Recent Results from the Automated Radiometric Calibration Test Site at Railroad Valley, Nevada

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Topics

- Introduction
- Reflectance-based vicarious calibration
- Radiometric Calibration Test Site (**RadCaTS**) concept
- Automated processing
- Comparison with Landsat 7 ETM+, Aqua, and Terra MODIS
- Conclusions and future work

Introduction

- RSG uses reflectance-based method to perform ground-based vicarious calibration
- Radiometric Calibration Test Site (RadCaTS) site was developed to obtain data in absence of ground personnel
  - Modeled on reflectance-based technique
  - Attempt to retain accuracy of in-situ measurements with flexibility of pseudo-invariant scenes
- Cost reduction through use of existing equipment and prototype instruments
  - Cimel sun photometer (AERONET)
  - Inexpensive ground-viewing radiometers (GVRs)
- Previous studies to analyze:
  - Placement of radiometers
  - BRF retrieved using automated vs. manned instruments

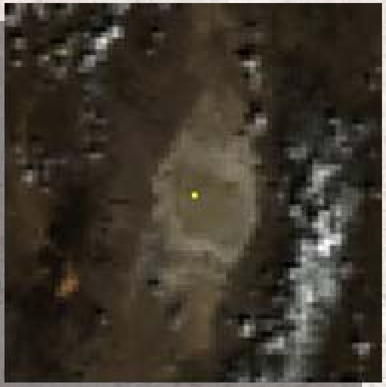
Reflectance-Based Approach to Vicarious Calibration

