Laboratory Measurement of Bidirectional Reflectance of Radiometric Tarps

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Objective

- To determine the magnitude of radiometric tarp BRDF
- To determine whether an ASD FieldSpec Pro spectroradiometer can be used to perform the experiment

Background

- Radiometric tarps with nominal reflectance values of 52%, 35%, 22%, and 3.5%, deployed for IKONOS, QuickBird, and OrbView-3 overpasses
- Ground-based spectroradiometric measurements of tarp and Spectralon® panel taken during overpass using ASD FieldSpec Pro spectroradiometer, and tarp reflectance calculated
- Reflectance data used in atmospheric radiative transfer model (MODTRAN) to predict satellite at-sensor radiance for radiometric calibration
- Reflectance data also used to validate atmospheric correction of high-spatial-resolution multispectral image products

Apparatus

- 1000-watt FEL lamp source
- Goniometer allows incidence and viewing angles to be varied separately
- Optronics OL 750 double monochromator/spectroradiometer
- Spectralon panel with reflectance calibrated at NIST, at incidence angles of 20°, 30°, 40°, and 50°, viewed normal to surface

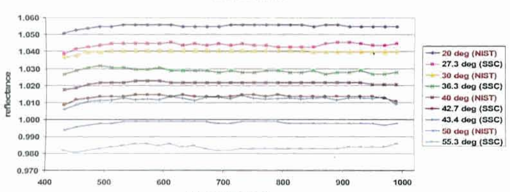
Procedure

1) Measure signal of NIST-calibrated Spectralon panel irradiated by collimated light at incidence angle of calibrated reflectance, viewing normal to panel surface ($L(\theta_{i,NIST})$).
2) Measure signal of Spectralon panel irradiated at incidence angle equal to solar zenith angle at time of overpass ($L(\theta_{i,solar})$).
3) Calculate reflectance of Spectralon panel irradiated at solar zenith angle, viewing normal to panel surface (ground geometry):

$$R(\theta_{i,solar}) = R(\theta_{i,NIST})\, L(\theta_{i,solar})/L(\theta_{i,NIST})$$

(R = reflectance, L = signal)

Spectralon Reflectance at Varying Incidence Angles Representing Solar Zenith Angles at Overpass; Viewing Direction Normal to Surface, Simulating FieldSpec Measurements



4) Measure signal of tarp sample at ground geometry, $L_{tarp}(0)$.
5) Calculate reflectance of tarp sample at ground geometry (for comparison with reflectance values determined from field measurements made with ASD FieldSpec Pro):

$$R_{tarp}(0) = R_{Spectralon}(0)\, L_{tarp}(0)/L_{Spectralon}(0)$$

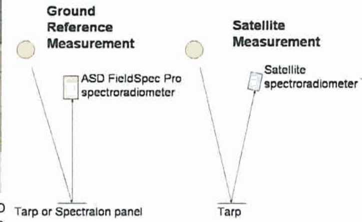
6) Measure signal of tarp sample at satellite geometry, $L_{tarp}(\theta_r,\phi_r)$, where θ_r = satellite zenith angle, ϕ_r = satellite azimuth.
7) Calculate tarp reflectance correction factor for satellite geometry:

$$C_{tarp} = L_{tarp}(\theta_r,\phi_r)/L_{tarp}(0)$$

Note that C_{tarp} is equal to the ratio of tarp reflectance at satellite geometry to tarp reflectance at ground geometry.

Why measure bidirectional reflectance of tarps?

Measuring tarp signal with ASD FieldSpec Pro during overpass

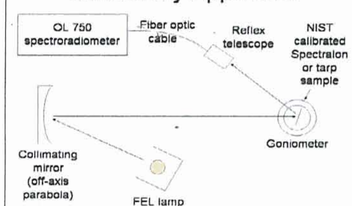


In general, satellite is not at zenith, and plane of reflection is not at same azimuth as plane of incidence.

Is tarp reflectance at satellite geometry the same as that determined at geometry of ground reference measurements?

An error in effective reflectance could cause a corresponding error in a satellite's radiometric calibration coefficients.

Laboratory Apparatus

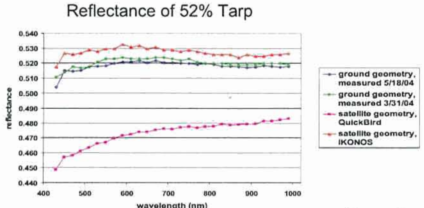


Laboratory Setup

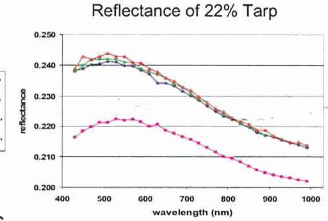
During actual use, the FEL lamp is housed inside an enclosure to block stray light.

