THE EFFECT OF WEAVE ORIENTATION ON THE BRDF OF RADIOMETRIC TARPS

Georgi T. Georgiev[1], James J. Butler[2]

[1]Science Systems and Applications, Inc., [2]NASA, Goddard Space Flight Center

Bidirectional Reflectance Distribution Function

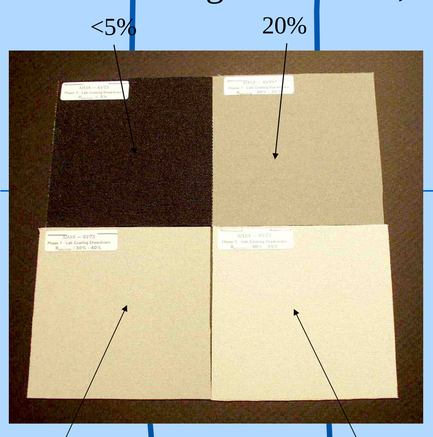
is defined after Nicodemus as the ratio of the scattered radiance L_s scattered by a surface into the direction (θ_s, ϕ_s) to the collimated irradiance E_i incident on a unit area of the surface

$$BRDF = \frac{P_s / \Omega}{P_i \cos\theta_s}$$

P_s is the scatter power, Ω is the solid angle determined by the detector aperture, A, and the radius from the sample to the detector, R, or $\Omega = A/R^2$, P_i is the incident power, and θ_s is the scatter angle

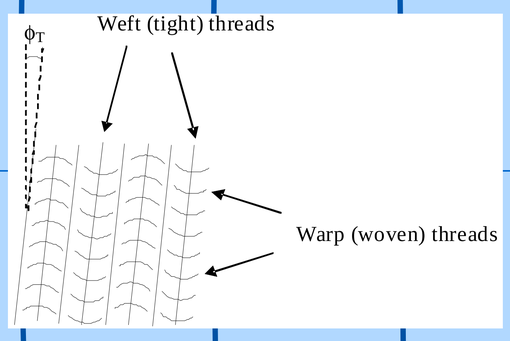
Radiometric Tarps

- The tarp samples are witness pieces from larger field-deployed tarps.
- The dimensions of the samples are 10 x 10.5 cm, cut along the weft (tight) threads.
- The witness pieces 8° directional/hemispherical reflectance is from 70% to 4%.
- The samples exhibit a wide range of BRDF values depending on angle of incidence and scatter.
- Their surface can be modeled as a highly regular wave-like structure.
- The witness pieces were characterized at:
- Incident angles: 0°, 10°, 20°, and 30°; samples at 0° and 90°,
- Detector zenith angles: 0°, 10°, 20°, 30°, 40°, 50° and 60°,
- Detector azimuth angles: 0°, 45°, 90°, 135°, and 180°,
- Wavelengths: 485 nm, 550 nm, 633 nm, and 800 nm,



