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Radiometric Measurement Comparison on the Integrating Sphere Source Used to Calibrate the Moderate Resolution Imaging Spectroradiometer (MODIS) and the Landsat 7 Enhanced Thematic Mapper Plus (ETM+)

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As part of a continuing effort to validate the radiometric scales assigned to integrating sphere sources used in the calibration of Earth Observing System (EOS) instruments, a radiometric measurement comparison was held in May 1998 at Raytheon/Santa Barbara Remote Sensing (SBRS). This comparison was conducted in support of the calibration of the Moderate Resolution Imaging Spectroradiometer (MODIS) and the Landsat 7 Enhanced Thematic Mapper Plus (ETM+) instruments. The radiometric scale assigned to the Spherical Integrating Source (SIS100) by SBRS was validated through a comparison with radiometric measurements made by a number of stable, well-characterized transfer radiometers from the National Institute of Standards and Technology (NIST), the National Aeronautics and Space Administration's Goddard Space Flight Center (NASA's GSFC), and the University of Arizona Optical Sciences Center (UA). The measured radiances from the radiometers differed by ±3 % in the visible to near infrared when compared to the SBRS calibration of the sphere, and the overall agreement was within the combined uncertainties of the individual measurements. In general, the transfer radiometers gave higher values than the SBRS calibration in the near infrared and lower values in the blue. The measurements of the radiometers differed by ±4 % from 800 nm to 1800 nm compared to the SBRS calibration of the sphere, and the overall agreement was within the combined uncertainties of the individual measurements for wavelengths less than 2200 nm. The results of the radiometric measurement comparison presented here supplement the results of previous measurement comparisons on the integrating sphere sources used to calibrate the Multi-angle Imaging SpectroRadiometer (MISR) at NASA's Jet Propulsion Laboratory (JPL), Pasadena, CA and the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) at NEC Corporation, Yokohama, Japan.

Key words: calibration; Earth Observing System (EOS); integrating sphere; Moderate Resolution Imaging Spectroradiometer (MODIS); Landsat 7 Enhanced Thematic Mapper Plus (ETM+); remote sensing; spectral radiometry; transfer radiometers.

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1. Introduction

The Earth Observing System (EOS) is an 18 year international multi-satellite, multi-instrument program in remote sensing of the Earth. The goal of the program is to advance the scientific understanding of the Earth system and its changes on a global scale. To achieve this goal, EOS instruments will make global, continuous, long time series radiance and reflectance measurements of the Earth. The first EOS satellite, Terra, launched in December 1999, is comprised of five instruments designed to monitor the Earth's atmosphere, oceans, land, cryosphere, and their interaction with the incident solar radiation. The five EOS Terra instruments include the Moderate Resolution Imaging Spectroradiometer (MODIS) [1], the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) [2], the Multi-angle Imaging SpectroRadiometer (MISR) [3], the Clouds and the Earth's Radiant Energy System (CERES) instrument [4], and the Measurements of Pollution in the Troposphere (MOPITT) instrument [5]. On orbit, these instruments make geolocated radiance and reflectance measurements that will be combined to form the basis for a multidisciplinary study of the Earth system. The resulting radiance and reflectance images from these instruments will be formed into a number of geophysical products. The Landsat 7 satellite, also launched in December 1999, carries the Enhanced Thematic Mapper Plus (ETM+) instrument [6]. Measurements from ETM+ will be combined with those made from the EOS Terra instruments for regional process studies and models. The MODIS and CERES instruments are also on the EOS Aqua platform that was launched on May 4, 2002, effectively continuing the data set acquired by the EOS Terra instruments; the follow-on to the ETM+ instrument, the Landsat Data Continuity Mission (LDCM), is in preparation.

The capability for researchers to combine radiometric measurements and derived geophysical products from multiple EOS instruments on the same or different satellite platforms is essential. The accuracy of these analyses is critically linked to the pre-launch calibration of the instruments and the assessment of the post-launch calibration. Accurate radiometric calibration and characterization is by reference to a common set of recognized physical standards, good measurement practice, and realistic uncertainty budgets. With respect to the pre-launch calibration of the EOS Terra and Landsat 7 ETM+ instruments, a set of transfer radiometers operating in the visible through shortwave infrared wavelength region (from 400 nm to 2500 nm) has been independently developed and calibrated by several metrology laboratories and used to assess standard sources of spectral radiance. These laboratories include the National Institute of Standards and Technology (NIST), the National Aeronautics and Space Administration's Goddard Space Flight Center (NASA's GSFC), the University of Arizona Optical Sciences Center (UA), and the National Metrology Institute of Japan/National Institute of Advanced Industrial Science and Technology—NMIJ/AIST (formerly the National Research Laboratory of Metrology—NRLM) in Tsukuba, Japan. Under the direction of the EOS Project Science Office, these radiometers make simultaneous, comparative measurements of the integrating sphere sources used to calibrate EOS instruments [7-10] to assess the accuracy of the radiometric values assigned to the integrating sphere sources by the EOS instrument builders. The transfer radiometers are calibrated by their home institution using radiometric standards maintained by the appropriate national standards laboratories. As part of the study, the radiometric stability and repeatability of the spheres are also determined.

In May 1998, NIST, UA, NASA's GSFC, and Raytheon Santa Barbara Remote Sensing (SBRS) participated in a radiometric measurement comparison using the SBRS Spherical Integrating Source (SIS100). The SIS100 is the large aperture, uniform radiant source used to calibrate the EOS Terra and Aqua MODIS instruments and the Landsat 7 ETM+ instrument. The 1998 measurement comparison addressed the validation of the SBRS-assigned radiometric values, sphere repeatability, and sphere stability. During the comparison, measurements were made by the participating radiometers on 37 sphere radiance levels. This paper presents and discusses the results from that radiometric measurement comparison.

The results are relevant to the calibration and characterization of current and future satellite and ground instruments. The radiance calibration approaches employed by SBRS on the SIS100 and described in this paper are used by a number of other institutions. The results presented here constitute the first, careful examination and validation of those approaches. The SIS100 will be used in the pre-launch radiance calibration of the Visible Infrared Imaging Radiometer Suite (VIIRS) scheduled to fly on both the National Polar-orbiting Environmental Satellite System (NPOESS) and the National Polar-orbiting Environmental Satellite System Preparatory (NPP) projects. The stability, repeatability, and radiance measurement methodologies of the SIS100 examined in this paper will provide important guidance to SBRS in their use of the SIS100 in the calibration of VIIRS.