Radiometric Calibration of Spaceborne Imaging Satellites

OPTI 696bx

Practical Optics Seminar

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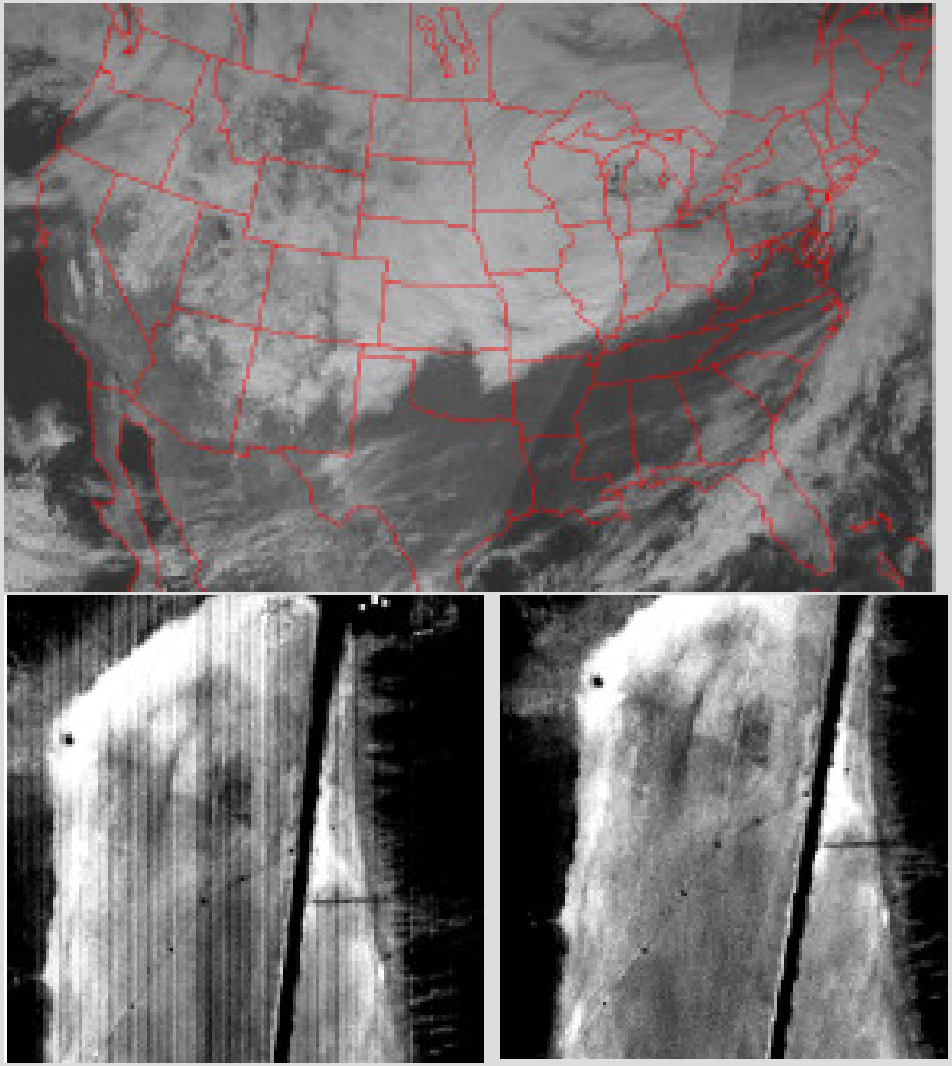
Overview

- Importance of radiometric calibration
- Difficulties of calibrating spaceborne systems
- Ground-based vicarious radiometric calibration technique
- Radiometric stability of spaceborne sensors over time