Examples of Tarp Reflectance Values Calculated at Ground and Satellite Geometry Corresponding to QuickBird and IKONOS Overpasses on 2/17/02

Reflectance of 52% Tarp



Reflectance of 22% Tarp



Results

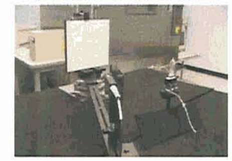
Minimum and Maximum Values for Tarp Reflectance Correction Factor (C_{tarp}) for the 52% Tarp, Averaged over Approximate Spectral Bandwidths for the Satellites

	Blue 450-510 nm	Green 510-590 nm	Red 630-690 nm	Infrared 750-870 nm
Maximum	1.075	1.068	1.062	1.058
Minimum	0.914	0.924	0.931	0.936

- The above results indicate that non-nadir viewing correction can change the effective reflectance of tarps by as much as 10%.
- A 10% error in tarp reflectance caused by BRDF effects could cause a corresponding error in satellite radiometric calibration coefficients.
- The tarp reflectance correction factor, C_{tarp}, was found at the geometrical parameters of 11 overpasses. Precision of tarp signal measurements was estimated to be 0.005 (1%). Because C_{tarp} consists of a quotient of two signal measurements, precision of C_{tarp} is estimated at 2%.
- This procedure has allowed us to detect the presence of non-Lambertian behavior of the tarps, to determine the magnitude, and to correct for the effects of the non-Lambertian behavior.

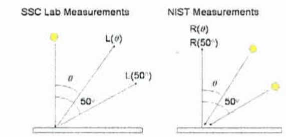
Is the ASD FieldSpec Pro sensitive enough to measure differences in radiance caused by bidirectional reflectance properties of Spectralon?

Measuring radiance of Spectralon panel with ASD FieldSpec Pro

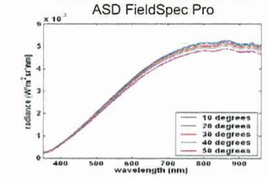


Comparing lab radiance measurements (L) to NIST reflectance measurements (R)

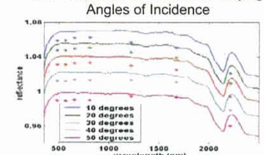
Is L(0)/L(50°) equal to R(0)/R(50°)?



Radiance Values Measured with ASD FieldSpec Pro



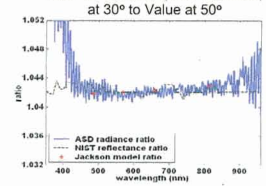
NIST Reflectance Values for Varying Angles of Incidence



Asterisks represent reflectance values calculated with Jackson (1992) model

Ratio of Radiance (or Reflectance) at 10° to Value at 50°

Ratio of Radiance (or Reflectance) at 30° to Value at 50°



- Over spectral range of 450 to 900 nm, ratio of radiance values measured with ASD FieldSpec Pro is close to ratio of reflectance values measured at NIST and calculated from Jackson model (Jackson et al., 1992).
- Signal-to-noise ratio for FieldSpec Pro data was poor, possibly due to internal stray light and low radiance levels in this experiment (ASD FieldSpec Pro is designed for higher radiance found outdoors).
- A decision was made to use the Optronics OL 750 double monochromator/spectroradiometer instead of the ASD FieldSpec Pro.

Reference

Jackson, R.D., T.R. Clarke, and M.S. Moran (1992), Bidirectional calibration results for 11 molded halon and 16 $BaSO_4$ reference reflectance panels, *Remote Sens. Environ.*, 40:231–239.

For the 52% tarp, the highest values for C_{tarp} occurred when satellite viewing direction was closest to the direction of incident solar irradiation. This behavior appears to be caused by tiny shadows cast by the weave of the tarp fabric; these shadows are least visible when the tarp is viewed along the direction of incidence. This behavior is less noticeable for the 35% and 22% tarps and is absent for the 3.5% tarp because the shadows are invisible against the dark tarp surface. For the 3.5% tarp, the tarp reflectance correction factor C_{tarp} was observed to increase by up to 5% as the viewing direction approached the direction of specular reflection.

The reflectance was measured for tarp samples that had bidirectional reflectance by Georgi Georgiev and James J. Butler at the NASA/GSFC Diffuser Calibration Facility (DCaF). The DCaF reflectance measurement results are discussed in Georgiev, G., and J. Butler (2003), The effect of weave orientation on the BRDF of tarp samples, *Proc. SPIE*, 5189:145–152.

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