Assessment of Automated Ground-based Vicarious Calibration Method using High-Resolution Commercial Sensors

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Background

Radiometric calibration continues to be a critical part of terrestrial imaging systems

- Realistically, it is often not a high priority for high spatial resolution data sets
  - Geometric calibration plays a bigger role
  - Often difficult to predict how data sets will be used in the future
- New methods are continually needed to allow uncalibrated sensors to be calibrated
  - Should not impact scheduling in a dramatic fashion
  - Hopefully, does not require spacecraft maneuvers
- Invariant scene approaches is one type of approach
- Automated test sites is another

Talk outline

Automated test sites combine accuracy of in situ vicarious methods with flexibility of invariant scene

- Ground systems are always collecting so are available to the imaging sensor at the convenience of the scheduler
- Describe how high-resolution commercial imagers are playing a role in the development of automated systems
- Talk overview
  - Describe past work with automated systems
  - Use of high-resolution data to assess accuracy
  - High-resolution data to understand spatial sampling
  - Summary

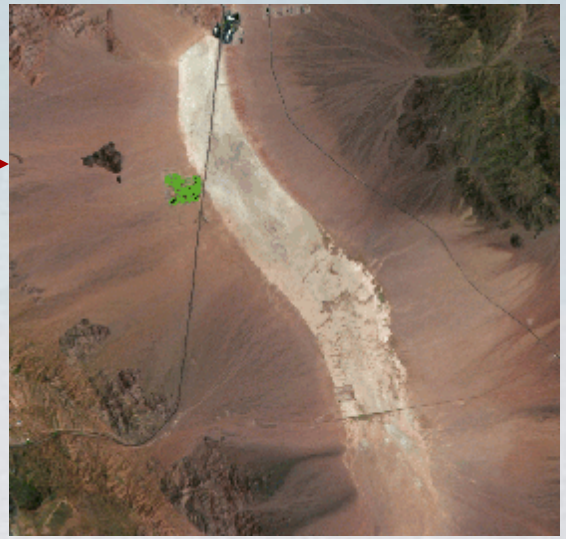
Reflectance-based approach

Measurements of surface reflectance of a homogeneous test site

Measurements of atmospheric conditions

RTC Code

Predict at-sensor radiance for a selected area of the site and compare to imagery



Reflectance-based drawbacks

Reflectance-based method gives high absolute accuracy (2.5% uncertainty in mid visible)

- Issues with the approach
  - RSG personnel needed to be present
  - Weather prevents successful collections on some dates
- Outcome is that the there are temporal limitations from the data collections but not with the sensors
  - Aqua and Terra MODIS pass over same area with near-nadir look every 8 days
  - Landsat7 ETM+ is every 16 days over CONUS
  - Limits trending analysis on sensors where degradation is ambiguous

RadCaTS solution

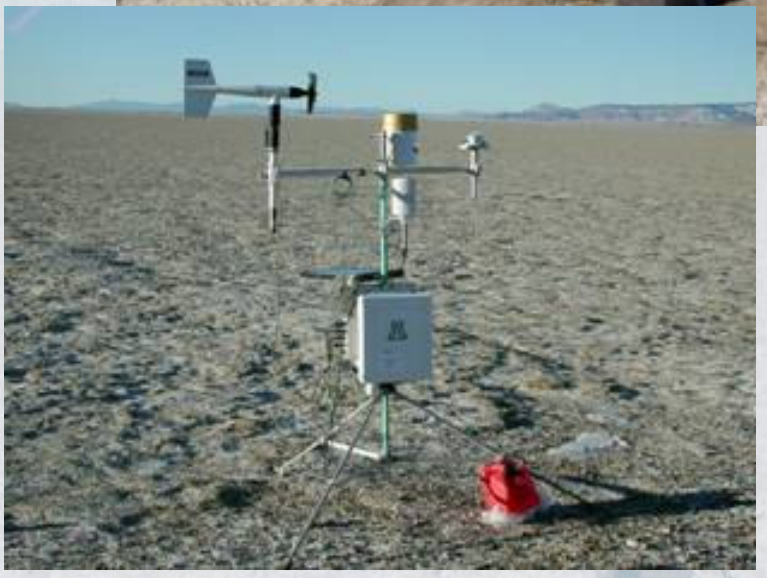
Radiometric Calibration Test Site is an autonomous, reflectance-based calibration site