Measure site: reflectance data

Measure site: atmospheric data

Radiative Transfer Code

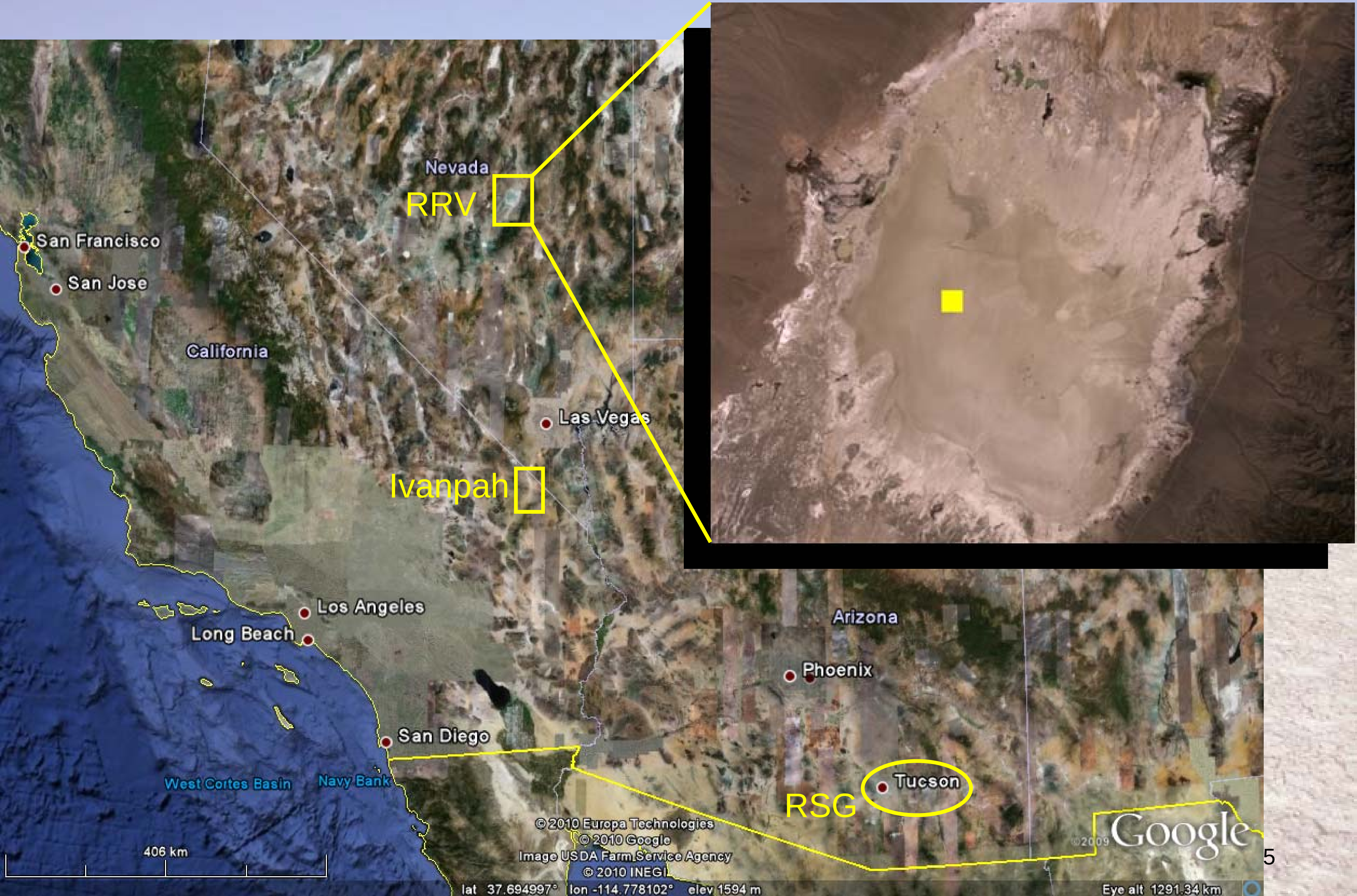
Compute top-of-atmosphere radiance



Average site DNs derived from image data

Calibration of sensor's spectral bands

Vicarious Calibration Test Sites



Instrumentation

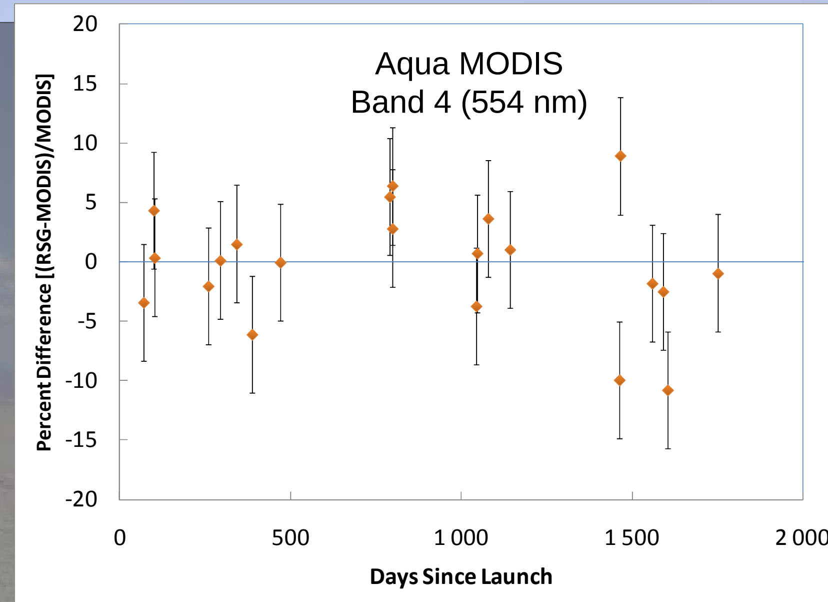
- Surface: Analytical Spectral Devices spectroradiometer
  - 3 detectors
    - 1.4-nm spectral sampling (350-1100 nm)
    - 10-nm spectral sampling (1100-2500 nm)
  - 8° full field of view foreoptic
  - Foreoptic attached to boom arm
  - Internal software interpolates data to 1-nm increments
  - Surface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

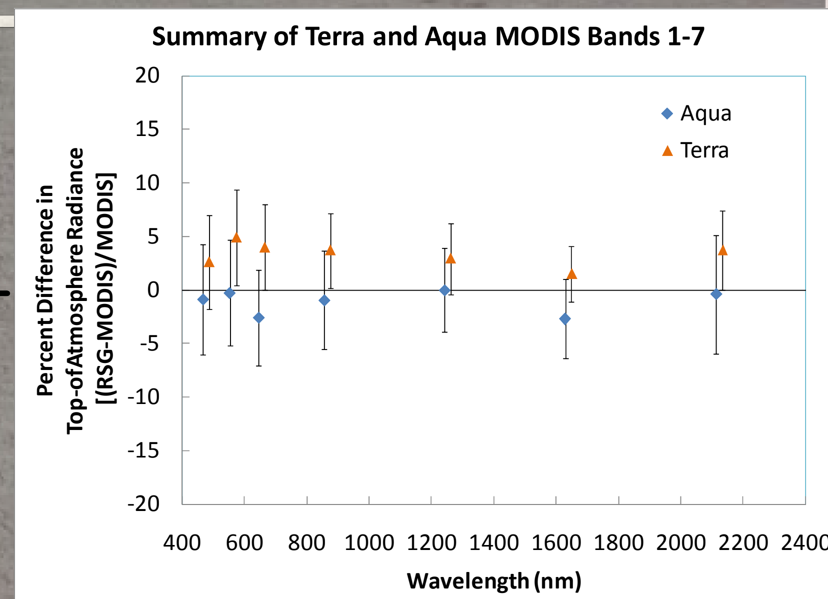
Instrumentation

- 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 Results for Terra and Aqua MODIS

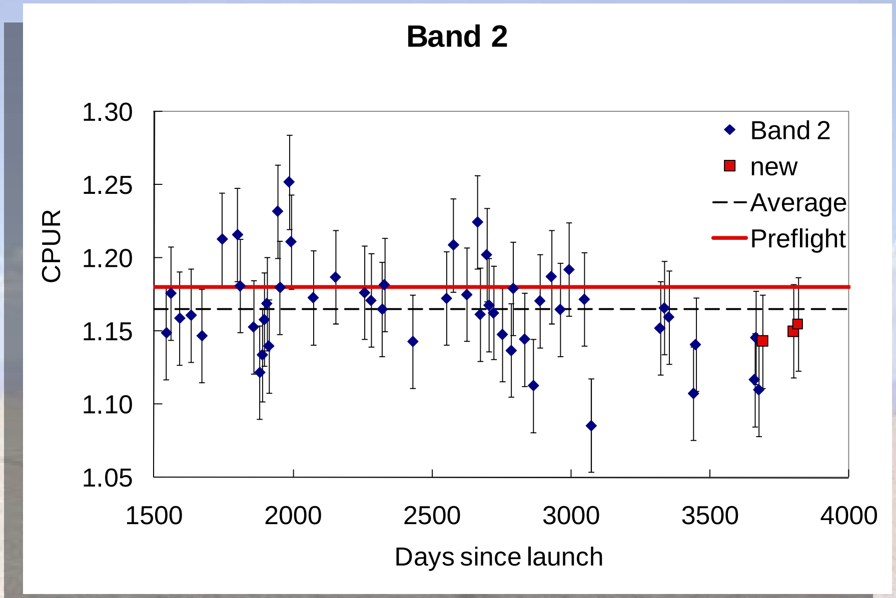
- All MODIS data collected at RRV
- **Aqua MODIS comparison to vicarious**
  - Average TOA spectral radiance difference less than 1% in five bands
  - Average TOA spectral radiance difference less than 3% in other two bands
  - Standard deviation ~5% in all bands
- **Terra MODIS comparison to vicarious**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



