Analysis of the Automated Radiometric Calibration Test Site at Railroad Valley, Nevada

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Joint Agency Commercial Imagery Evaluation
Civil Commercial Imagery Evaluation Workshop
Fairfax, Virginia
16-18 Mar 2010

Topics

- Remote Sensing Group and the reflectance-based method
- Radiometric Calibration Test Site (**RadCaTS**) concept
- Analysis of RadCaTS surface
- Automated processing
- Comparison with Landsat-7 ETM+ and MODIS
- Conclusions and future work

Introduction

- RSG uses reflectance-based method to perform ground-based vicarious calibration
- An effort to increase data collection throughout the year led to the development of Radiometric Calibration Test Site (RadCaTS)
- Data collection in absence of ground personnel
  - Modeled on reflectance-based technique
  - Attempt to retain accuracy of in-situ measurements with flexibility of invariant scene
- Surface BRF retrieval is largest uncertainty in RadCaTS
  - Prototype ground-viewing radiometers
  - Temperature stabilization issues
- Studies to analyze:
  - Placement of radiometers
  - BRF retrieved using automated vs. manned instruments

Vicarious Calibration: Reflectance-Based Approach

- Measurements of atmospheric properties and surface reflectance are used in radiative transfer code to calculate top-of-atmosphere radiance
- Atmospheric measurements made with automated solar radiometer
- Surface reflectance: ASD portable spectrometer (350-2500 nm) and NIST-traceable reference panel
- Only two experienced people required for field data collection

Instrumentation

- Surface: Analytical Spectral Devices spectroradiometer
  - 3 detectors
    - 1.4-nm spectral sampling (350-1100 nm)
    - 10-nm spectral sampling (1100-2500 nm)
  - 8 full field of view foreoptic
  - Foreoptic attached to boom arm
  - Internal software interpolates data to 1-nm increments
  - Surface BRF determined using ratio of panel to surface

Instrumentation

- Automated solar radiometer:
  - 10- or 12-channel: 380, 400, 441, 520, 611, 670, 780, 870, 940, 1030 nm center wavelengths (12-channel model also includes 1250 and 1550-nm channels)
  - Aerosol optical depth
  - Aerosol size distribution
  - Ozone amount
  - Water vapor

- Sky monitor package:
  - Downwelling irradiance
  - Temperature and pressure

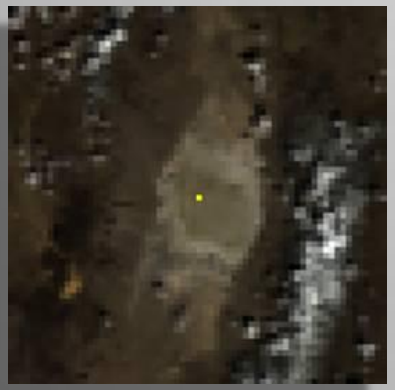
Reflectance-Based Approach to Vicarious Calibration

Measure site reflectance data

Measure site atmospheric data

Radiative Transfer Code

Compute top-of-atmosphere radiance



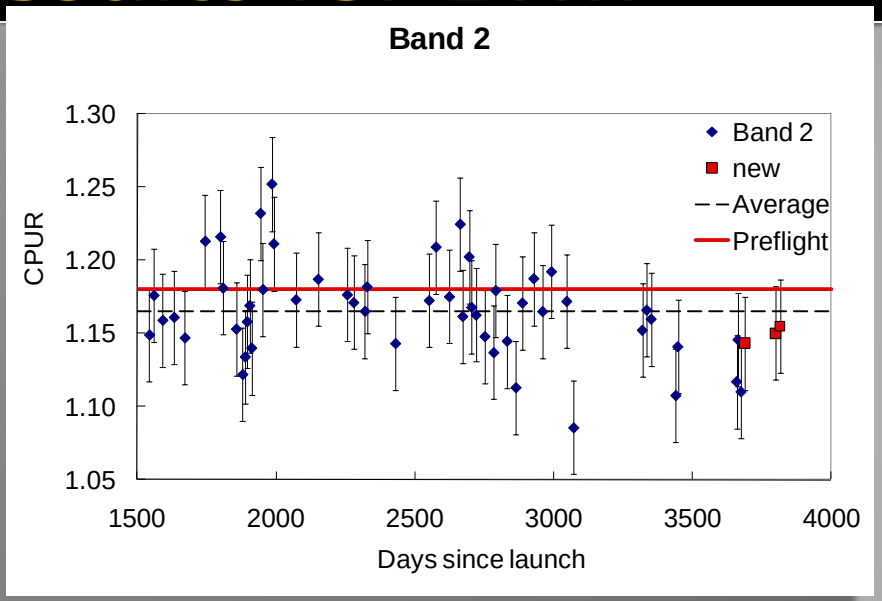
Average site DNs derived from image data

Calibration of sensor's spectral bands

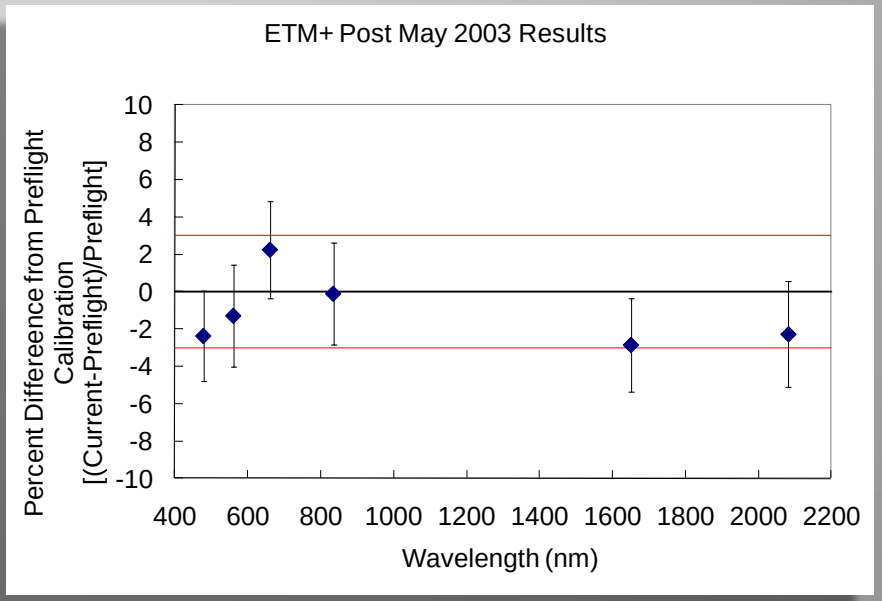
Vicarious Calibration Test Sites

Reflectance-based Results for ETM+

- Example: Landsat-7 band 2 (561 nm)
- Counts per unit radiance (CPUR) as a function of time
- Post May 2003 results