- Basic concept is core & node site philosophy at Railroad Valley Playa
- Central core site
  - Highly instrumented for spatial and spectral detail
  - Used for high-spatial-resolution sensors (< 4 m)
- Node sites
  - Smaller instrument suite
  - Designed to give spatial information
  - Used for low-spatial-resolution sensors (> 250 m)
- Combine the two for moderate resolutions
- Improve temporal sampling without loss of accuracy

Current instrumentation

Currently a suite of instruments to obtain atmospheric and surface information

- Atmospheric data from Cimel sun photometer
  - Atmospheric optical depth
  - Angstrom exponent
  - Water vapor
- Weather information from meteorological station
  - Temperature
  - Pressure
  - Precipitation

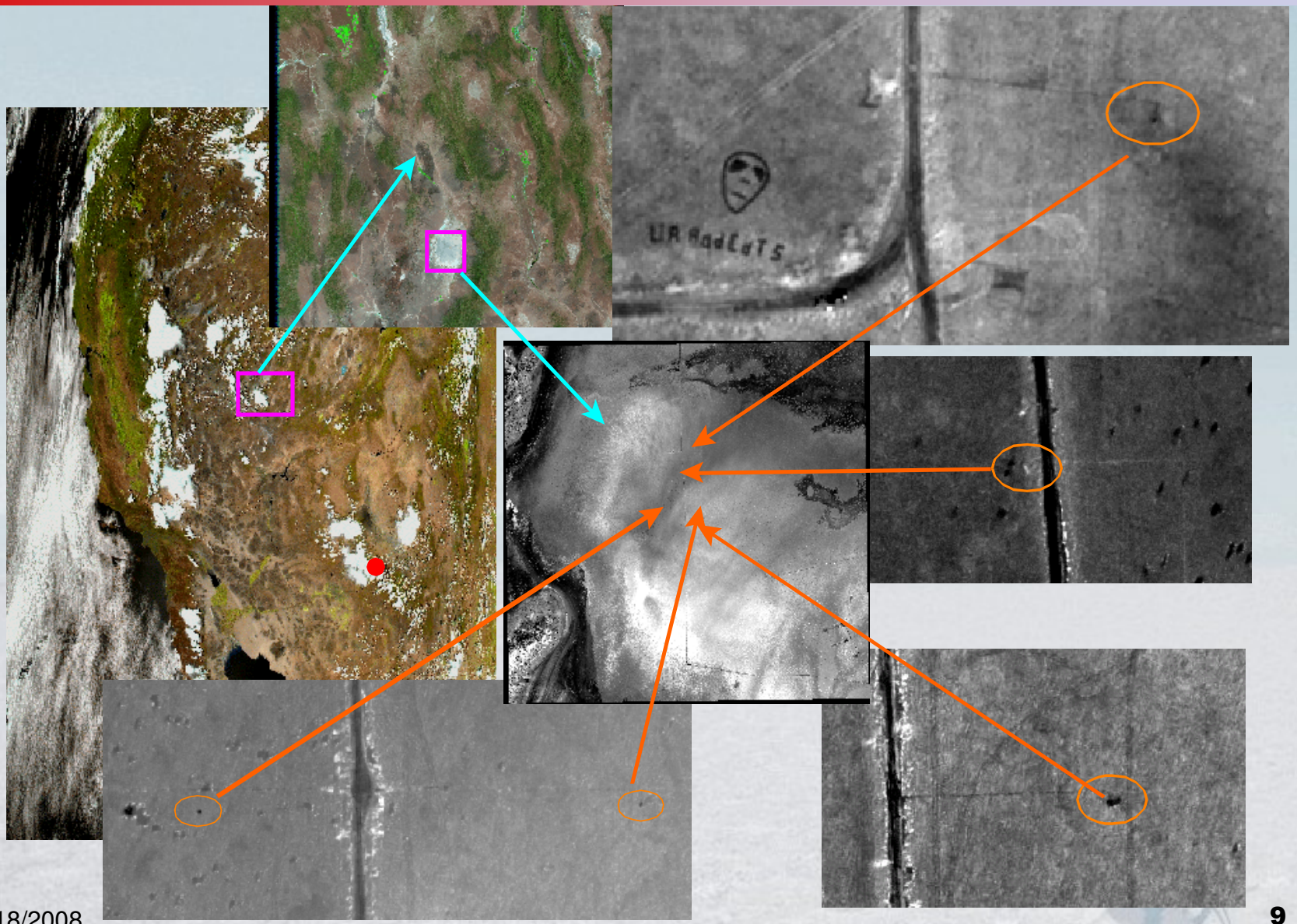


Ground viewing radiometer

Data have been collected since 2003 with varying quality of instruments

- Current ground-viewing radiometers rely on LED detectors
  - Nadir-look used for simplicity
  - Matches view angle for on-site measurements
  - Azimuth not critical
- 3 bands (539, 622 & 839 nm)
- LED reflectance scales hyperspectral reflectance
- Temperature corrected
- Currently 5 instruments