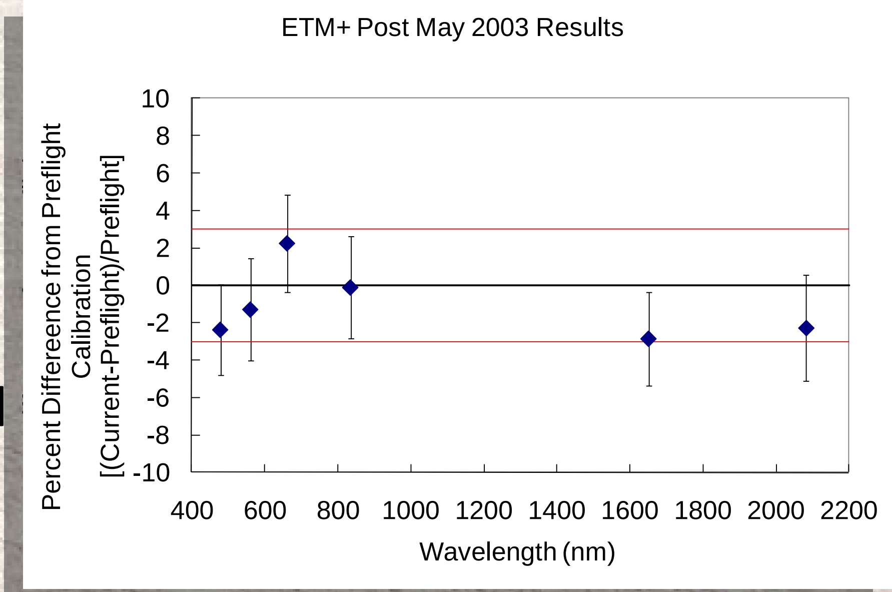


Reflectance-based Results for Landsat 7

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

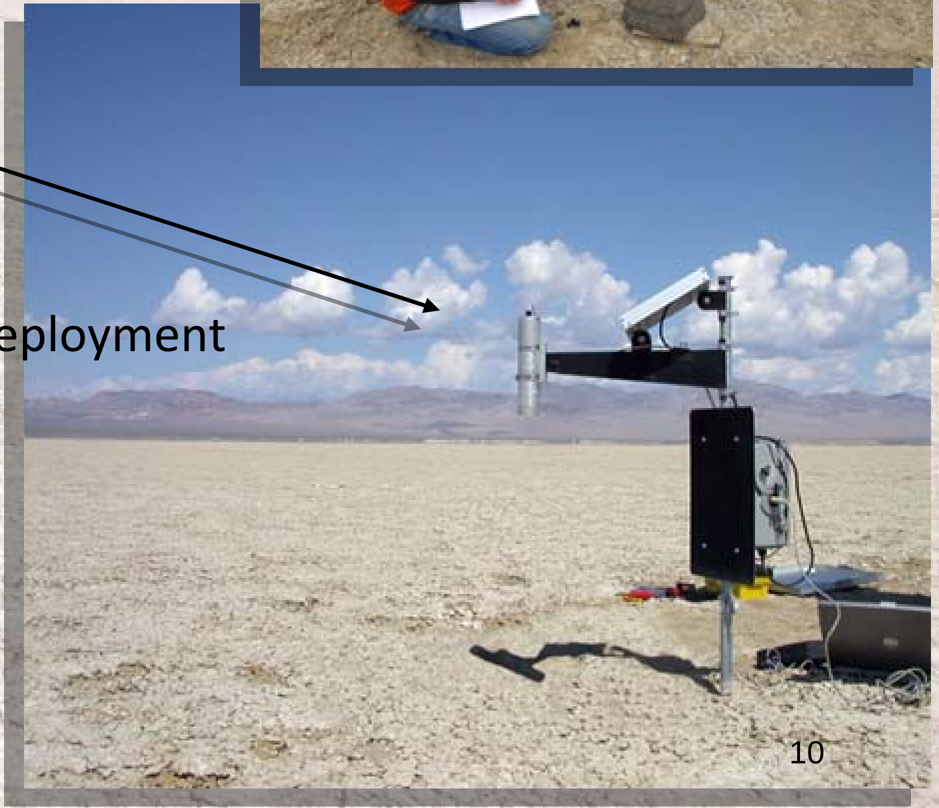


- Summary of all bands from May 2003
- Percent difference within 3% of preflight values
- Standard deviation less than 3% for all bands