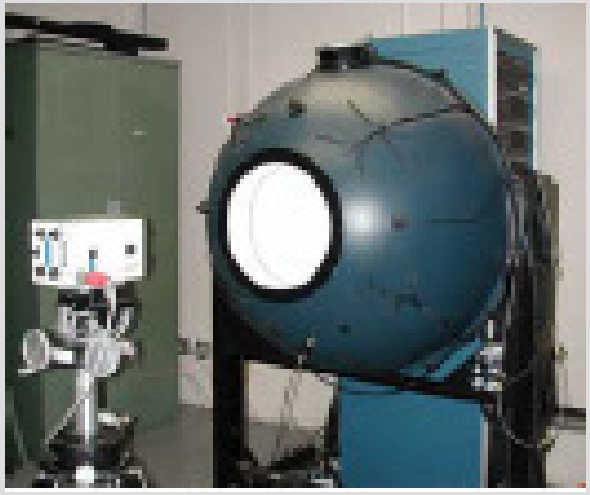
Importance of Radiometric Calibration

- **Optics, filters, and detectors degrade over time**
- Data can be put on a consistent scale
- Combining imagery from different sensors
- Correction of individual detector gain settings
- Conversion of sensor output to spectral radiance
- Radiometric stability measurement over time



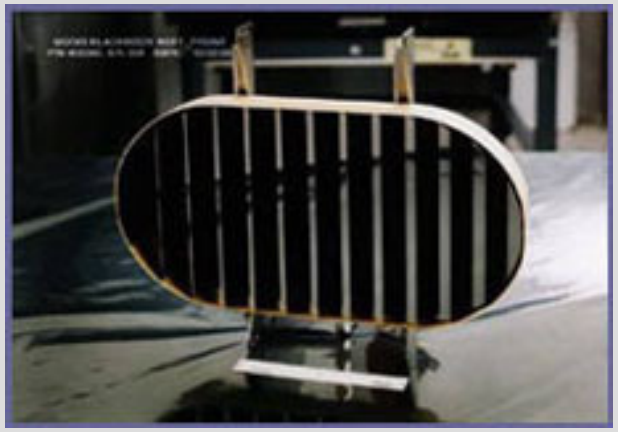
Absolute Radiometric Calibration

- Ideally, calibration is done with a known source
- Provides traceability to a internationally recognized standard
- In the U.S., the standards are supplied by NIST (National Institute of Standards and Technology).



On-board Calibration Methods

- Solar diffuser with known spectral reflectance for reflective bands
- Blackbody source for thermal bands
- NIST lamp for all bands