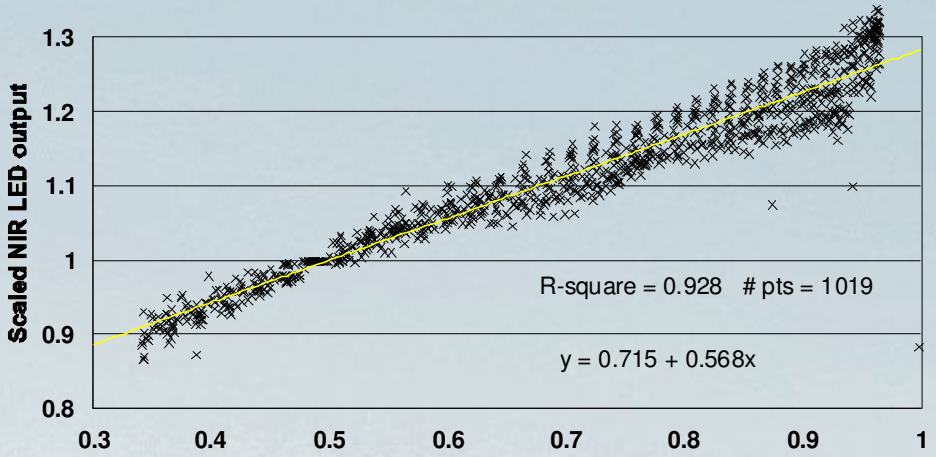
Site locations

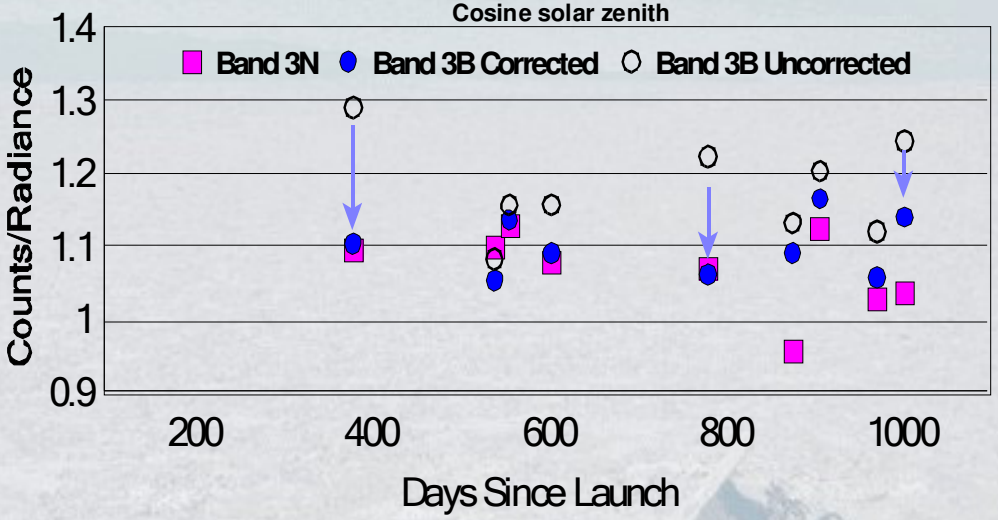


Example result

One early use of automated radiometers was the assessment of directional reflectance effects

- Two years of data from a single sensor
- Filtered for clouds, rainfall, and sun angle
- Cause of scatter are
  - Sensor thermal effects
  - Moisture effects
  - Rain periods may indicate cloud issues
- Results improved calibration of off-nadir view of ASTER

