2%. As the $k = 1$ uncertainties of the calibration radiances produced by the laboratories are typically about 2% and the $k = 1$ uncertainties of the SXR-II are about 0.8%, the differences are well within the expected range.

Many laboratories transfer the calibration from a primary standard to a secondary standard. The quality of the transfer was investigated at three laboratories (NRL, Biospherical and UCSB), with highly satisfying results (variations of less than 0.5% were found [4]). At Satlantic, only primary standards calibrated by Optronics Laboratories are used for calibration. Although this eliminates the uncertainty introduced by the calibration transfer, the variations between primary standards are surprisingly large; a difference of almost 2% was found comparing the irradiance standard reported in table 2 and another irradiance standard at Satlantic.

The uncertainty introduced by the Labsphere Spectralon plaques is a difficult problem. The SIMBIOS Project suggests including information on the handling of the plaque reflectance in all issued calibration reports. This would include the serial number of the plaque, the calibration date of the plaque reflectance and information on the reflectance quantity used. Other results from SIMRIC-1 not discussed here (see [4]) support the use of the conversion factor for converting 8°/hemispherical reflectance factors to 0°/45° spectral reflectance factors reported in [10], but a small survey of reflectance calibrations delivered by Labsphere suggests a conversion factor that is on average about 1.5% smaller, see table 1. Further research is necessary on this subject.

Furthermore, it would be useful to identify on each calibration report the NIST irradiance standard with which the calibration can be ultimately traced. This information should include the number of the NIST FEL, its year of calibration and the year of the NIST irradiance scale. In addition, the FEL number and date of calibration of each secondary standard involved in the calibration chain should be documented.

The effective distance correction suggested by [8] encounters considerable reluctance in the oceanographic community. None of the three laboratories that illuminate the plaque at a greater distance than the calibration distance of 50 cm employs this correction. The recommendation from NIST staff (Howard Yoon, personal communication) that each lab should determine the effective distance correction factor for their own lamps by themselves probably cannot be accomplished because of a lack of sufficiently precise equipment. More work is necessary to settle this issue.