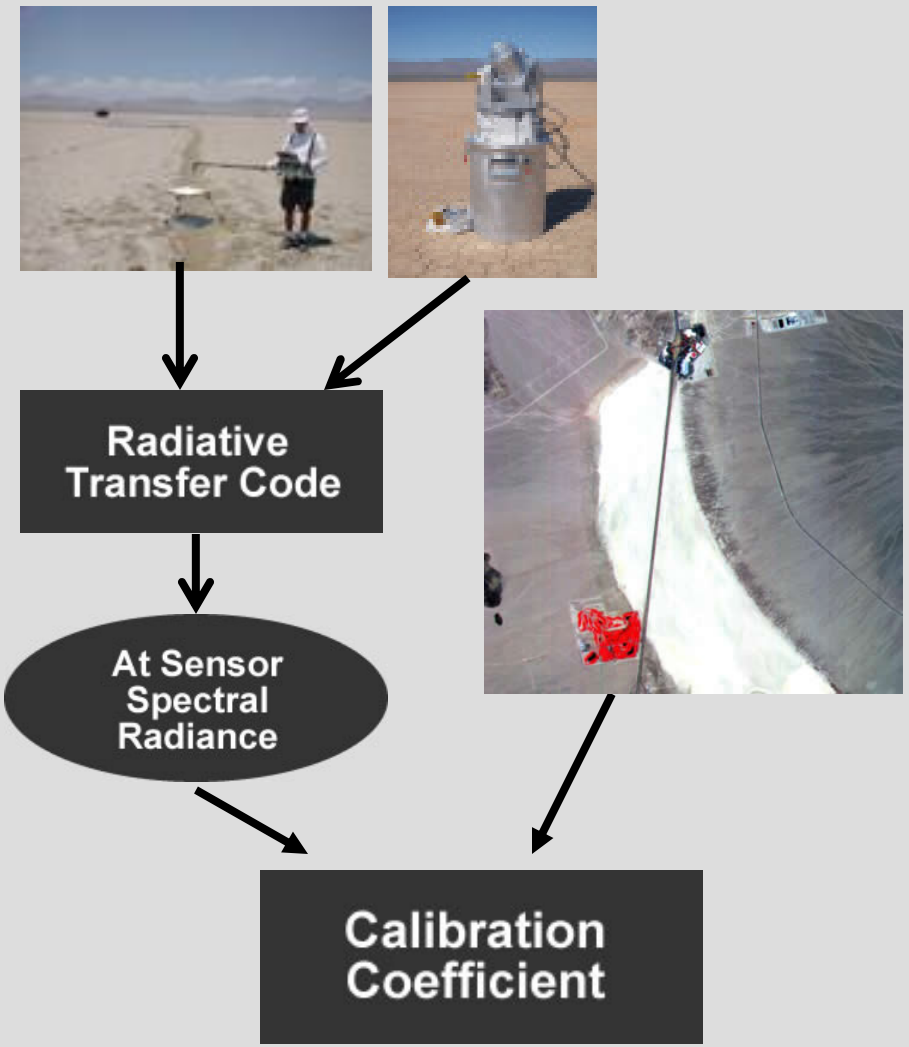


Problems with Calibration of Spaceborne Sensors

- Lamps and diffusers degrade over time or fail completely
- Unable to clearly distinguish between degradations in sensor and on-board calibrators
- Since the calibration devices cannot be easily examined or repaired, a ground based technique is desired.

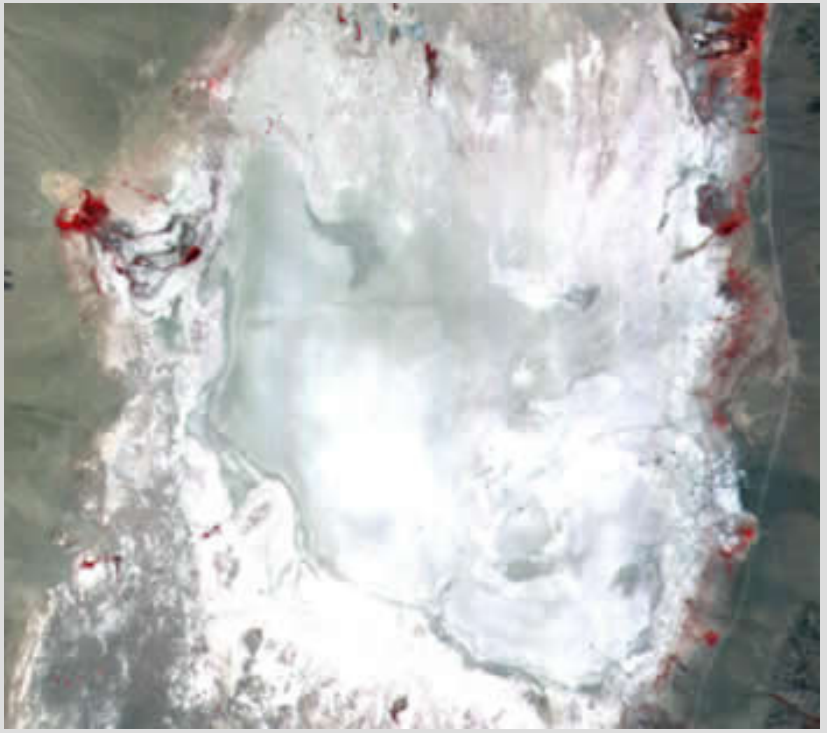
Ground-based Vicarious Radiometric Calibration

- Ground data is collected during a coincident overpass of a sensor, which is viewing the same test site
- Using surface reflectance and atmospheric measurements as input, a radiative transfer code is used to predict the at sensor spectral radiance
- Using coincident imagery of test site, a calibration coefficient is derived