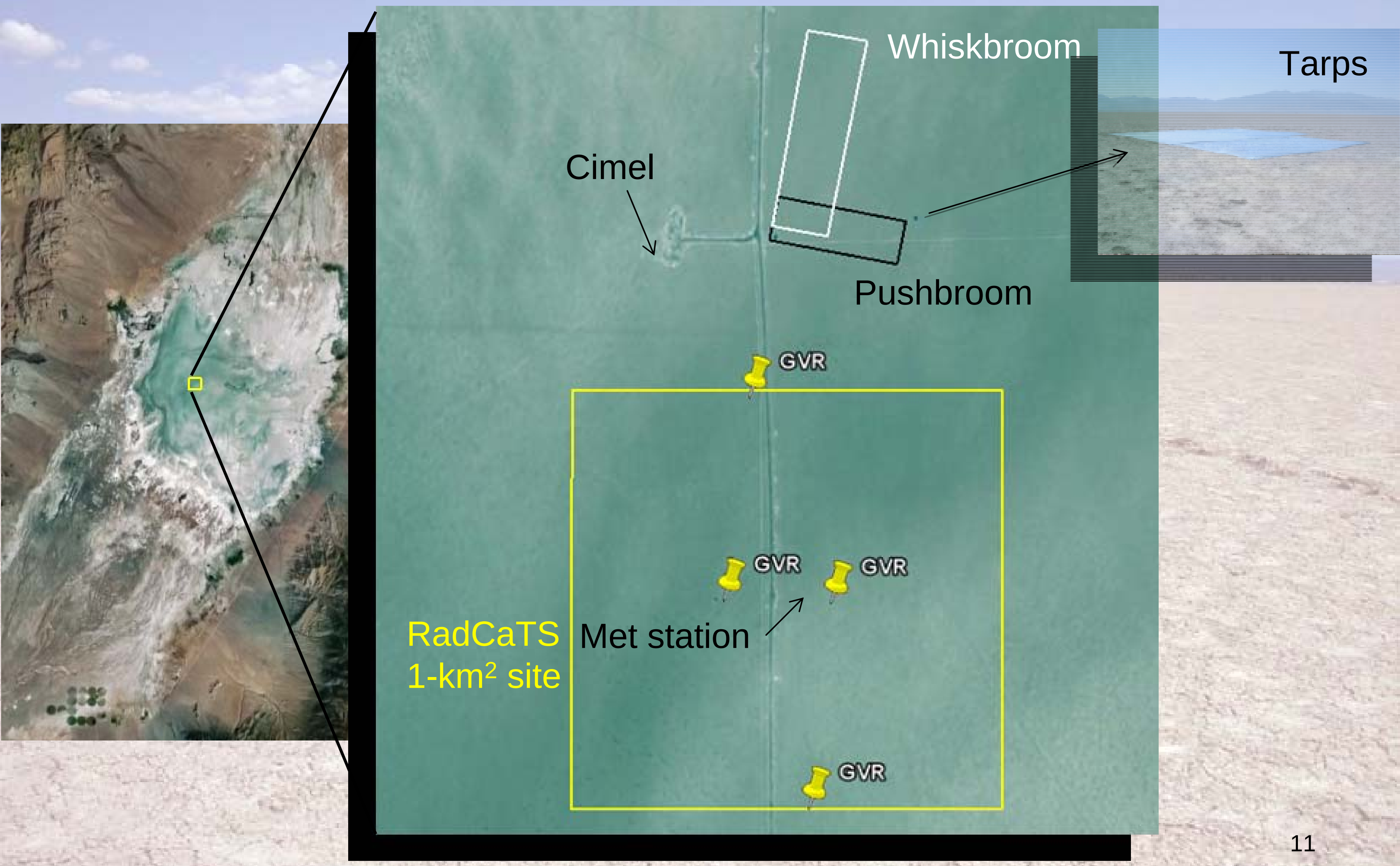


Automated Vicarious Calibration: Radiometric Calibration Test Site (RadCaTS)

