

Radiometric Stability of a Calibration Transfer Standard Spectroradiometer and a Spectralon Sphere Illuminated Internally or Externally

D. F. Heath

Ball Aerospace and Technology Corp, Boulder, Co, USA

M. G. Kowalewski

Science Systems and Applications Inc., Lanham, MD, USA

Abstract. Results are presented on the radiometric stability of a calibration transfer standard spectroradiometer that has been calibrated repeatedly against NIST spectral irradiance standards, and it has been used in the radiometric calibrations of the Dutch Ozone Monitoring Instrument (OMI), and the Ball Aerospace & Technology Corporation (BATC) Ozone Mapping and Profiling Suite (OMPS), High Resolution Imaging Science Instrument (HiRISE), Ralph, and World View instruments. This spectroradiometer has also been used to investigate the radiometric stability of a 50.4 cm diameter Spectralon integrating sphere illuminated internally by quartz tungsten halogen (QTH) lamps or externally by xenon arc lamps.

Calibration Transfer Standard Spectroradiometer

A calibration transfer standard spectroradiometer (CTSS) was developed in the late 1990s at Research Support Instruments, Inc, (RSI). The system utilizes a series of narrow band ion-assisted-deposition filters in multiple filter wheels (23 filters) for spectral discrimination in the 250 nm-1000 nm region that is combined with either an IRD UVG-100 nitrided silicon photodiode for wavelengths < 400nm or a Hamamatsu 1337 silicon photodiode for wavelengths > 1000 nm.

The BATC/RSI transfer spectroradiometer has been calibrated for spectral irradiance against 12 different NIST standards of spectral irradiance at RSI, Technische Physiche Dienst (TPD), Goddard Space Flight Center (GSFC), and BATC with both IRD UVG-100 and Hamamatsu 1337 silicon photodiodes with the same set of narrow band hardened interference filters. The spectral radiance calibrations have been derived based on BRDF measurements of three Spectralon panel diffusers by Jim Butler's group at GSFC. One was measured in October 2000 and the other two were measured in October 2003.

A measure of the long-term radiometric stability of the CTSS is given by the standard deviation / mean of the spectral irradiance calibration constants. These data are shown in Figure 1. The measurements of the spectral irradiance calibration constants were made for NIST 1000 W FEL lamps which had been used for variable amounts of burn time.

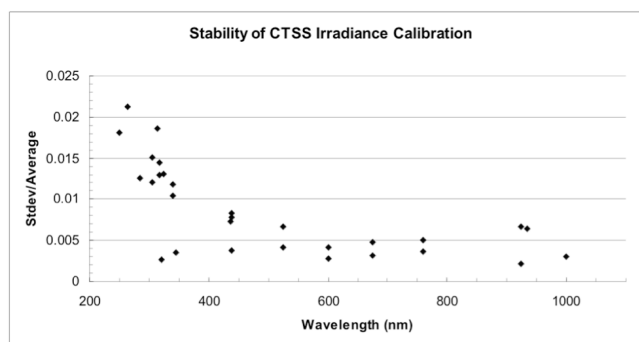


Figure 1. Standard deviation / average of the spectral irradiance calibration coefficients from 10 NIST 1000 W FEL lamps is given for the period from August 2001 to October 2004. There are multiple data points at the same wavelength due to the use of filters in two different filter wheel configurations. The uncertainty for wavelengths < 300 nm increases because of the large corrections for out-of-band contributions to the in-band signal.

Integrating Sphere Characterization

During early March 2005 as part of cooperative calibration program with GSFC, the CTSS, the BATC Labsphere 50.4 cm diameter Spectralon integrating sphere which had been modified by SphereOptics to accommodate a xenon arc for external illumination were calibrated at GSFC.

The purpose of this program was to calibrate the CTSS using GSFC NIST spectral irradiance standards and Spectralon panel diffusers with BRDF measurements from Jim Butler's group at GSFC, and to calibrate the BATC Spectralon sphere illuminated internally by QTH lamps or externally with the 150 W and 300 W Hamamatsu xenon arc sources. These cooperative calibration activities between GSFC and BATC are to be an important part of the radiometric calibration of OMPS and the subsequent participation of NIST in the OMPS calibration activities.

The results of the spectral radiance and irradiance calibrations of the CTSS are shown in Figure 2 as the ratios of the irradiance to radiance calibration constants which are invariant geometrical constants of the CTSS. The advantage of this approach is that once these ratios are determined accurately, one can then derive the spectral radiance calibration constants from the irradiance calibration coefficients and the ratios given in Figure 2. The irradiance calibration coefficients have a lower uncertainty than the radiance calibration coefficients.

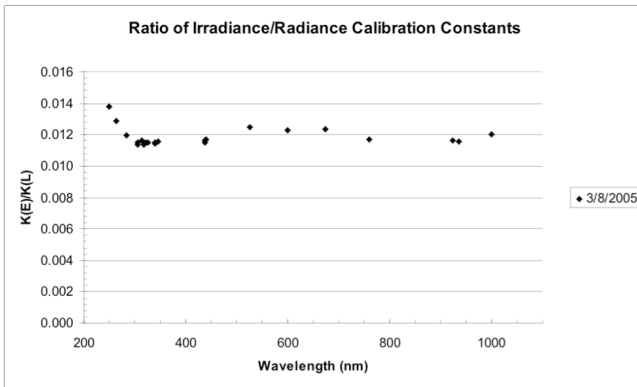


Figure 2. The ratio of the irradiance to the radiance calibration coefficients are geometrical invariants of the CTSS which to zero order is the effective solid angle of the CTSS.

After the completion of the one week of radiometric calibration activities at GSFC, all the equipment, including the integrating sphere and xenon arc sources, was shipped back to BATC for recalibration. A surprising feature of the recalibration of the BATC Spectralon sphere is shown in Figure 3.

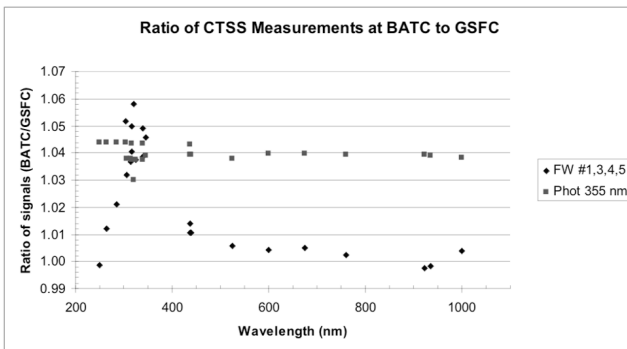


Figure 3. The ratios of the radiance calibration signals of the recalibration at BATC to the calibration signals recorded at GSFC are shown for the CTSS and a separate photometer which has a central wavelength of 355 nm. Each data point consists of 100 samples from a CTSS filter interleaved with 100 photometer samples.

These data indicate that either the sphere radiance data were abnormally low in the 300 nm to 400 nm wavelength region at GSFC or that the sphere radiance exhibited an abnormally high radiance subsequently at BATC.

Conclusions

Multiple calibrations over the course of three years has shown the CTSS to be radiometrically stable to 1.5 % or better at wavelengths greater than 300 nm. It should be noted that this uncertainty also includes any drift in the NIST 100W QTH FEL lamp standards of spectral irradiance associate with variable lamp burn times. The ratios of the irradiance to radiance calibration constants are geometrical invariants of the CTSS to within approximately 2 %.

The general conclusion is that large aperture radiance calibration source uncertainties can be reduced significantly by the combined use of National Laboratory spectral irradiance standards, derived spectral radiance standards and a calibration transfer standard spectroradiometer.