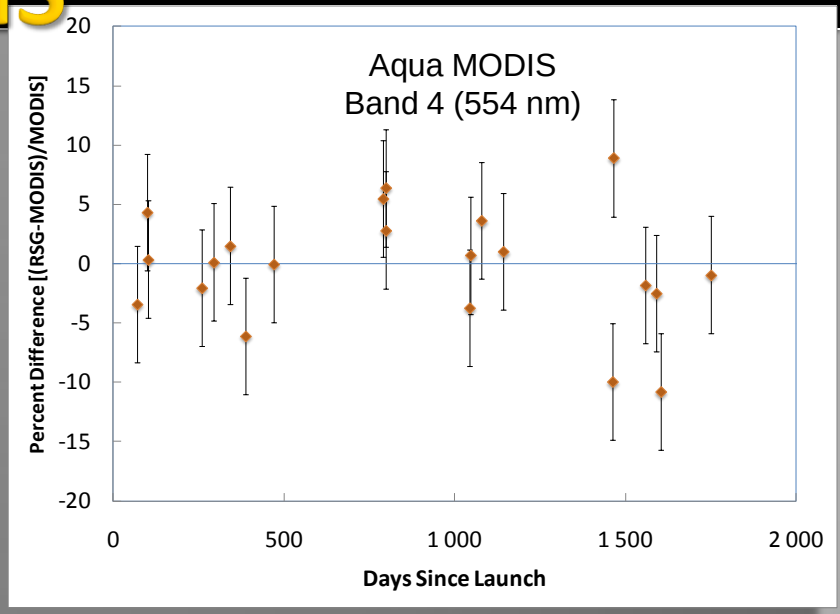


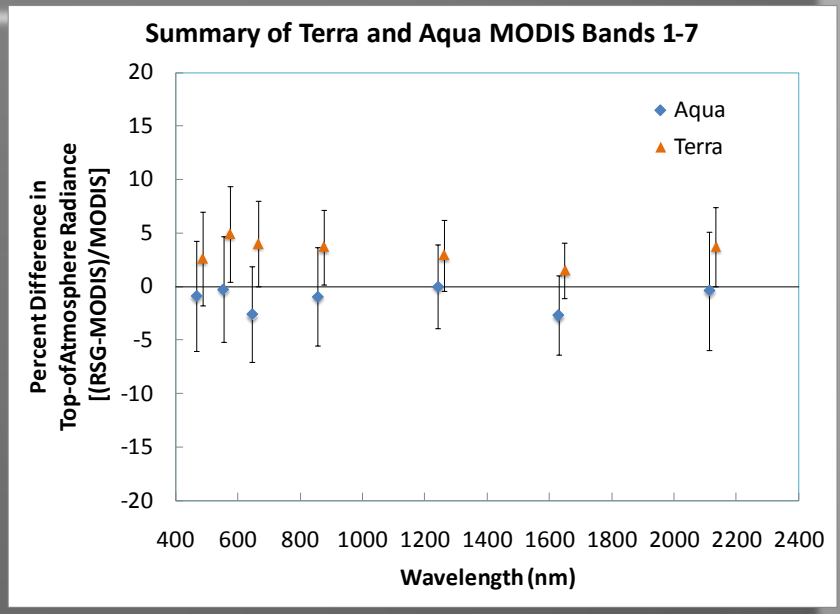
- Summary of all bands from May 2003
- Percent difference within 3% of preflight values
- Standard deviation less than 3% for all bands



Reflectance-Based Results for Terra and Aqua MODIS

- All MODIS data collected at RRV
- **Aqua MODIS comparison to vicarious**
  - Average TOA radiance difference less than 1% in five bands
  - Average TOA radiance difference less than 3% in other two bands
  - Standard deviation ~5% in all bands
- **Terra MODIS comparison to vicarious**
  - Average TOA radiance difference less than 5% in seven land bands
  - Standard deviation ~4% in all bands

