LONG-TERM CALIBRATION STUDY OF GRAY-SCALE SPECTRALON DIFFUSERS BRDF

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In this paper we present a long-term calibration monitoring of the Bidirectional Reflectance Distribution Function (BRDF) of gray-scale Spectralon diffusers. The BRDF was measured using a short-arc Xenon lamp/monochromator assembly producing an incoherent, tunable light source with a well-defined spectral bandpass at ultraviolet, visible and near-infrared wavelengths as well as coherent light source in the shortwave infrared. A set of twelve Spectralon diffusers with specified hemispherical reflectance of 2%, 5%, 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90%, and 99%, Fig.1, was monitored in this study. All samples were measured using P and S incident polarized light over a range of incident and scatter angles. By comparing these results, we quantitatively examine the wavelength and geometrical scatter properties of gray-scale Spectralon. The measurements are compared, and the influence of material composition on the BRDF is described. The future application of gray-scale Spectralon in the calibration of spaceborne sensors is discussed.

The global nature of Earth's processes requires consistent long-term calibration of all instruments involved in data retrieval[1]. The BRDF defines the directional reflection characteristics of an optical surface. It provides the reflectance of a target in a specific direction as a function of illumination and viewing geometry. The BRDF is a function of wavelength and reflects the structural and optical properties of the surface. Various space and airborne radiometric and imaging remote sensing instruments use diffuse scatter plates as calibration sources. These plates require preflight BRDF calibration measurements[2]. On-board diffusers are used to trend on-orbit instrument radiance or reflectance calibration. Laboratory based diffusers are used for pre-flight instrument radiance calibrations. BRDF measurements of natural targets are also used in the remote sensing characterization of vegetation canopies and soils[3], oceans[4], or especially large pollution sources[5].

Many on-orbit satellite instruments such as MODIS, MISR, and MERIS, among others, use white, 99% reflective space grade Spectralon for their on-orbit radiance and reflectance calibrations. This provides a one-point on-orbit radiance calibration. In the past, gray-scale Spectralon has been considered by Earth remote sensing satellite programs as a means to achieve radiance calibrations at other levels. In accordance with the goal of calibrating "like with like," gray-scale Spectralon is of particular interest to satellite programs which measure darker targets such as oceans and land.

The BRDF data of this study was obtained between 2006 and 2009 using the scatterometer located in the NASA's Goddard Space Flight Center Diffuser Calibration Laboratory (DCL). The initial 8^o/hemispherical reflectance was determined using a Perkin-Elmer Lambda-19 spectrometer with an RSA-PE-19 integrating sphere by Labsphere. The samples were kept in a dark, cleanroom environment and were never used for any other measurement. The DCL scatterometer can perform in-plane and out-of-plane bidirectional reflectance distribution function (BRDF) and bidirectional transmission distribution function (BTDF) measurements with typical measurement uncertainties of 1 % ($k = 1$), where k is the coverage factor or better. The diffusers were measured at 0^o and 60^o incident angles and from 0^o to 80^o scatter zenith angles in steps of 5^o. The accuracy of measured BRDF depended on the signal-to-noise ratio and was determined by a sample's spatial optical scatter properties. wavelengths between 230 nm and 1520 nm and at number of incident and scatter angles. Spectral features in the BRDF of Spectralon are also discussed. The comparison shows how the BRDF of these Spectralon samples changed over time under cleanroom deployment conditions.

The BRDF of samples with reflectance factor from 2% to 20% increases with the scatter zenith angles. The BRDF of samples with reflectance factors from 40% to 99% decreases with increase of scatter zenith angles. The sample with reflectance factor of 30% has a flat BRDF. The BRDF spectral dependence is given at 45^o scatter zenith angle. It is almost flat from 300 nm up to 900 nm for all samples, however at 250 nm it increases for samples with reflective factors from 2% to 80% and decreases for the90% and 99% samples. The Spectralon with a reflectance factor of 99% is known to have forward scattering properties. However the Spectralon with reflectance factors of 2%, 5%, and 10% have spectrally independent backscattering properties. This type of stability/degradation study is the logical step in determining the usefulness of gray-scale Spectralon to satellite instruments.

The results presented here are traceable to the National Institute of Standards and Technology's (NIST's) Special Tri-function Automated Reference Reflectometer (STARR)[6].

Fig.1: The set of twelve Spectralon samples

REFERENCES

[1] J.J. Butler, B.C. Johnson, R.A. Barnes, "The calibration and characterization of Earth remote sensing and environmental monitoring instruments", in Optical Radiometry, Ed. A.C. Parr, R.U. Datla, J.L. Gardner, Academic Press, New York (2005),

[2] G.B. Courreges-Lacoste, J.G. Schaarsberg, R. Sprik, S. Delward, "Modeling of Spectralon diffusers for radiometric calibration in remote sensing", *Opt. Eng*., **42**, 3600-3607 (2003),

[3] C.K. Gatebe, M.D. King, S. Platnick, G.T. Arnold, E.F. Vermote, B. Schmid, "Airborne spectral measurements of surface-atmosphere anisotropy for several surfaces and ecosystems over southern Africa", *J. Geophysical Research*, **108**, D13, 25-1-16 (2003).

[4] C.K. Gatebe, M.D. King, A.I. Lyapustin, G.T. Arnold, J. Redemann, "Airborne spectral measurements of ocean directional reflectance", *J. Atmospheric Sciences*, **62**, 1072-1092 (2005).

[5] M.D. King, "Directional and spectral reflectance of the Kuwait oil-fire smoke", *J. Geophysical Research*, **97**, D13, 14545-14549 (1992).

[6] Proctor J.R., Barnes P.Y., "NIST High accuracy reference reflectometer - spectrophotometer", *J. Res. Nat. Inst. Stand. Technol.*, 1996, **101**, 619-627,