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

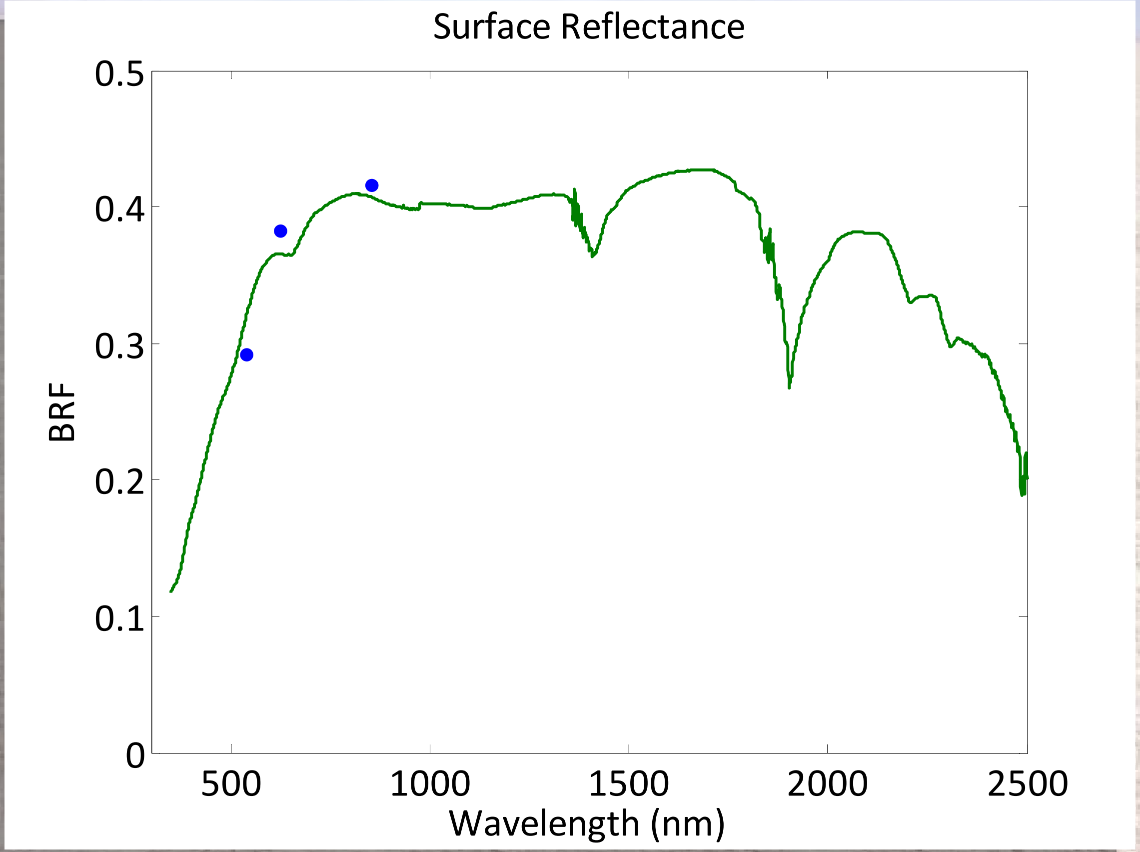


RadCaTS at Railroad Valley



Determination of surface reflectance

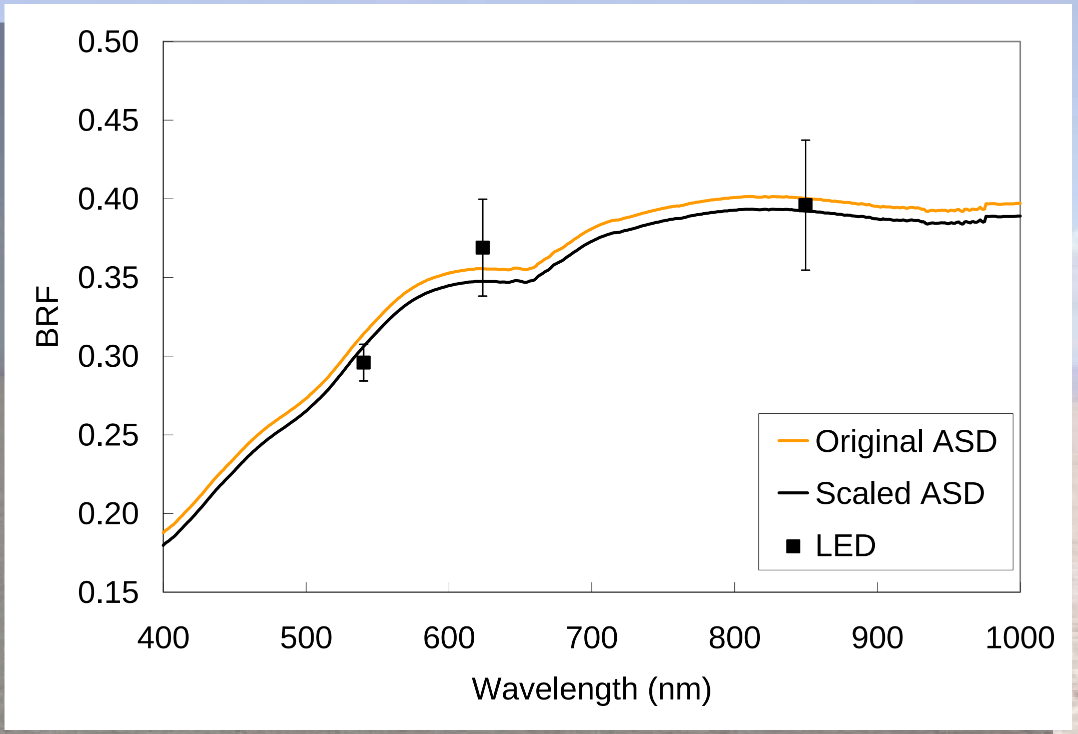
- At desert test sites, BRF is the most important measured quantity
- RRV and Ivanpah have surface BRF > 0.3 for most of VNIR and SWIR
- Yearly average of aerosol optical depth, ~0.05 at 550 nm
- Surface reflectance drives the uncertainty in TOA spectral radiance



RadCaTS Surface BRF Retrieval

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

- 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

GVR radiometric calibration (C_{GVR})

- Solar-radiation-based calibration (SRBC)
  - Sun is illumination source
  - Spectralon reference panel
  - GVR views panel
  - Panel shaded with parasol in order to measure diffuse illumination

GVR Calibration Coefficient ($W\ m^{-2}\ sr^{-1}\ \mu m^{-1}\ V^{-1}$)

	2			3			4			8		
Date (yymmdd)	G	R	NIR	G	R	NIR	G	R	NIR	G	R	NIR
080423										318.6	310.0	134.3
080529	192.6	238.1	108.2				299.0	307.7	159.4	327.1	312.1	129.9
080530							314.0	317.9	167.6			
080818				181.3	227.8	129.3				349.9	330.5	142.9
080819										324.4	313.1	137.8
090324				187.2	205.6	129.2						
090520	210.6	225.3	108.7									
Average	201.6	231.7	108.5	184.3	216.7	129.2	306.5	312.8	163.5	330.0	316.4	136.2
Std Dev										4.2%	3.0%	4.0%

Landsat 7 and MODIS data for this work

2008: Aqua and Terra MODIS

- L1B imagery
- 6 dates for each sensor
- 1-3 GVRs depending on date
- Issues with GVR gains due to reduced number of SRBCs

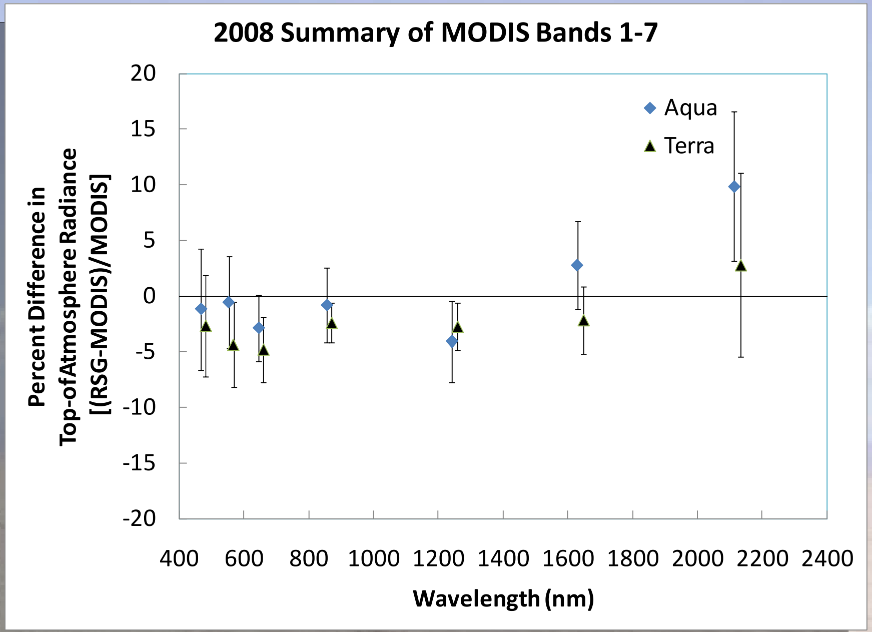
2009: Landsat 7 ETM+

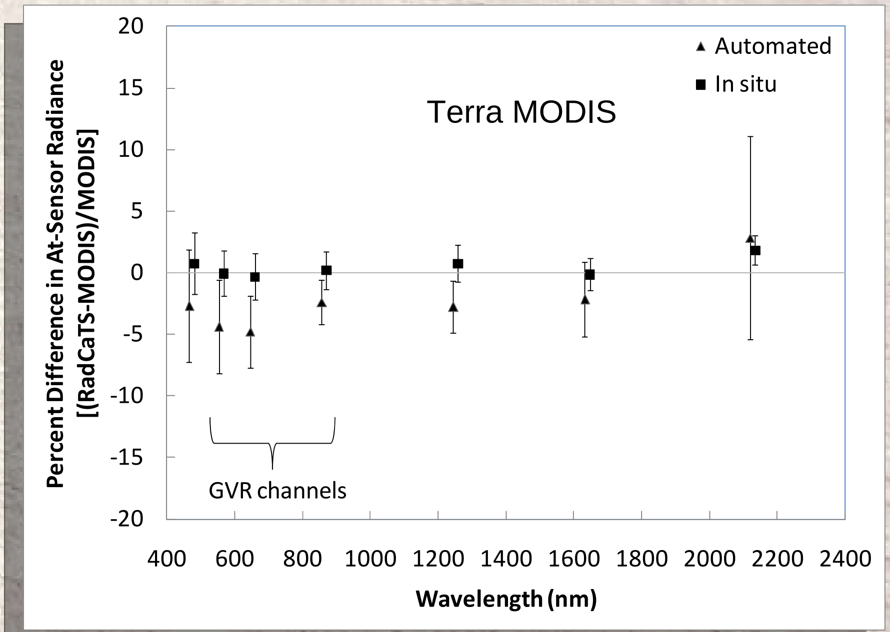
- L1T imagery
- 20 potential dates
- 10 successful
- 10 unsuccessful
    - 1 with snow cover
    - 6 with cloud cover
    - 3 with no GVR data
- 2-4 GVRs used to sample site