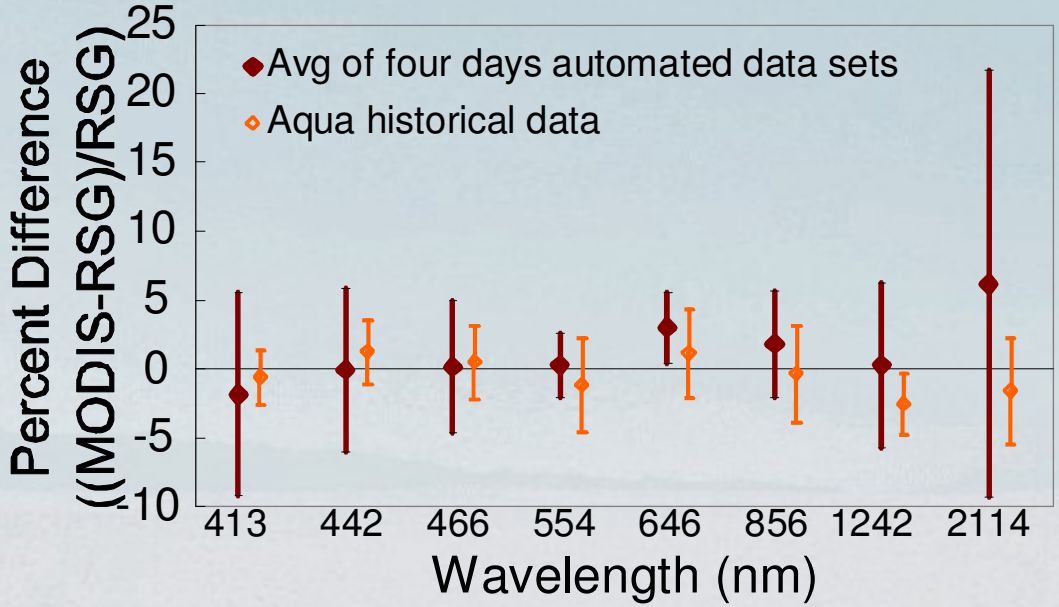




Large-footprint results

Instrumentation and automated approach was first tested with MODIS

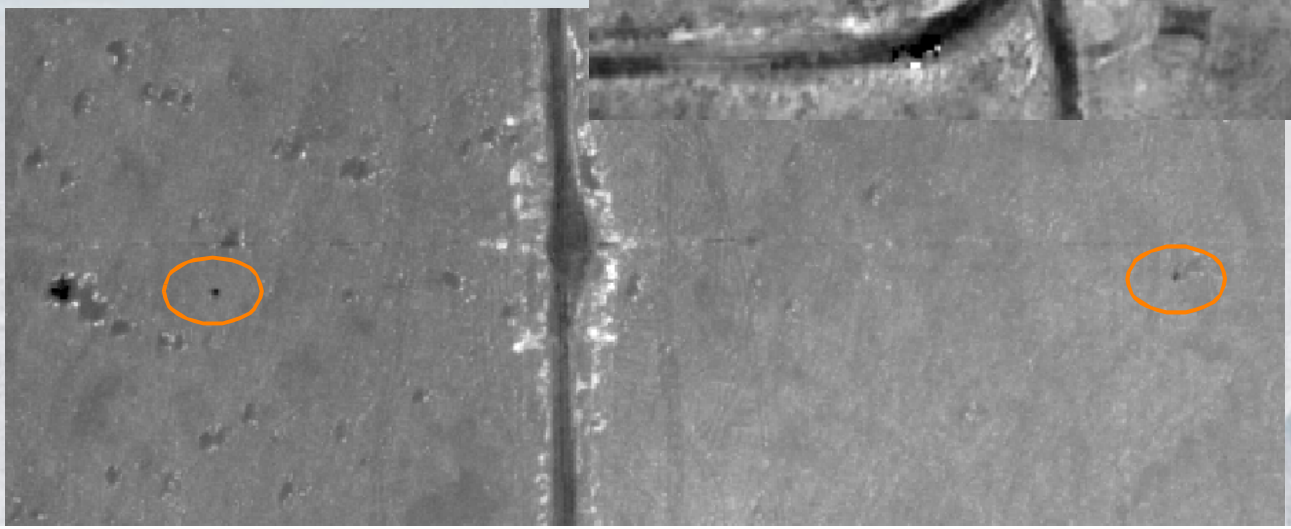
- 1-km spatial resolution
- Not an ideal test but goal was to increase number of possible calibrations
- Question is what is the primary error source
  - Spectral sampling