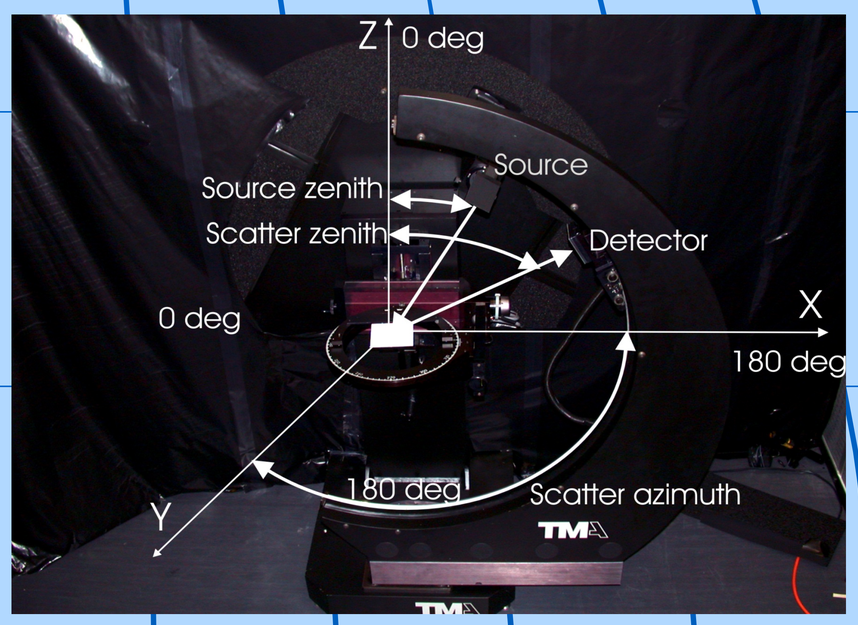
4" Tarp Samples

Microscopic image of Tarp #1



Tarp surface structure

BRDF Measurement Setup



- in- and out-of-plane measurements,
- Light source Xenon-Arc lamp,
- Chromex monochromator,
- Silicon photodiode,
- P & S polarization = unpolarized scatter,
- NIST calibrated Spectralon standards

RESULTS AND DISCUSSION

BRDF at normal incidence

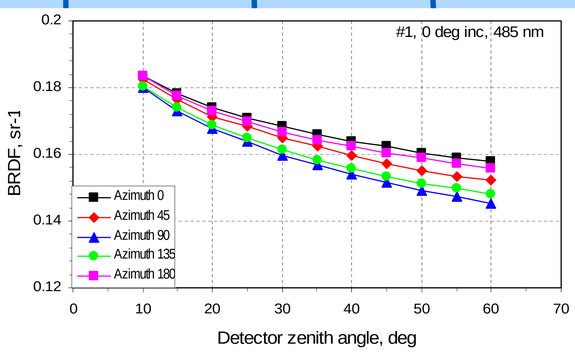


Fig.4: BRDF at normal incidence, 485 nm, sample #1

- 0° incidence, 485 nm;
- Detector zenith from 0° to 60°;
- Detector azimuth 0°, 45°, 90°, 135°, 180°
- BRDF decreases with increasing scatter zenith angles;
- Highest BRDF at 0° and 180° scatter azimuth; lowest at 90° scatter azimuth;
- The same at 550, 633 and 800 nm.

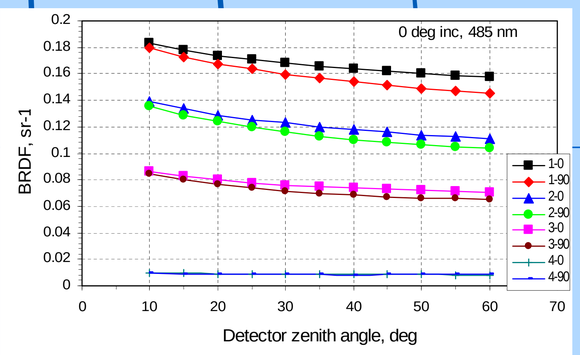


Fig.5: Normal incidence, 0 and 90 deg detector azimuth, 485 nm, samples 1 to 4

- 0° incidence, 485 nm;
- Detector zenith from 0° to 60°;
- Detector azimuth 0° and 90° ;
- BRDF decreases with increasing scatter zenith angles ;
- Linear dependence - BRDF of #2, #3 and #4 can be derived from #1 with coefficients: 0.73, 0.45, 0.05 ;

BRDF at non-normal incidence

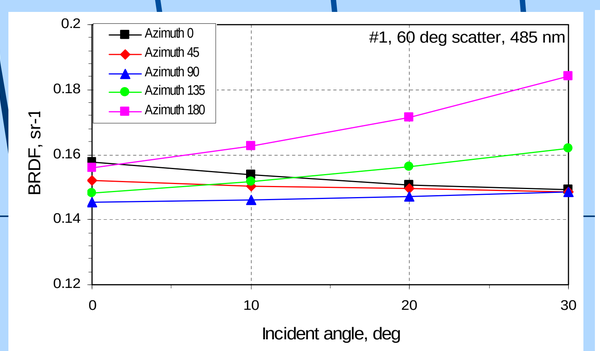


Fig.7: BRDF at 60 deg detector zenith angle, 485 nm, sample #1

- Incident angles 0°, 10°, 20° and 30°
- Detector zenith angle 60°
- Detector azimuth 0°, 45°, 90°, 135°, 180°
- BRDF decreases up to 6% at 0° scatter azimuth and increases up to 16% at 180° scatter azimuth
- Differences shown in Table 1.
- The same at 550, 633 and 800 nm and different scatter zenith angles