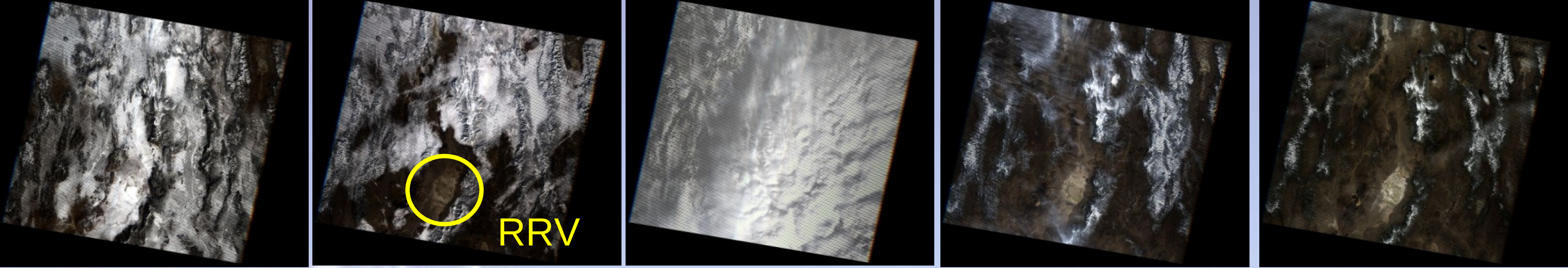
2008 RadCaTS MODIS Results

- **Summary of RadCaTS results for 2008**
  - Previous study shows that 2 GVRs should produce BRF uncertainty of ±4%
  - Site is generally spatially undersampled as in Landsat case

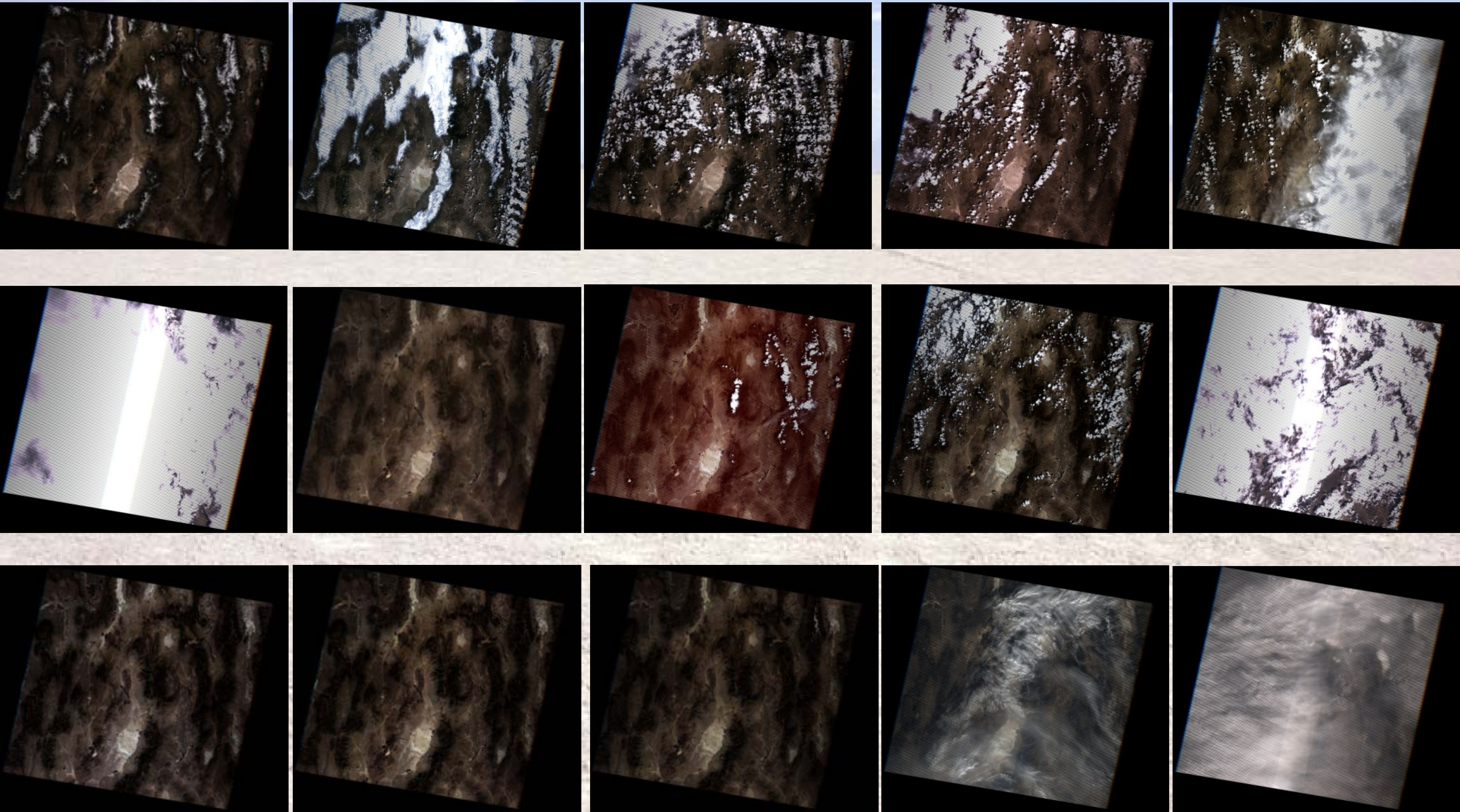
- **Comparison of RadCaTS and in-situ data for Terra MODIS in 2008**
  - RadCaTS results have bias compared to manned vicarious
  - Uncertainty is also greater