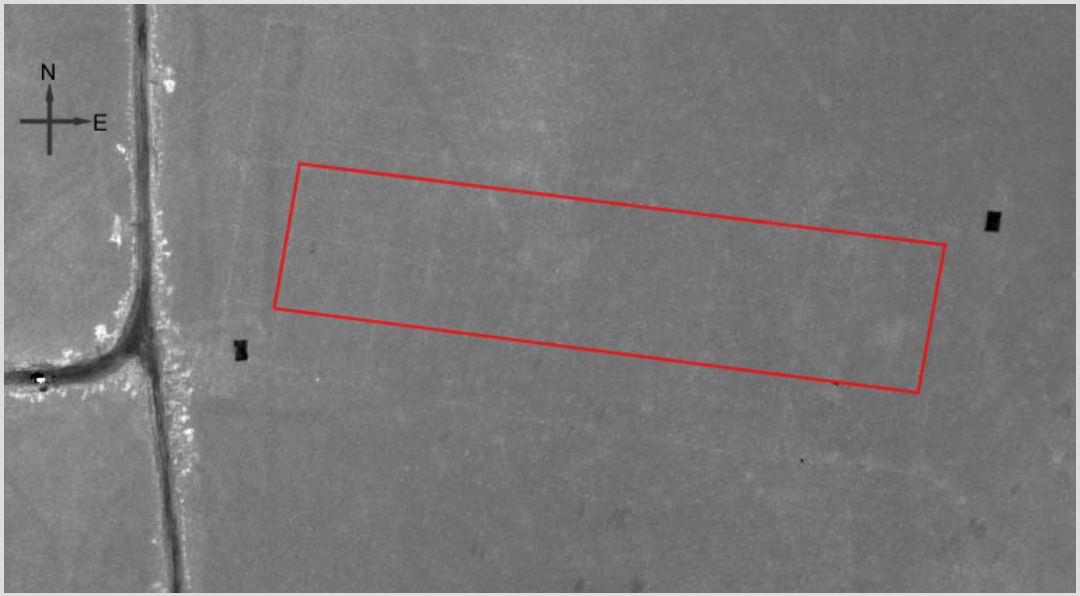
Test Site Characteristics

- High surface reflectance, >0.3
- Spatially uniform
- Flat spectral reflectance
- Near lambertian reflectance
- High altitude and arid location to reduce water vapor and possibility of clouds