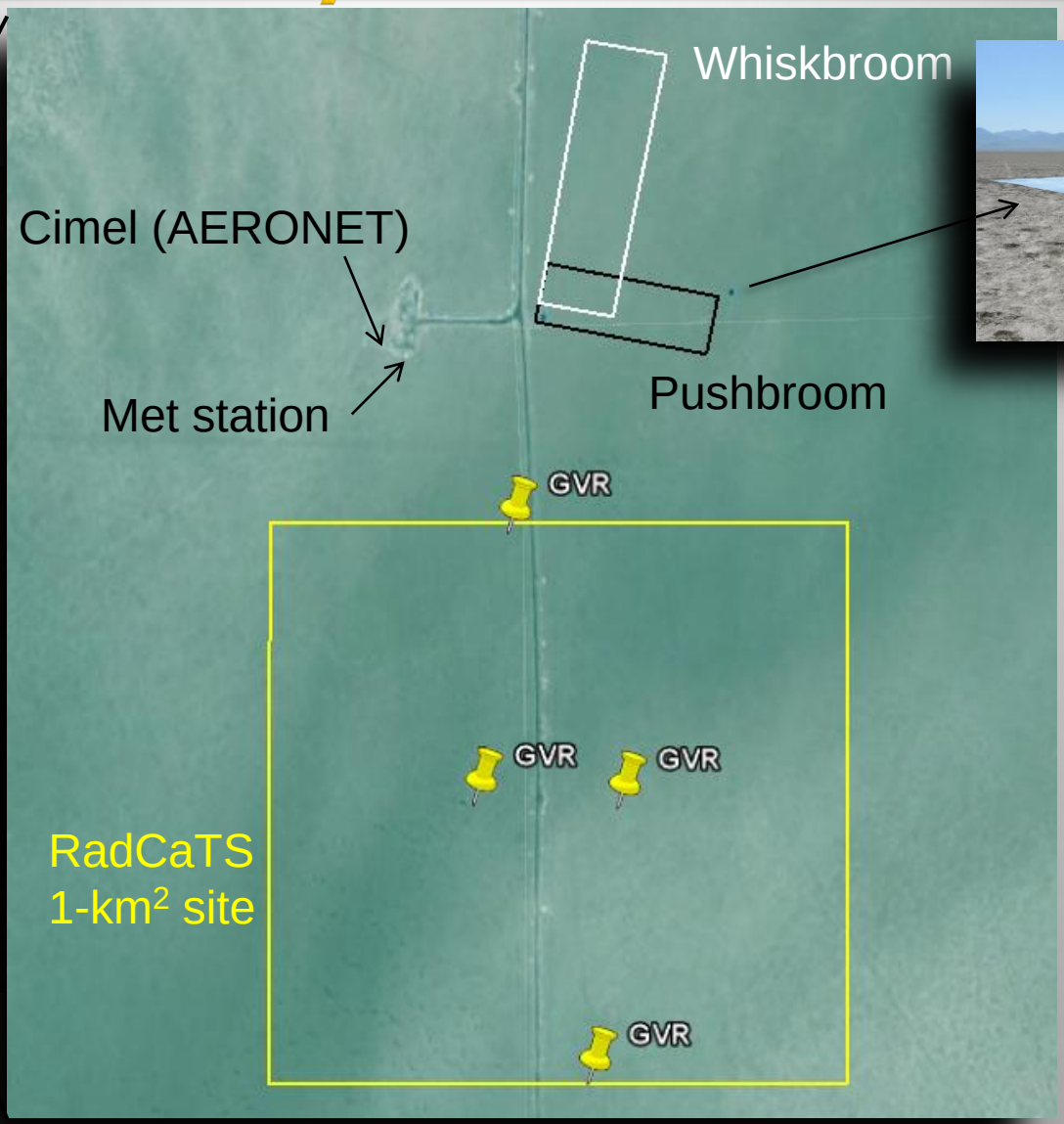




Automated Vicarious Calibration: Radiometric Calibration Test Site (RadCaTS)

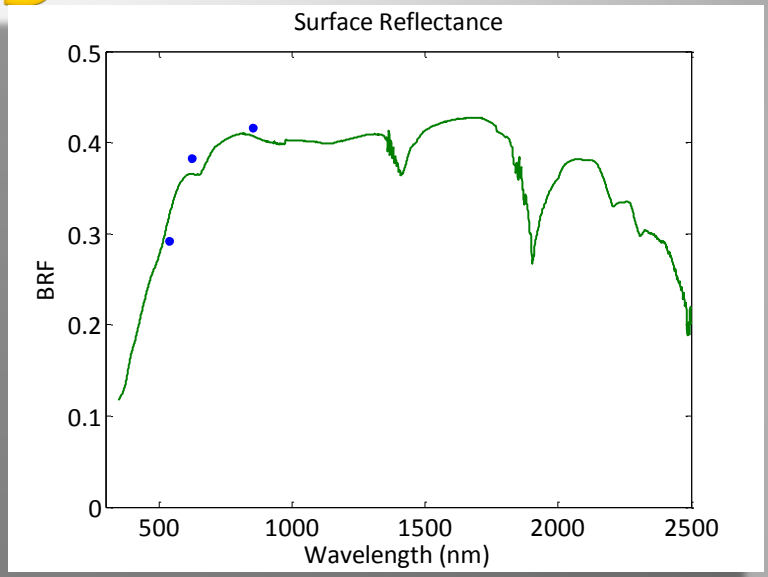
- **Determine at-sensor radiance without ground personnel present at overpass**
- Surface and atmospheric data collection
  - Cimel sun photometer (AERONET)
  - Meteorological station
  - Ground-viewing radiometer (GVR)
    - 534, 622, and 848 nm channels
    - Laboratory calibration prior to deployment
      - Spectral responsivity
      - Field of view
      - Calibration coefficient
    - Radiometric calibration after deployment (SRBC)

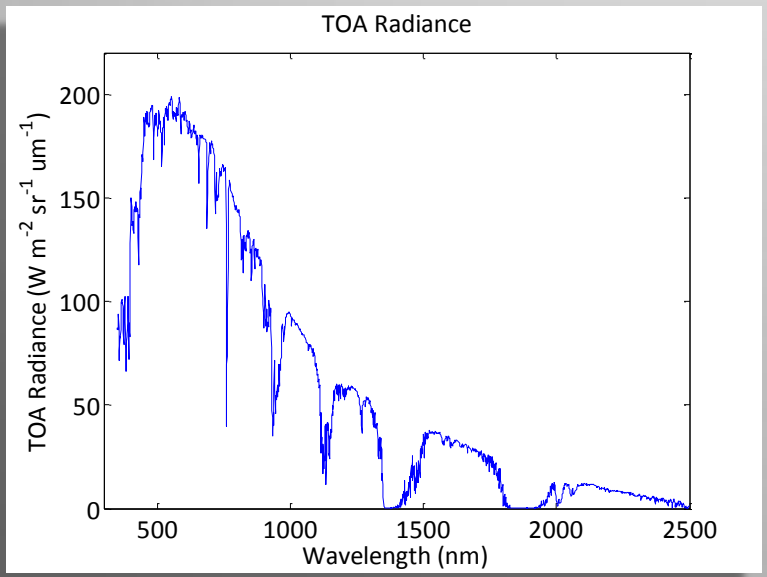
Railroad Valley Test Site

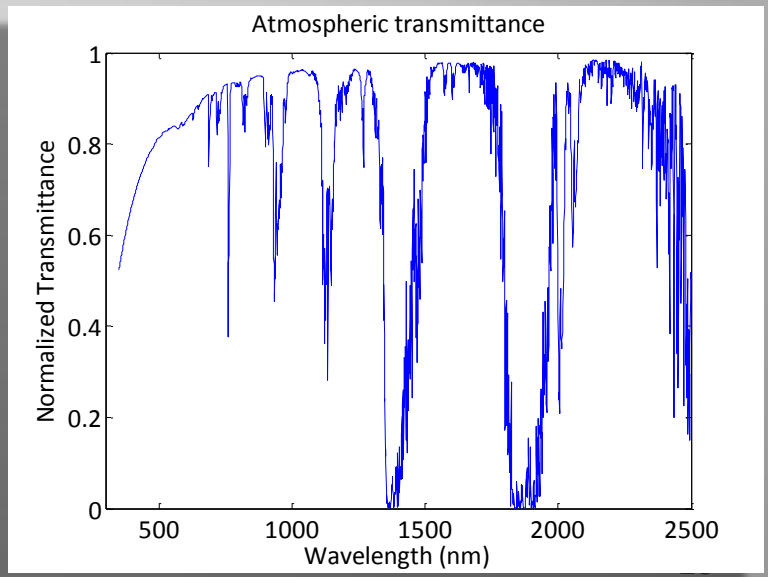


Automated Processing

- Matlab-based GUI
- Surface and atmospheric data collected using GVRs and Cimel Sun photometer
- Met station measures ambient conditions
- New data loggers will enable more time between required retrieval from logger
- Time to process: minutes vs. 3+ hours
- Web-based portal for data distribution