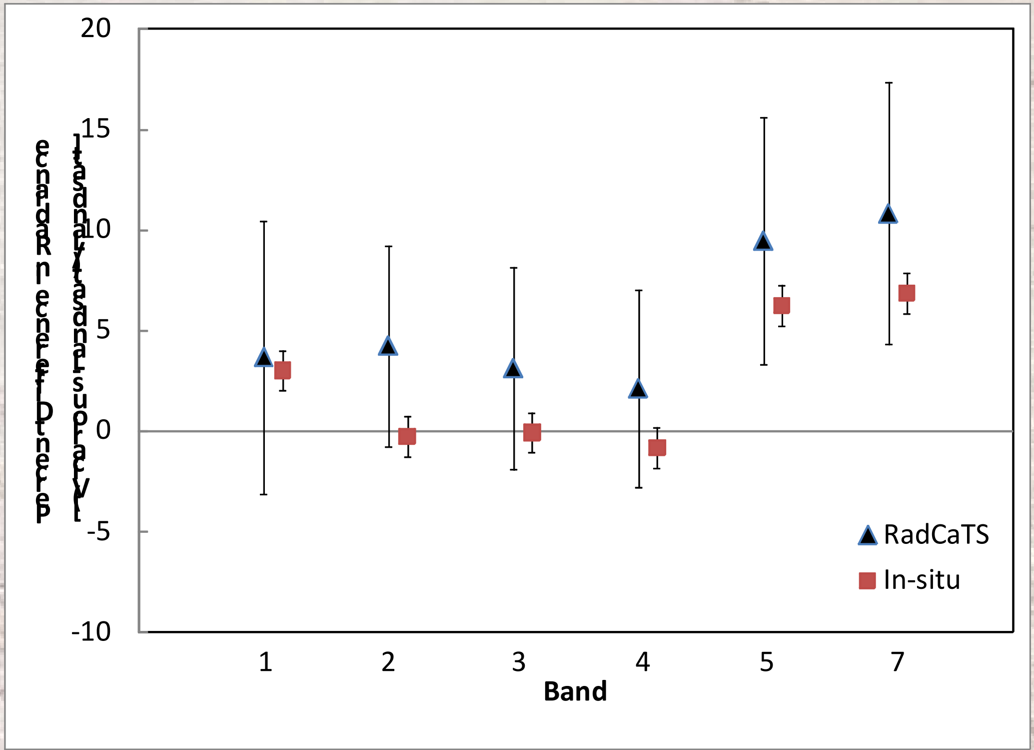


2009 RadCaTS Landsat 7 ETM+ Results



2009 Landsat 7 RadCaTS Results

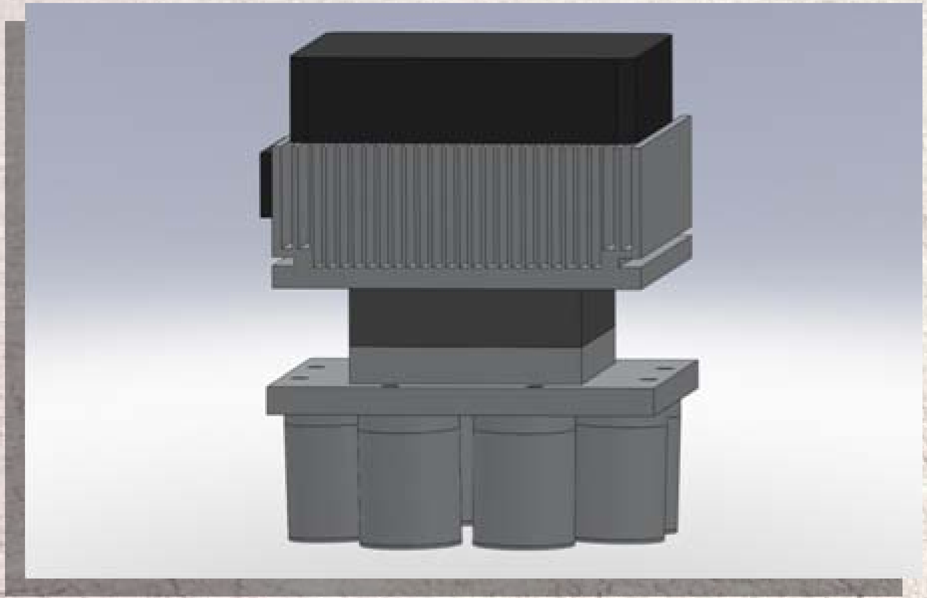
- **Summary of ten RRV dates in 2009**
  - 2-4 GVRs used to sample site
  - Leads to higher uncertainty
  - Spatially undersampled based on previous uniformity study
  - Standard deviation not spectrally dependent
  - Note: three GVR channels operate in VNIR only (Landsat 7 bands 2-4)