  - Spatial sampling
  - Instruments



Evaluation with high resolution

High resolution data can be “seen” in the imagery and bands are similar to ground radiometers

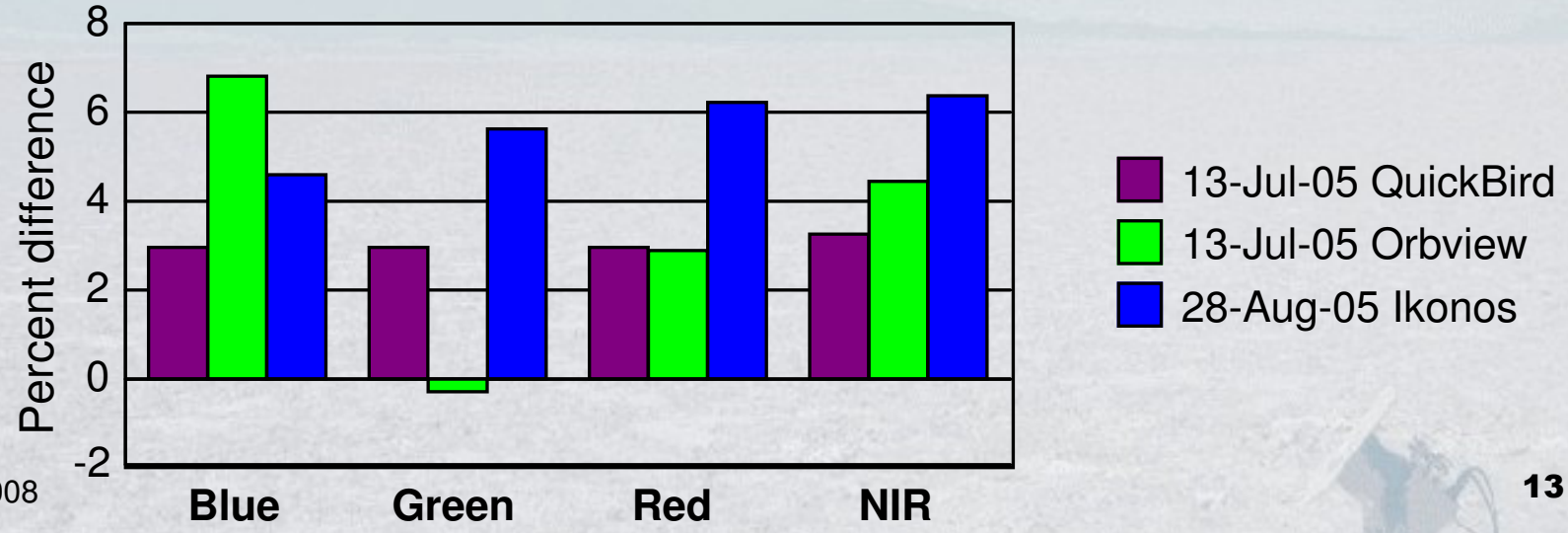
- Reduces errors from spatial sampling
- Spectral extrapolation issues are smaller
- Limited data sets
  - Only RRV Playa data sets
  - Snow on one date