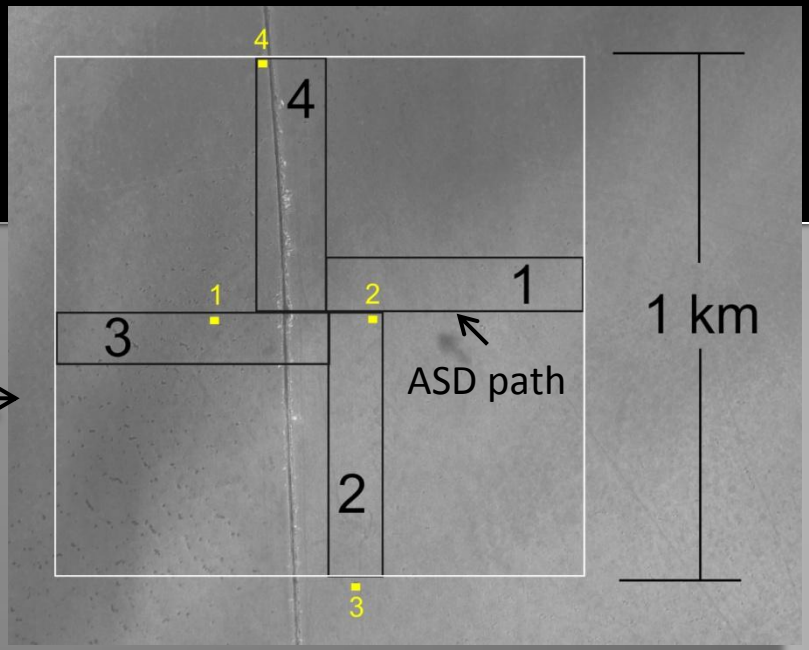




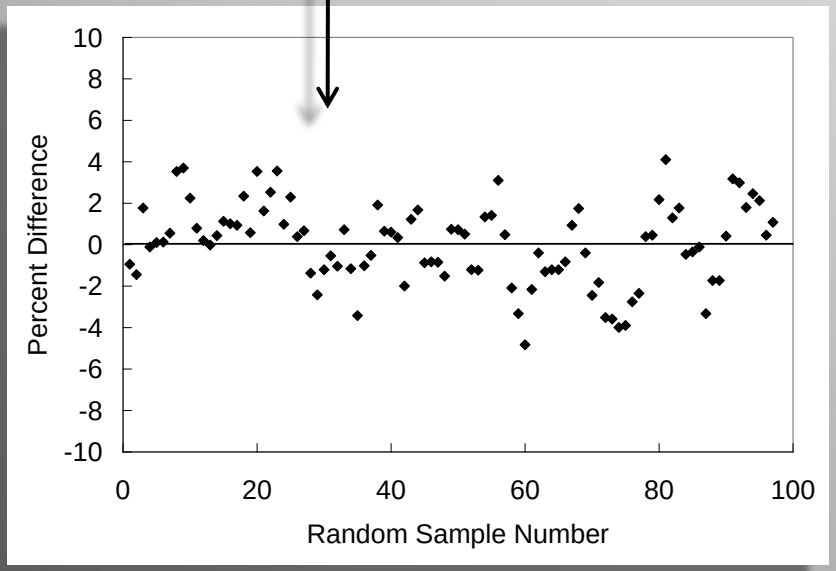
Spatial Uniformity Assessment of RRV

- Need to determine how many, and where, GVRs are required
- Initial deployment based on balance of:
  - Easy access
  - "Correct" spatial sampling
- GVR data must be downloaded from data loggers, and GVRs must be periodically calibrated on site
- Study of RadCaTS 1-km^2 area to better understand site
  - High spatial resolution, panchromatic
  - High spatial resolution, multispectral
  - Medium and low spatial resolution, multispectral

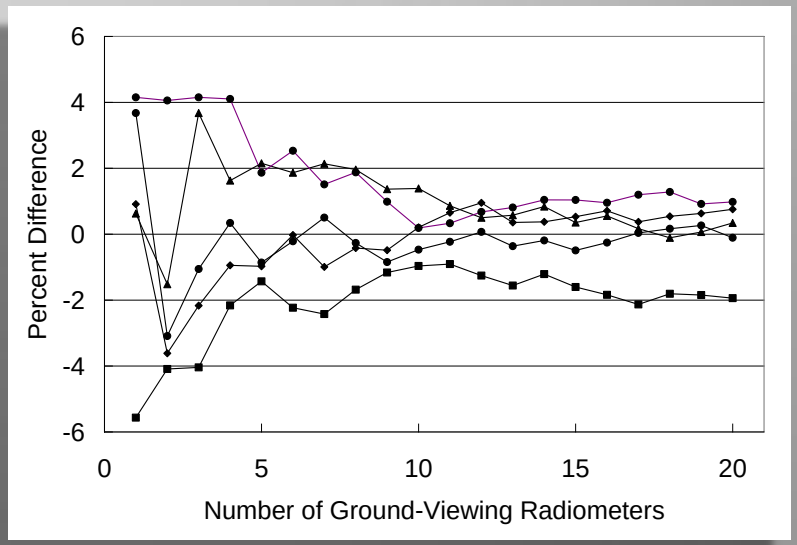
High Spatial Resolution, Panchromatic Study



- **QuickBird image of 1-km² site**
- Analyze site using image DNs only
- **Simulation of GVR locations:**
  - 100 trials using 4 randomly-placed GVRs
  - BRF determined using 4 GVRs was within 2% of the average value of the site



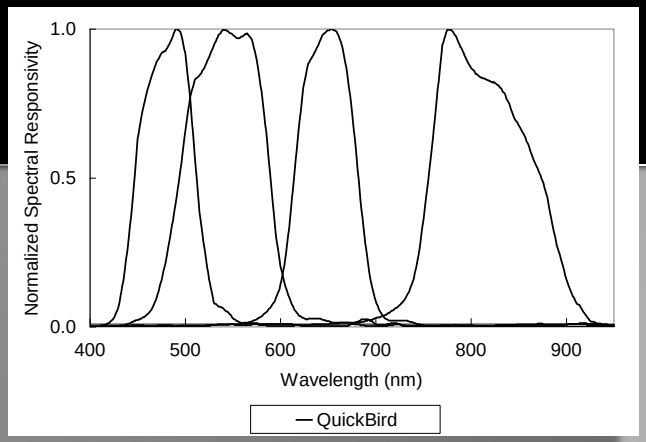
- **Number of GVRs:** 4 GVRs show the same BRF uncertainty as 20 radiometers (generally less than 2%)

