NASA's GSFC Diffuser Calibration Facility (DCaF): Description and Traceability

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The Scatterometer

• The out-of-plane scatterometer used to measure Bidirectional Reflectance and Transmittance Distribution Functions (BRDF & BTDF) and Directional/ Hemispherical Scatter is housed in a class 10,000 cleanroom facility.

•Scatterometer capabilities:

- Absolute and relative BRDF measurements

- Sources:
  - 230nm to 900 nm using Xe arc/monochromator with bandwidth adjustable from 4 to 12 nm.
  - 543.5, 594.1, 612.0, and 632.8nm He/Ne and 325.4 nm He/Cd laser
  - SWIR tunable lasers from 1.47 microns to 1.63 microns

- Detectors:
  - UV Sensitive Silicon Photodiode; Photomultiplier Tube;
  - InGaAs and InSb detectors

- Angular range:
  - Incident elevation angle: 0 to 80 degrees
  - Incident azimuthal angle: 0 to 360 degrees
  - Scatter elevation angle: 0 to 80 degrees
  - Scatter azimuthal angle: 0 to 180 degrees
  - Scatter raster measurements: 5.9 inch by 5.9 inch area

- Sample size:
  - Up to 12 inches on a side and 10 pounds weight

- Sample types:
  - Diffuse and specular reflective
  - Diffuse/translucent and transparent transmissive
  - Liquid and granular materials
  - Tether materials

- Noise Equivalent BRDF:
  - Arc source: 10^{-4} to 10^{-6} sr^{-1}
  - Laser sources: 10^{-7} sr^{-1}

Uncertainty Component	Uncertainty	Method of Determination
Δ_{NS}	0.001 at 230nm	Measurement
Δ_{LIN}	0.0035	Measurement using ND filters
Δ_{SLD}		
Δ_{RM}	0.2mm	Measurement using dual theodolites
Δ_{RZ}	0.2mm at 15 deg. 0.15mm at 45 deg. 0.05mm at 75 deg.	Measurement using dual theodolites
Δ_{RA}	0.01mm	Measurement through THR integration
$\Delta_{\theta S}$		
$\Delta_{\theta M}$	0.035 deg.	Measurement using dual theodolites
$\Delta_{\theta Z}$	0.007 deg. at 15 deg. 0.019 deg. at 45 deg. 0.025 deg. at 75 deg.	Measurement using dual theodolites
$\Delta_{\theta T}$	0.05 deg.	Conservative estimate based on actual sample alignments
Overall Uncertainty	0.61% at 15 deg. 0.61% at 45 deg. 0.74% at 75 deg.	QSS of uncertainty components

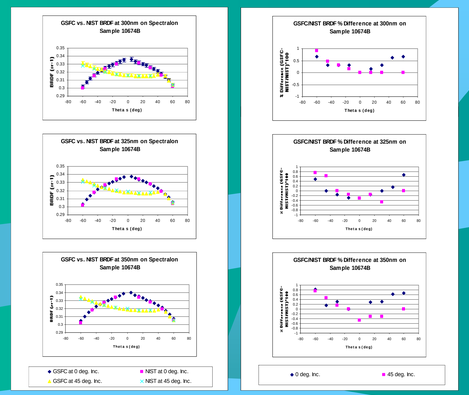
DCaF – a secondary standards facility

The DCaF is a secondary standard reflectance measurement laboratory traceable to the NIST primary standard instrument, the Spectral Tri-function Automated Reference Reflectometer (STARR).

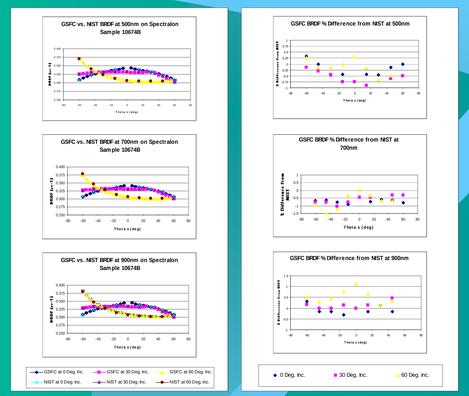
– DCaF scatterometer absolute reflectance measurements are compared to STARR absolute reflectance measurements through sets of laboratory calibration samples.

– The laboratory calibration samples include Spectralon, pressed halon, and roughened aluminum/overcoated aluminum diffusers and front surface aluminum coated/magnesium fluoride overcoated mirrors.

•Ultraviolet BRDF comparison with NIST STARR



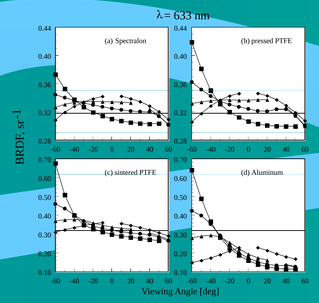
•Visible/near infrared BRDF comparison with NIST STARR

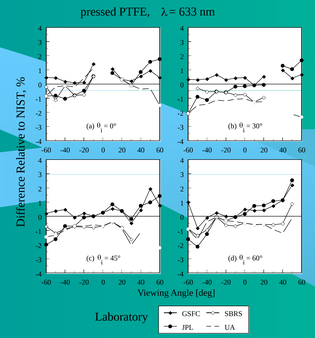


•In addition to maintaining traceability to the NIST primary standard facility, the DCaF participates in reflectance measurement round-robins and comparisons.