High resolution sensors

Automated radiometer results differed from on-site measurement results from 3-7%

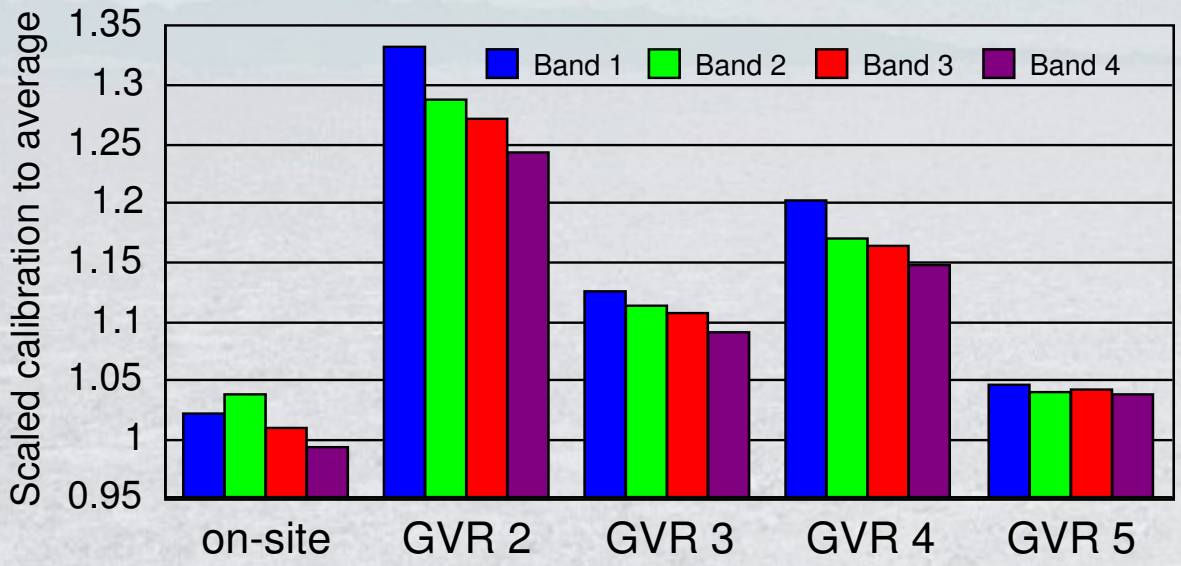
- Not due to spectral or spatial resampling
- Implies uncertainty due to
  - Radiometer measurements
  - Conversion to reflectance
- Indicates that the ground-viewing radiometers (GVRs) are the limiting error source at this time