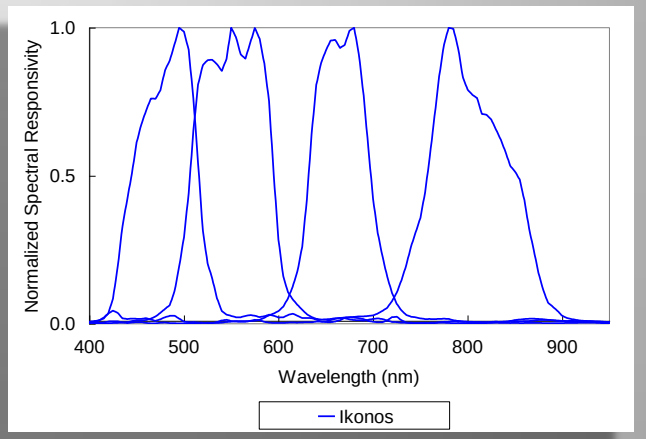


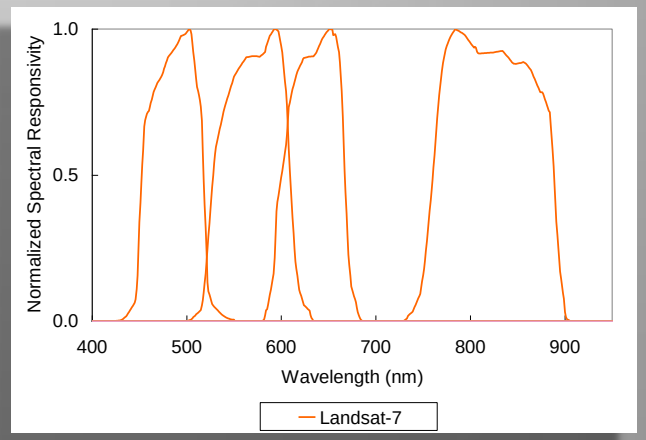
Multispectral Study

- Multispectral imagery
  - High-spatial-resolution: **Ikonos** (4 m), **QuickBird** (2.4 m)
  - Medium spatial resolution: **Landsat-7 ETM+** (30 m)
- Imagery from these sensors was also used to analyze the uniformity of the site

Band-Averaged Center Wavelength (nm)			
Band	**QuickBird**	**Ikonos**	**Landsat-7**
1	492	496	479
2	551	560	561
3	653	606	661
4	810	792	835
5	-	-	1650
7	-	-	2208

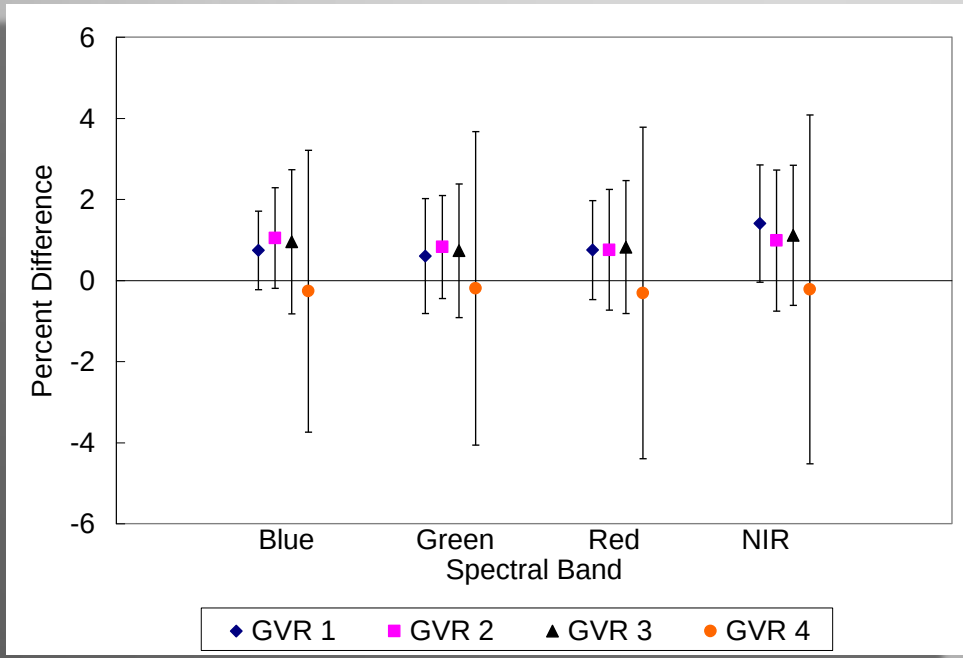


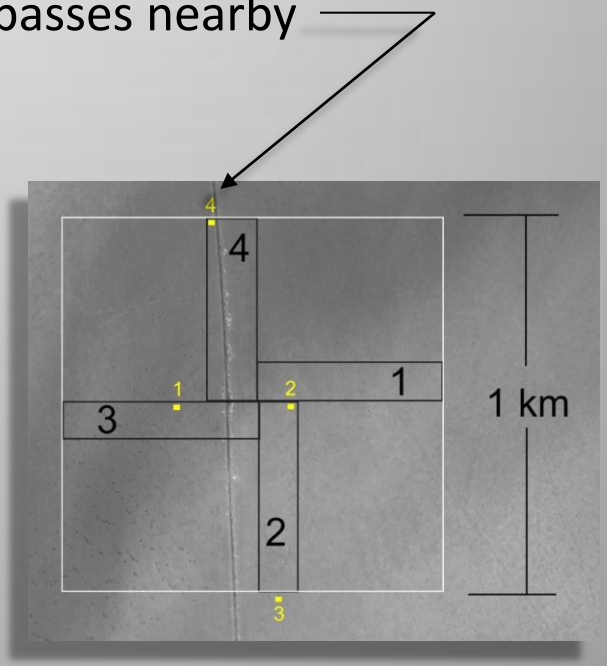




High Spatial Resolution, Multispectral: DNs at GVR Position vs. ASD Path

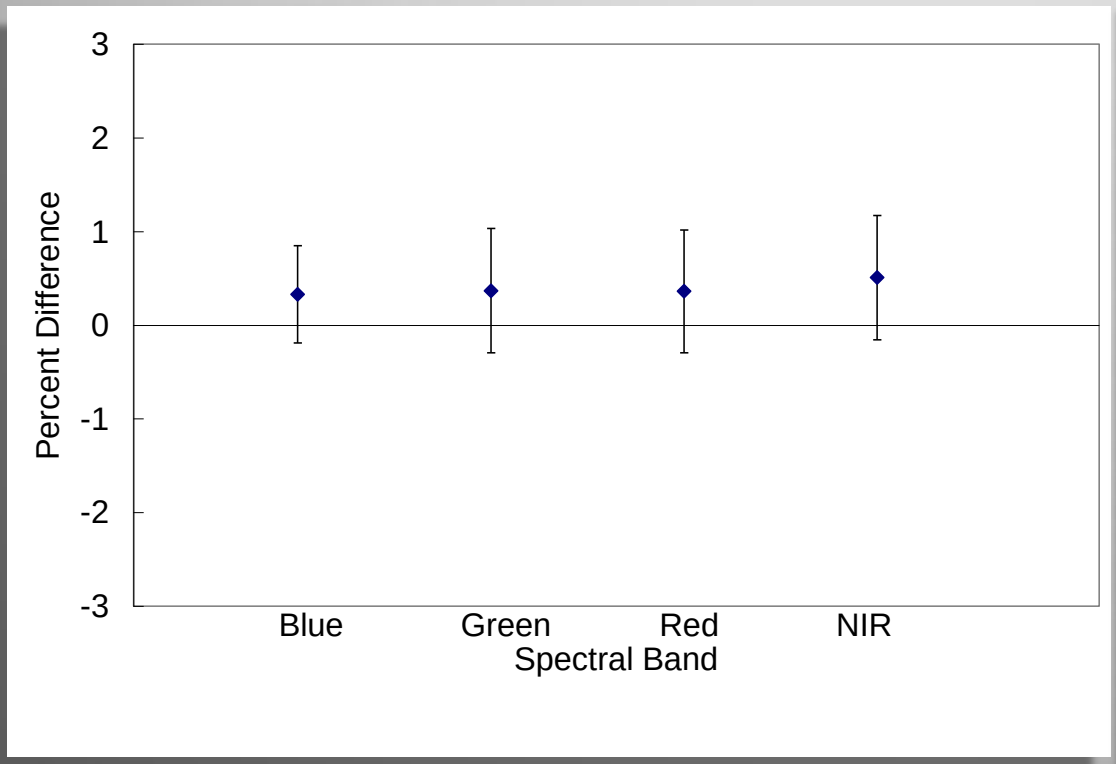
- **How do the current GVR positions represent the path carried by the ASD portable spectroradiometer?**
- Three Ikonos images, and three QuickBird images
- Graph shows percent difference in DN between GVR position and 4.7-km spectroradiometer path
- Generally no greater than 2% on average
- GVR 4 has a larger uncertainty due to road that passes nearby