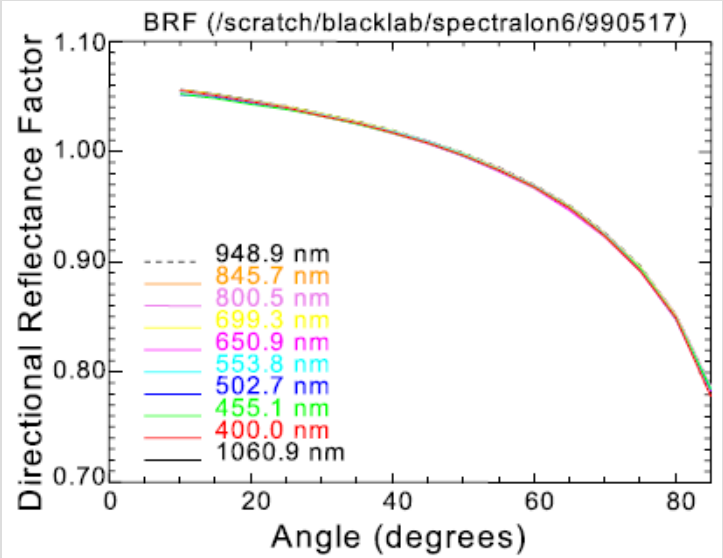
Measurement of Surface Reflectance

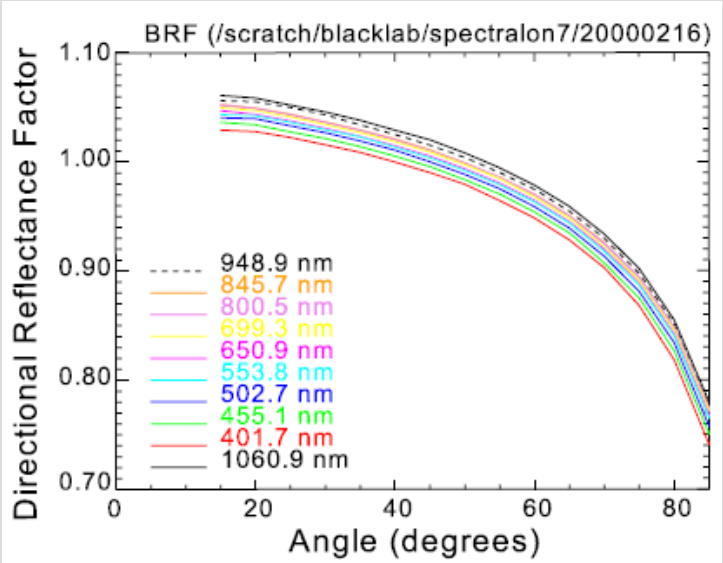
- Test site is spatially sampled with a portable spectroradiometer during sensor overpass
- Nadir view angle collection to simulate sensor view geometry
- Each sample scanned over 350-2500nm spectral range at 3nm resolution (VNIR)
- About 3% of test site sampled (80m x 300m)
- Surface measurements are compared to measurements of a field reference panel to derive surface reflectance



Spectralon Reference Panel

- Reference panel is measured in laboratory to determine spectral and lambertian properties
- Spectralon material of reference panel is NIST traceable
- NIST lamp used for laboratory measurements
- Provides a NIST field reference for surface reflectance measurements

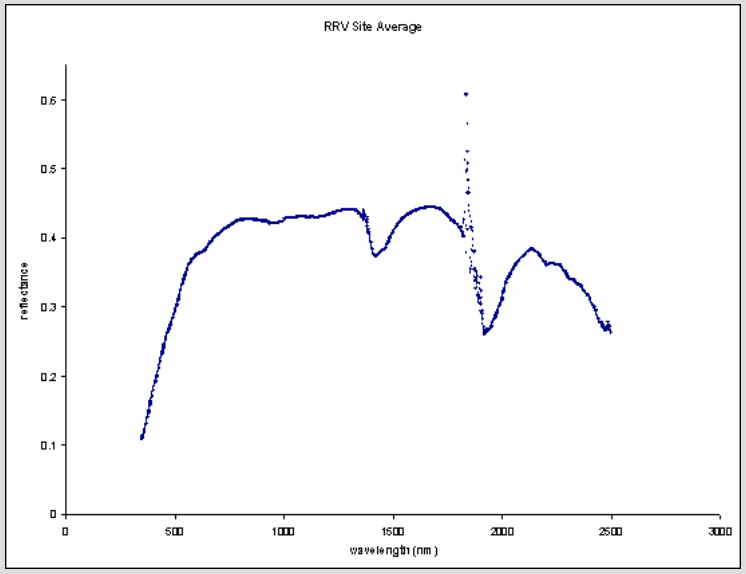




Deriving Surface Reflectance

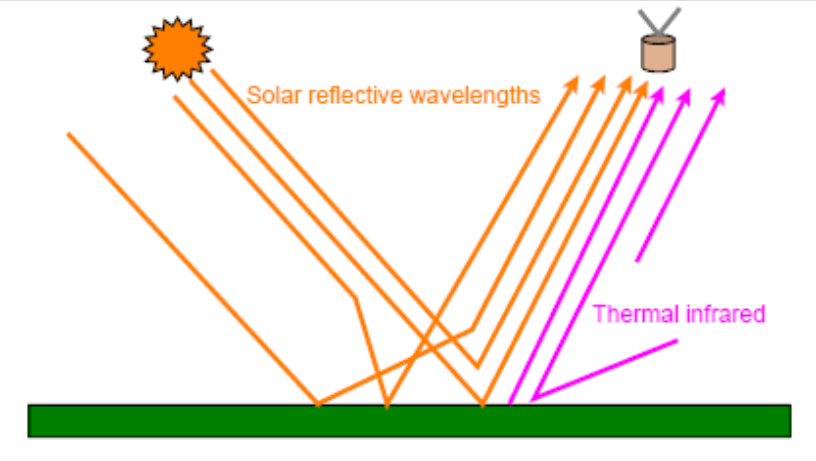
- Ratio method of test site and field reference data
- Ratio is multiplied by known reflectance factor of reference to derive test site reflectance
- Illumination conditions are effectively mitigated by ratio method