– EOS BRDF Round-robin

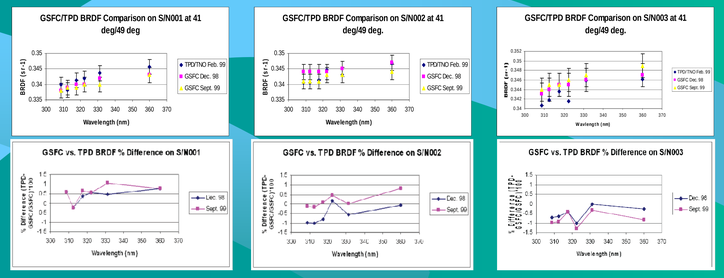
- Spectralon, pressed halon, scintered halon, and roughened aluminum samples circulated among 5 metrology labs
- Participants: NIST (hub institution), NASA's GSFC, NASA's JPL, the University of Arizona, Raytheon SBRS, and TPD/TNO, the Netherlands.





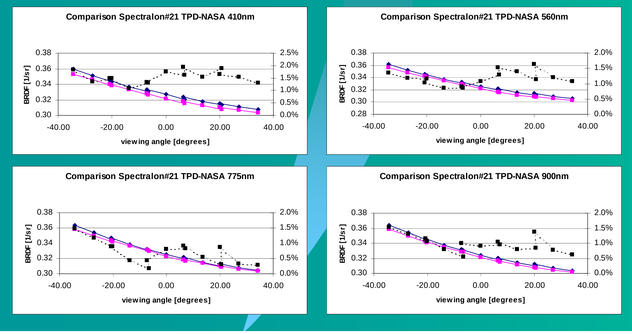
–TOMS Spectralon BRDF Round-robin

- 4 Spectralon calibration targets circulated among 2 metrology labs
- Participants: NASA's GSFC and TPD/TNO, the Netherlands



–NASA/ESA Spectralon BRDF Comparison

- 2 Spectralon calibration targets used in the calibration of the ESA MERIS instrument
- Participants: NASA's GSFC and TPD/TNO, the Netherlands

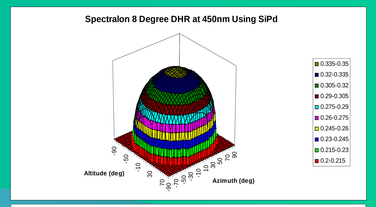


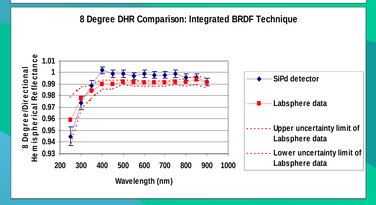
8 Degree Directional/Hemispherical Reflectance

•8 Degree Directional/Hemispherical Reflectance Measurement Techniques:

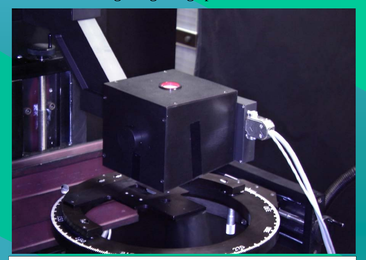
– Integration of BRDF measured at 8°incidence over the complete scatter hemisphere

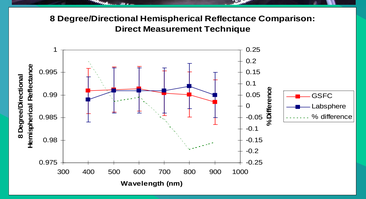
- 8° DHR= $\int_0^{2\pi}\int_0^{\pi/2} BRDF(\theta_i, \phi_i, \theta_s, \phi_s) \cos\theta_s \, d\phi_s \, d\theta_s$



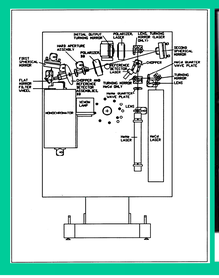


– Direct measurement using integrating sphere/detector scatterometer attachment

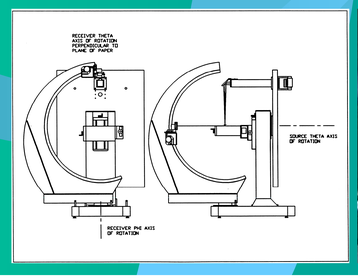


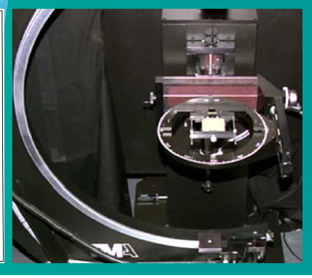


Scatterometer Light Source:



Scatterometer Goniometer and Sample Stages:





International and Domestic DCaF Facility Customers

- SSBUV
- SBUV/2
- TOMS EP, Meteor, and Adeos
- NRL/FAME
- EO-1 ALI
- MODIS
- SORCE
- NOAA Ocean Color Validation
- NOAA SIMBIOS Validation
- SOLSE/LORE
- JWST
- OMPS
- ORCA
- VIIRS
- JPL/TES
- CAR
- JPL/MISR
- Satellite Tether Program
- GOES
- Landsat-7 ETM+
- HST
- TRMM Project
- Stereo COR-1
- GLAS
- FAME/NRL
- TES
- SSC Commercial Remote Sensing
- OMI
- LRS
- ESA MERIS
- GOME
- NRAO/ALMA
- ITT/GOES-R
- NIST/EOS Calibration