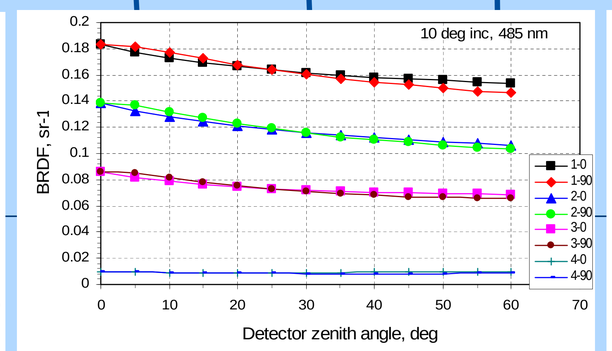


Fig.8.a: 10 deg incidence, 0 and 90 deg detector azimuth, 485 nm, samples 1 to 4

- 10° and 30° incident angles at 485 nm;
- Detector zenith angles from 0° to 60°; Detector azimuth angles at 0° and 90° ;
- BRDF difference between 0° and 90° scatter azimuth is 2% for 1; 1.4% for 2; 1% for 3 at 30° incident;
- The surface structure; BRDF below 25° scatter zenith at 0° scatter azimuth is higher than at 90° scatter azimuth.

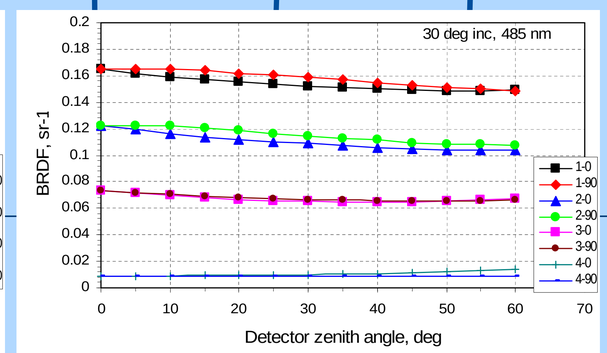


Fig.8.b: 30 deg incidence, 0 and 90 deg detector azimuth, 485 nm, samples 1 to 4

BRDF difference between 10° and 30° incident angles

Detector zenith angle, deg	Detector azimuth angle, deg				
	0	45	90	135	180
10	-15.55%	-13.50%	-9.16%	-5.56%	-5.52%
20	-12.05%	-8.62%	-3.71%	2.60%	7.54%
40	-9.05%	-5.34%	0.32%	7.76%	17.02%
60	-5.76%	-2.35%	2.35%	8.41%	15.33%

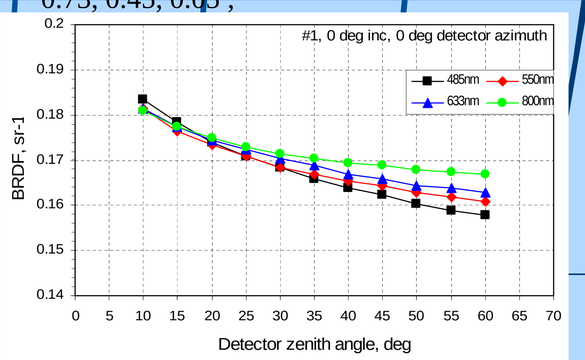


Fig.6: BRDF at 485, 550, 633 and 800 nm; sample #1

- 0° incidence, 485, 550, 633, and 800 nm
- Detector zenith from 0° to 60°; Detector azimuth 0°;
- BRDF decreases with increasing scatter zenith angles;
- Highest BRDF at 800 nm; lowest at 485 nm;
- The same for samples #2, #3, and #4.

CONCLUSIONS AND FUTURE WORK

- Monochromator based light source in the UV, VIS and NIR spectral regions;
- In-plane and out-of-plane BRDF measurements at a number of incident angles over a range of scatter angles;
- The BRDF dependence on weave orientation is well defined for both normal and non-normal incident light; can approach 17% for non-normal illumination, 6% for normal;
- The spectral dependence of the weave orientation on BRDF is apparent at lower scatter zenith angles for both normal and non-normal incident light;
- The BRDF data obtained are important for future NASA SSC vicarious calibrations through analysis of the BRDF dependence on weave orientation.

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