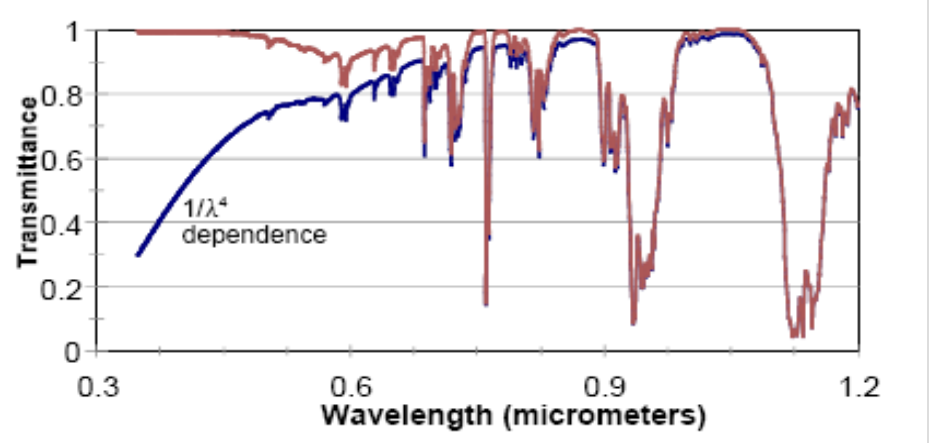
$$RF_{sample} = RF_{standard} \frac{\Phi_{sample}}{\Phi_{standard}}$$



Measurement of Atmospheric Properties

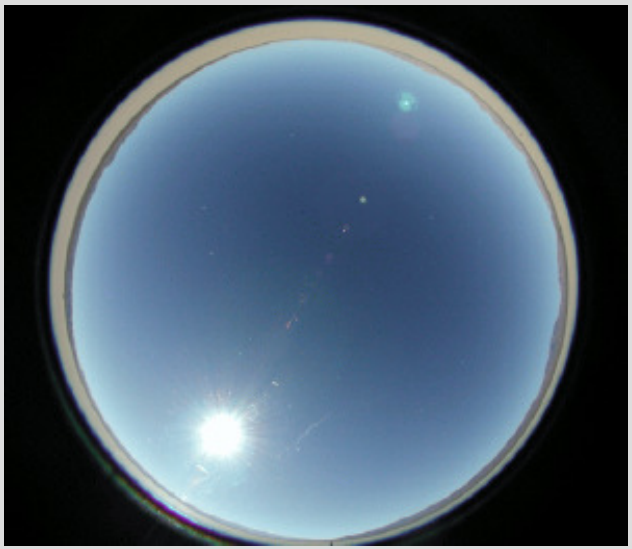
- Characterization of atmospheric properties is important to predict the at sensor radiance
- Could directly measure the attenuation of the direct solar path, but not other paths
- Need to predict the ground to sensor attenuation and the contributions of atmospheric scattering





Atmospheric Instruments

- 10 channel Automated Solar Radiometer (ASR) to measure total optical thickness along solar path
- Pyronometer for global downwelling irradiance (solar and sky contributions)
- Temperature, pressure, and ground wind speed are also measured