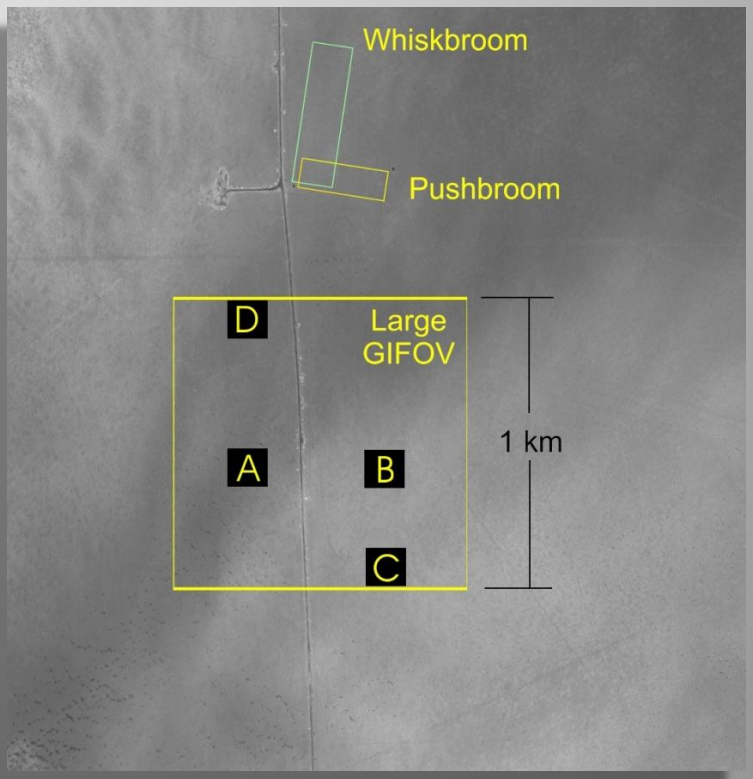




High Spatial Resolution, Multispectral: DNs at GVR Position vs. 1-km² Site

- **Using current GVR positions, how close are DNs to entire 1-km² site?**
- Three Ikonos and three QuickBird images
- Results determined using DNs on day-to-day basis, then averaged for three Ikonos and three QuickBird dates
- Average percent difference is less than 0.5%

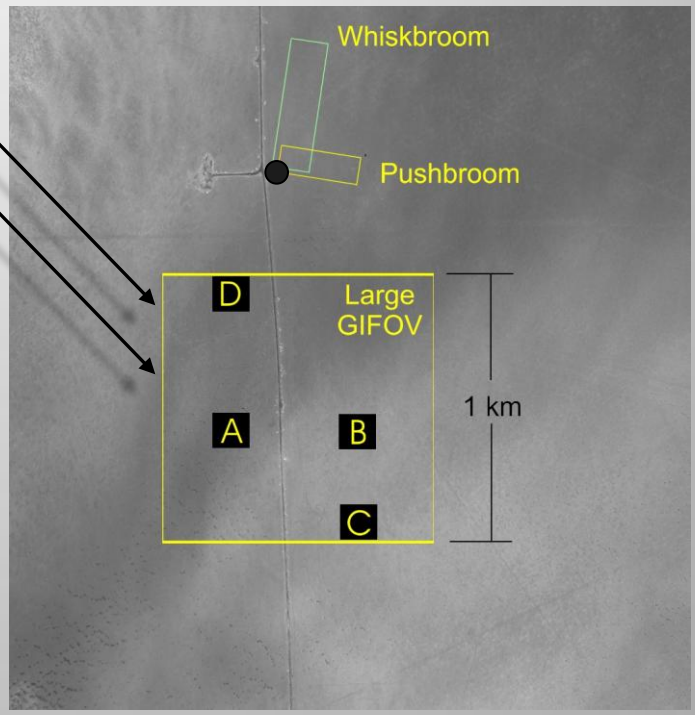




Medium and Low Spatial Resolution, Multispectral

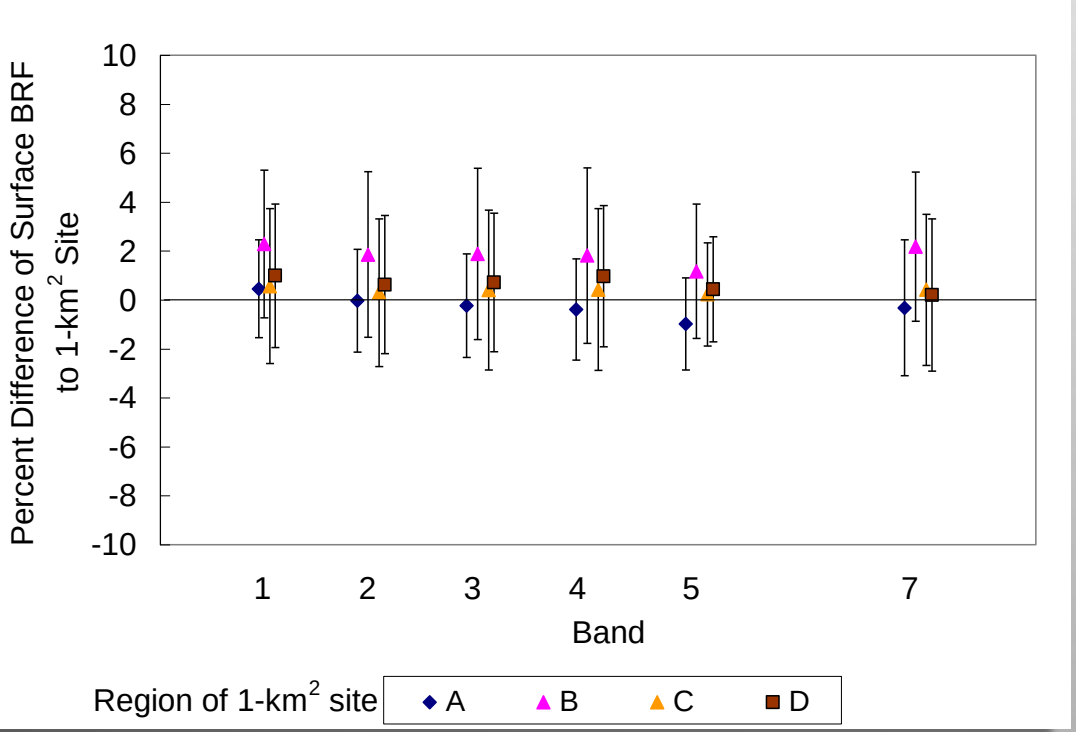
- Landsat-7 ETM+
- Terra and Aqua MODIS
- Both sensors chosen because of their long-term radiometric stability