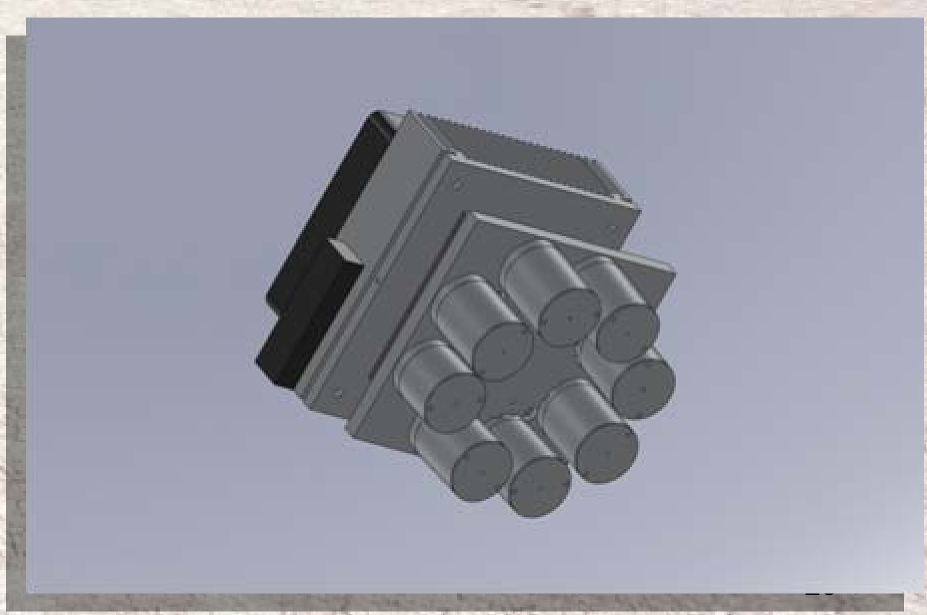


New GVR Design

- 8 spectral channels (400, 450, 500, 550, 650, 850, 1000, 1550 nm)
- 10° full field of view
- 1.5 m above ground (reduces dust accumulation)
- Focal plane is temperature controlled (better radiometric stability)
- Silicon detectors (VNIR), InGaAs detector (SWIR)
- Interference filters for spectral selection

- Benefits: better spectral, temperature, and FOV control. SWIR spectral sampling.





Conclusions and Future Work

- Conclusions:
  - GVR radiometric stability needs further study and more frequent SRBCs
  - Uncertainties are most likely due to:
    - Temperature calibration of GVRs and electronics
    - Possible change in spectral response with temperature
    - Determination of diffuse skylight
  - Next-generation GVRs should alleviate many calibration issues

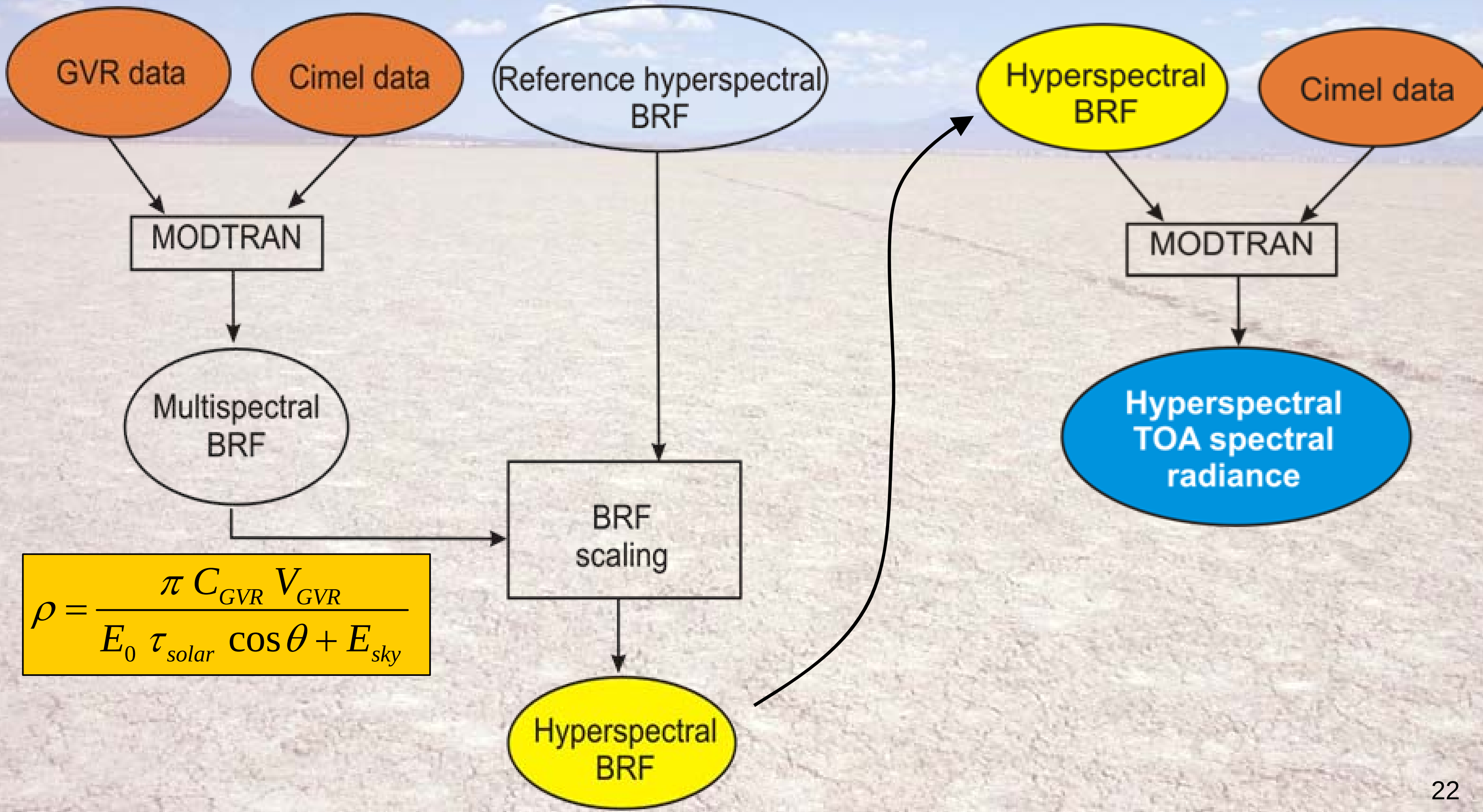
- Future work:
  - Manufacture, test, and deploy new GVRs
  - Fine tune Matlab code for data processing
  - Compare MODTRAN to in-situ measurements of diffuse skylight
  - Compare Cimel results with solar radiometers
  - Process more data and compare to Landsat, MODIS, and others

Questions?

Surface BRF Determination and TOA Radiance

Surface BRF

TOA spectral radiance



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

Automated Processing

- Matlab-based GUI
- Surface and atmospheric data collected using GVRs and Cimel sun photometer
- Met station measures ambient conditions
- Time to process: minutes vs. 3+ hours
- *Web-based portal for data distribution