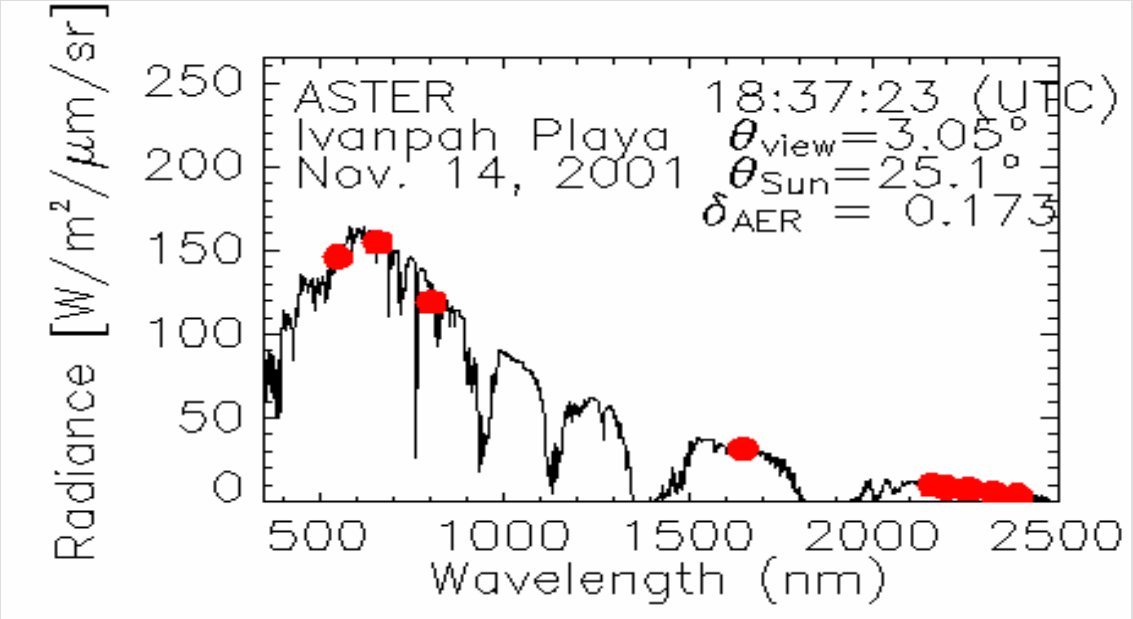
Radiative Transfer Code

- Measured optical thickness is used in inversion scheme to estimate aerosol size distribution and columnar amounts of ozone and water vapor
- Solar and sensor view geometry
- Sensor overpass time and date
- Temperature and pressure
- Derived test site reflectance data

$$L_\lambda^{su} = L_\lambda^{reflected,solar}\,\tau_{\lambda,view} = \frac{\rho_\lambda E_\lambda^{incident,solar}\, e^{-\delta_\lambda/\cos\theta_{solar}}\,\cos\theta_{solar}}{\pi}\, e^{-\delta_\lambda/\cos\theta_{view}}$$

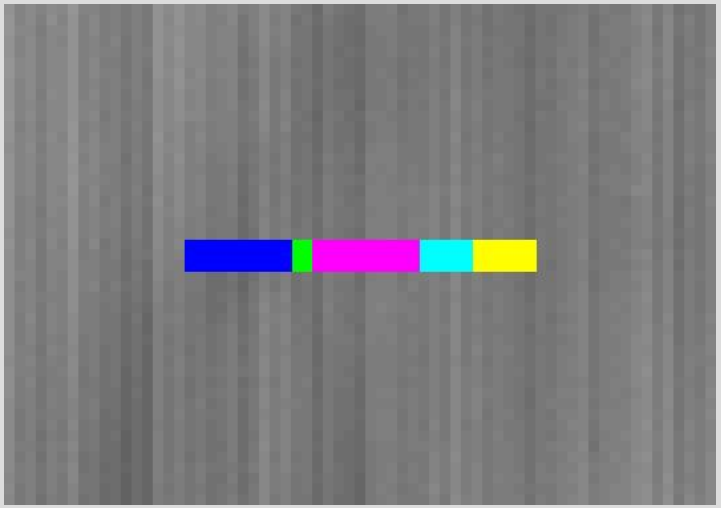
Top-of-atmosphere Spectral Radiance

- Radiative transfer code predicts the spectral radiance at the sensor
- For a given sensor, band-average radiance provided
- One half of the calibration coefficient