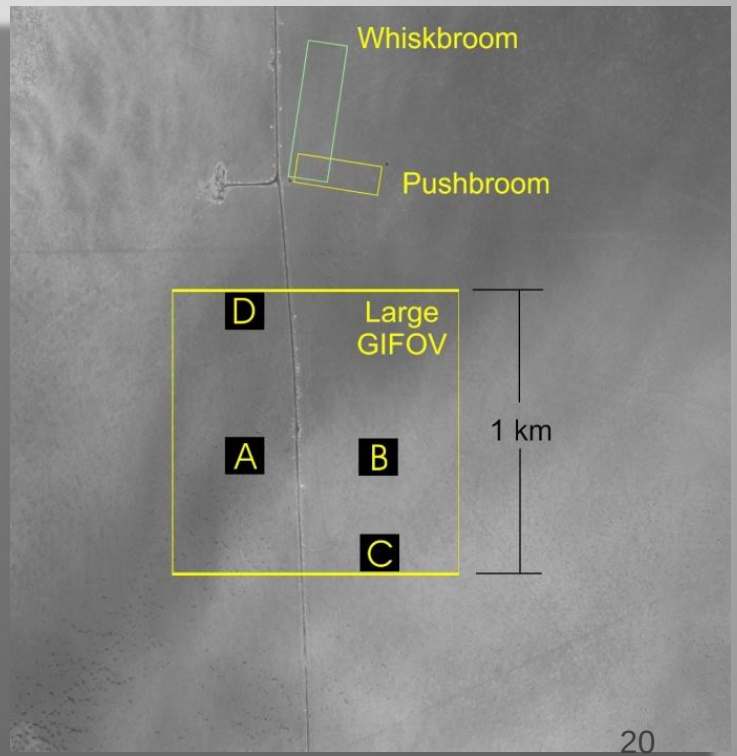
- Landsat-7: compare BRF retrieval with ASDs and GVRs
- Landsat-7 and MODIS: Compare TOA radiance retrievals



Medium Spatial Resolution, Multispectral: Landsat-7 Temporal Study

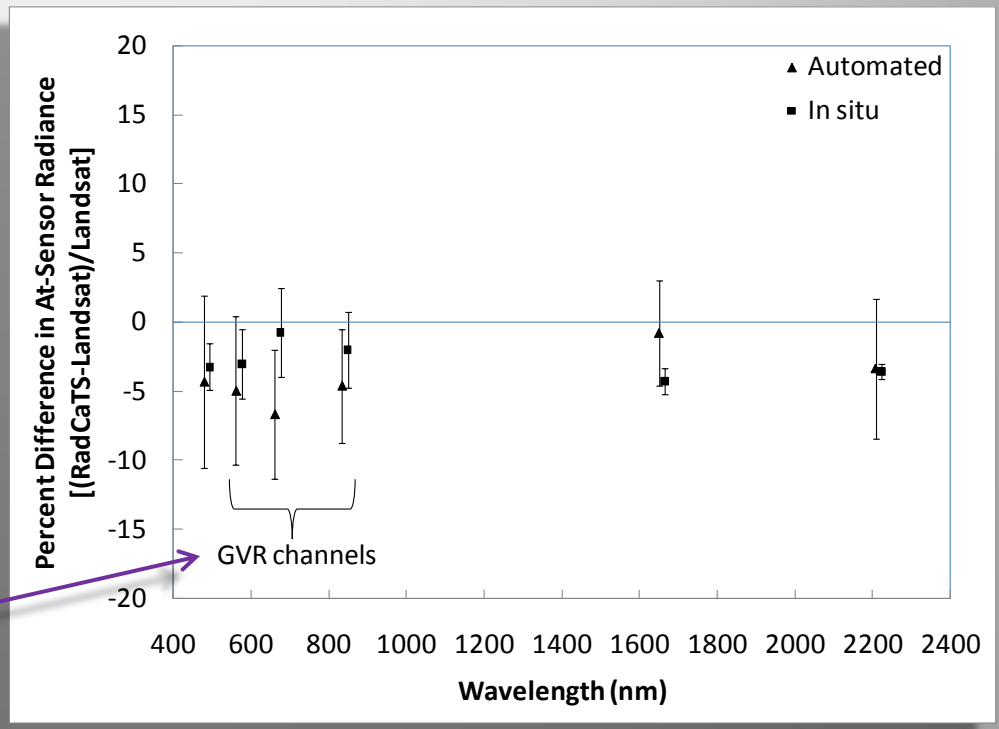
- **Landsat imagery (DNs only)**: comparison of four areas surrounding the GVRs to the entire 1-km^2 site
- Five dates: 2004-2006
- Result: each 150 150-m area is within 2% of the average value
- Error bars due to temporal variability in BRF





