Laboratory Measurement of Bidirectional Reflectance of Radiometric Tarps

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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
- Predicted at-sensor radiance values used to check radiometric calibration of satellite sensor
- Reflectance data also used to validate atmospheric correction of high spatial resolution multispectral image products

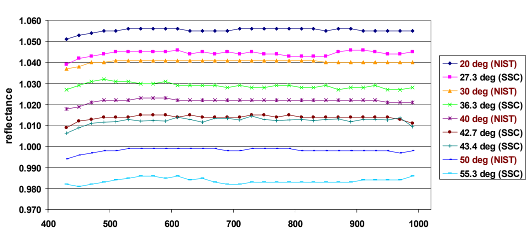
Procedure

1) Assemble laboratory apparatus to duplicate ground reference measurement geometry and satellite measurement geometry.
2) Measure spectral radiance with Optronics OL 750 double monochromator/spectroradiometer.
3) Measure radiance of NIST-calibrated Spectralon panel irradiated by collimated light at incidence angle of calibrated reflectance (20º, 30º, 40º, or 50º), viewing normal to panel surface ($L(\theta_{i,NIST})$).
4) Measure radiance of Spectralon panel irradiated at incidence angle equal to solar zenith angle at time of overpass ($L(\theta_{i,solar})$).
5) 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 = radiance)

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



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

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

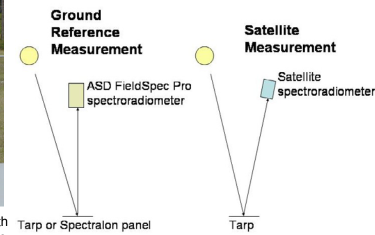
8) Measure radiance of tarp sample at satellite geometry, $L_{tarp}(\theta_r,\phi_r)$, where θ_r = satellite zenith angle, ϕ_r = satellite azimuth.
9) Calculate tarp reflectance correction factor for satellite geometry:

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

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 radiance of tarp with FieldSpec Pro during overpass

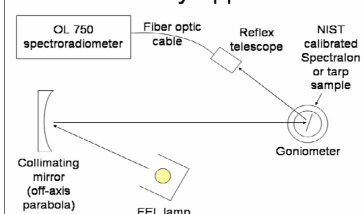


In general, satellite is not at zenith, and plane of reflection is not at same azimuth as plane of incidence.

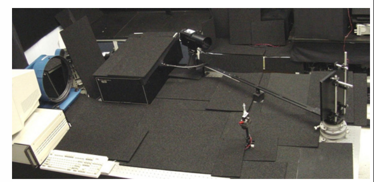
Is tarp reflectance at satellite geometry the same as that determined at geometry of ground reference measurements?

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

Laboratory Apparatus



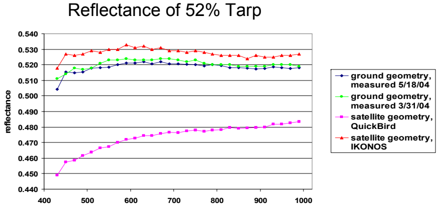
Laboratory setup



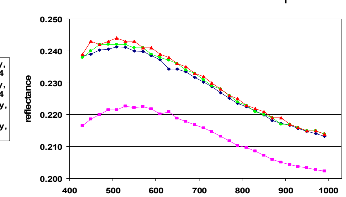
During actual use, the FEL lamp is housed inside an enclosure to block stray light

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

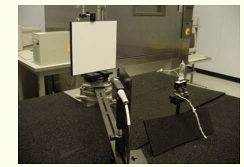
Minimum and Maximum Values for Tarp Reflectance Correction Factor (C_{tarp}) for the 52% Tarp, Averaged over Approximate Spectral Bandwidths for the Satellites

	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 bidirectional reflectance effects 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 eleven overpasses. Precision of reflectance measurement was estimated to be 0.005 (1%). Relative uncertainty in C_{tarp} is estimated at 2%.
- This experiment has allowed us to detect the presence of non-Lambertian behavior of the tarps, determine the magnitude, and correct for the effects of the non-Lambertian behavior.

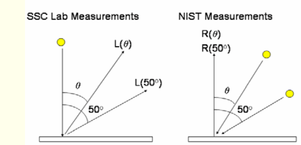
Is FieldSpec Pro sensitive enough to measure differences in radiance caused by bidirectional reflectance properties of Spectralon?

Measuring radiance of Spectralon panel with FieldSpec Pro

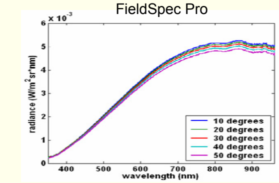


Comparing lab radiance measurements (L) to NIST reflectance measurements (R)

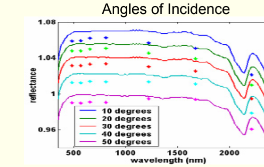
Is $L(0)/L(50°)$ equal to $R(0)/R(50°)$?



Radiance Values Measured with FieldSpec Pro

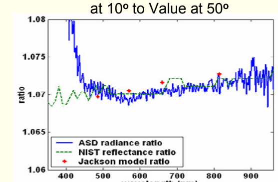


NIST Reflectance Values for Varying Angles of Incidence

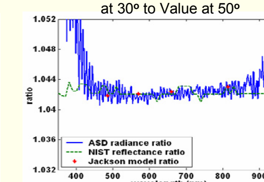


Asterisks represent reflectance values calculated with Jackson (1992) model.

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



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



- Over spectral range of 450 nm to 900 nm, ratio of radiance values measured with 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 because of low radiance levels in this experiment. The FieldSpec Pro is designed for higher radiance levels encountered outdoors.
- A decision was made to utilize the Optronics OL 750 double monochromator/spectroradiometer instead of the FieldSpec Pro

Reference

Jackson, R. D., Clarke, T. R., and Moran. M. S. (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 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 which had bidirectional reflectance measured 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 Butler, J. (2003), The effect of weave orientation on the BRDF of tarp samples, Proc. SPIE Vol. 5189, pp. 145 – 152.

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