Sensor Imagery

- Digital Numbers (DNs) are extracted from sensor overpass imagery of test site
- Average test site DN value for each band
- Second half of calibration coefficient



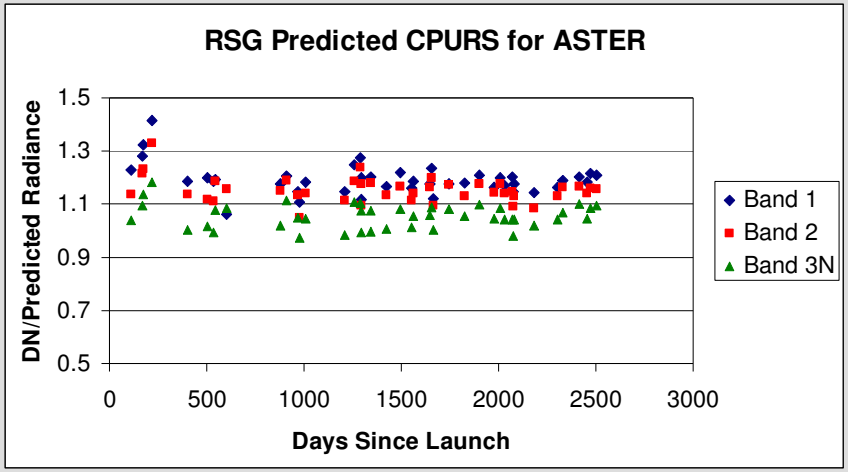
	Min	Max	Mean	Stdev	
Band 1	187	196	190.660000	2.475006	
Band 2	172	181	176.280000	2.344476	
Band 3N	118	127	123.130000	2.537218	
Band 3B	132	139	135.410000	1.700238	
Band 4	114	120	117.133333	1.736690	magenta
Band 5	120	124	122.733333	0.907187	cyan
Band 6	117	120	118.400000	0.932183	yellow
Band 7	108	113	110.866667	1.306043	blue
Band 8	100	105	102.666667	1.422318	green
Band 9	91	93	92.233333	0.626062	red

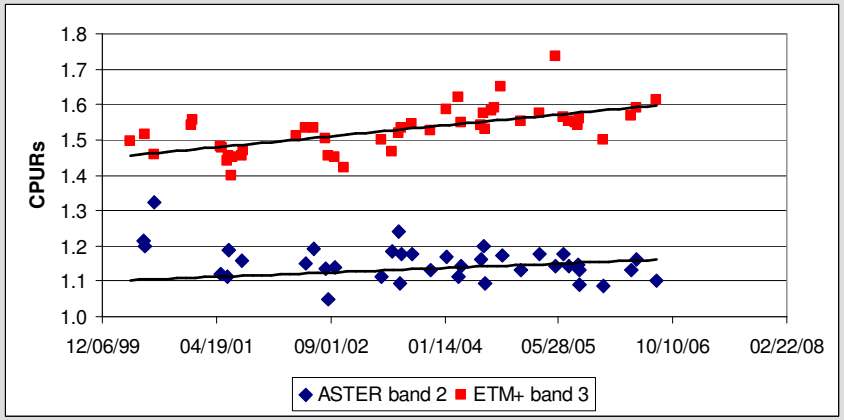
Calibration Coefficient

- Calibration coefficient is derived by the ratio of DN and radiance for each band
- Counts per unit radiance (CPUR)
- Allows for the conversion of sensor imagery to band averaged radiance

Radiometric Stability of Sensors

- Trend of calibration coefficients used for radiometric stability assessment
- Allows for cross-calibration of different sensors
- Comparison of similar bands between many different sensors provides basis for error analysis of ground-based approach





Conclussions

- Ground-based calibration method provides an assessment of radiometric stability independent of the sensor
- Major advantage comes from the ability to continuously (annually) measure our NIST traceable reference
- Provides a basis to compare output from many sensors

Questions ?