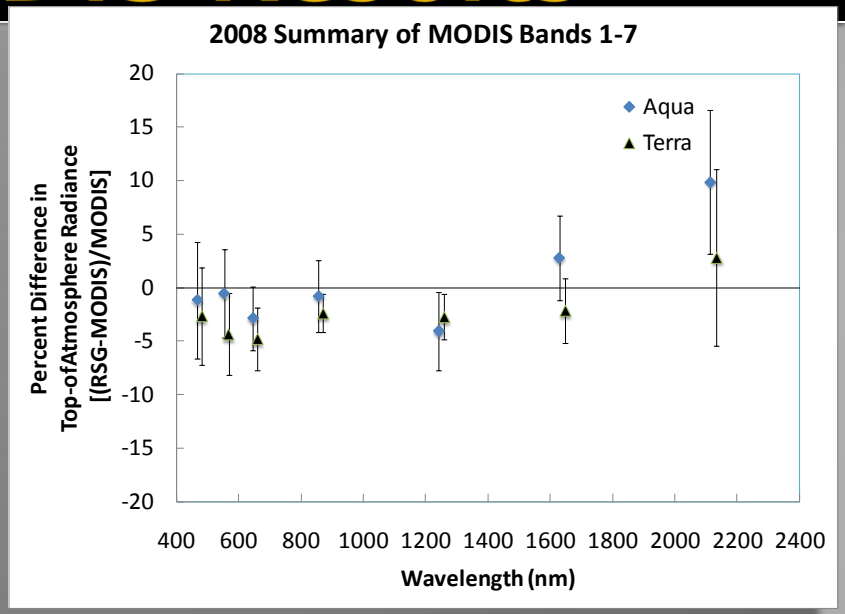
2008 Landsat-7 ETM+ Results

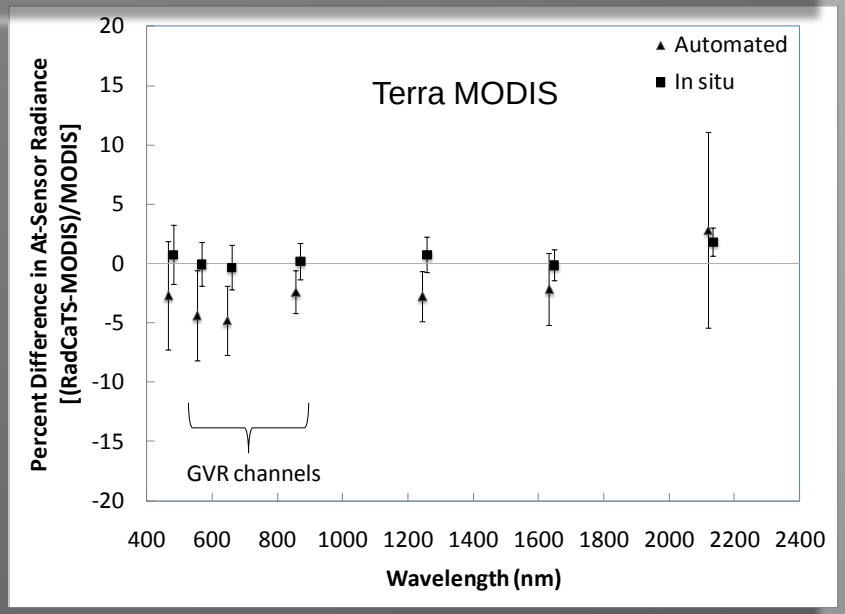
- **Summary of five RRV dates in 2008**
  - 2-4 GVRs used to sample site
  - Leads to higher uncertainty
  - Spatially undersampled based on previous uniformity study
  - Standard deviation not spectrally dependent
  - Note: three GVR channels operate in VNIR only



2008 RadCaTS MODIS Results

- **Summary of RadCaTS results for 2008**
  - Six dates for each sensor
  - GVRs used: 2-4, depending on date
  - Recall: 2 GVRs should produce BRF uncertainty ~ 4%
  - Site is generally spatially undersampled as in Landsat case
- **Comparison of RadCaTS and in-situ data for Terra MODIS in 2008**
  - RadCaTS results have bias compared to manned vicarious
  - Uncertainty greater in non-GVR bands
  - Standard deviation is also higher





Conclusions and Future Work

- Conclusions:
  - Present location of four GVRs is satisfactory
  - Uncertainties are most likely due to:
    - Temperature calibration of GVRs and electronics
    - Determination of diffuse skylight
  - Automation of data processing is critical to better understand results

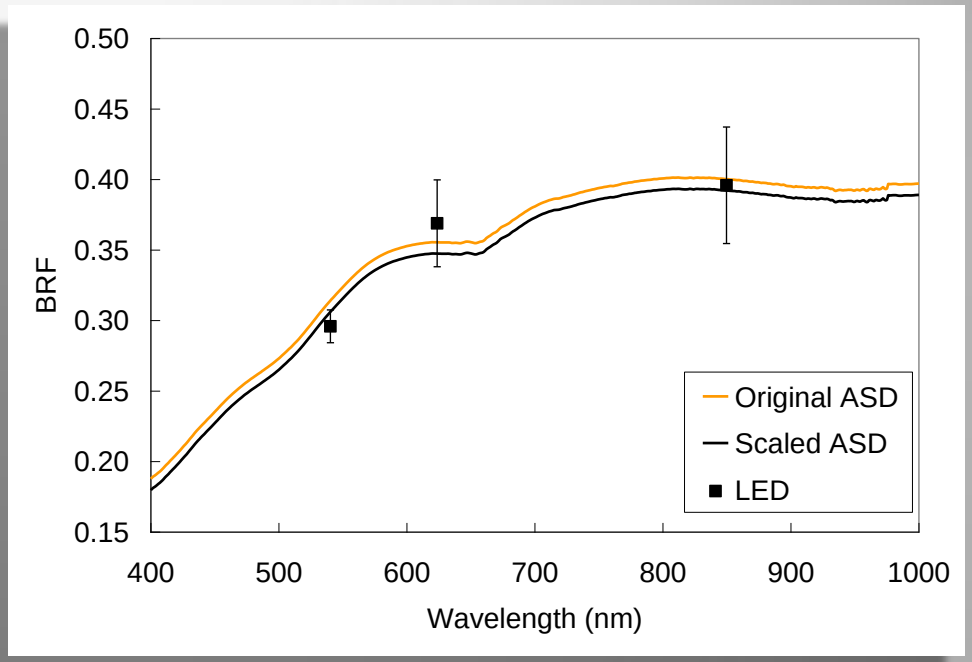
- Future work:
  - Complete Matlab code for data processing
  - Compare previous MODTRAN4 results with MODTRAN5
  - Compare Cimel results with solar radiometers
  - Continue with development of new 8-channel GVR design
  - Manufacture, test, and deploy new GVRs

Questions?

Surface BRF Methodology

$$\rho = \frac{\pi \, C_{GVR} \, V_{GVR}}{E_0 \, \tau_{solar} \, \cos\theta + E_{sky}}$$

- ρ = surface BRF
- C_{GVR}= GVR calibration coefficient
- V_{GVR} = GVR output voltage
- E_0 = exoatmospheric solar irradiance
- τ_{solar} = direct solar beam transmission
- θ = solar zenith angle
- E_{sky} = diffuse sky irradiance



- **Original ASD** BRF data collected using ASD portable spectroradiometer
- **LED** are the three retrieved BRF values during overpass
- **Scaled ASD** are the final values that are used in the radiative transfer code