Multiple radiometer results

Process results from all available radiometers from single date

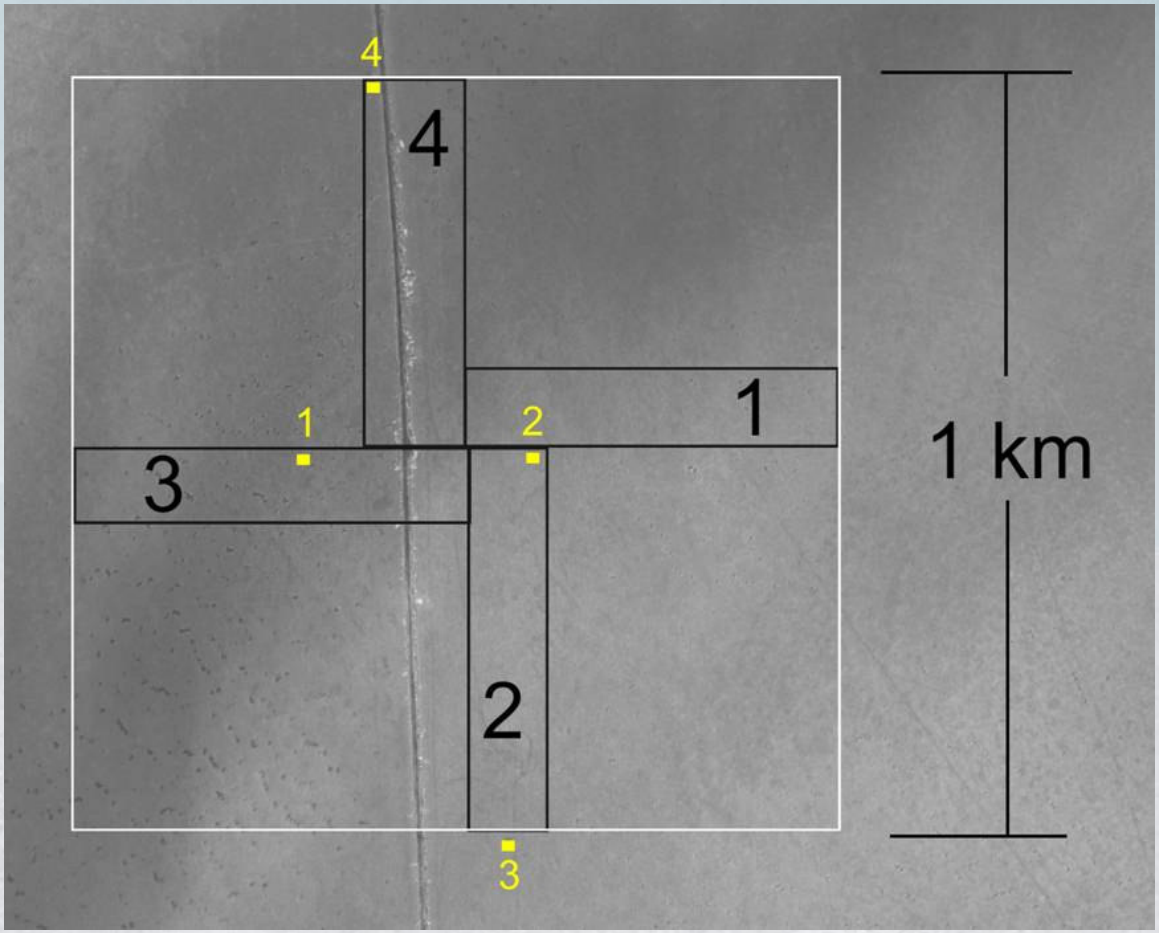
- Results shown here are from multiple radiometers on a single date for an Orbview-3 calibration
- All data are scaled to the average Orbview reflectance-based results
- GVR 5 is a newer model of ground-viewing radiometer
- Most likely issue is temperature correction



Spatial sampling impact

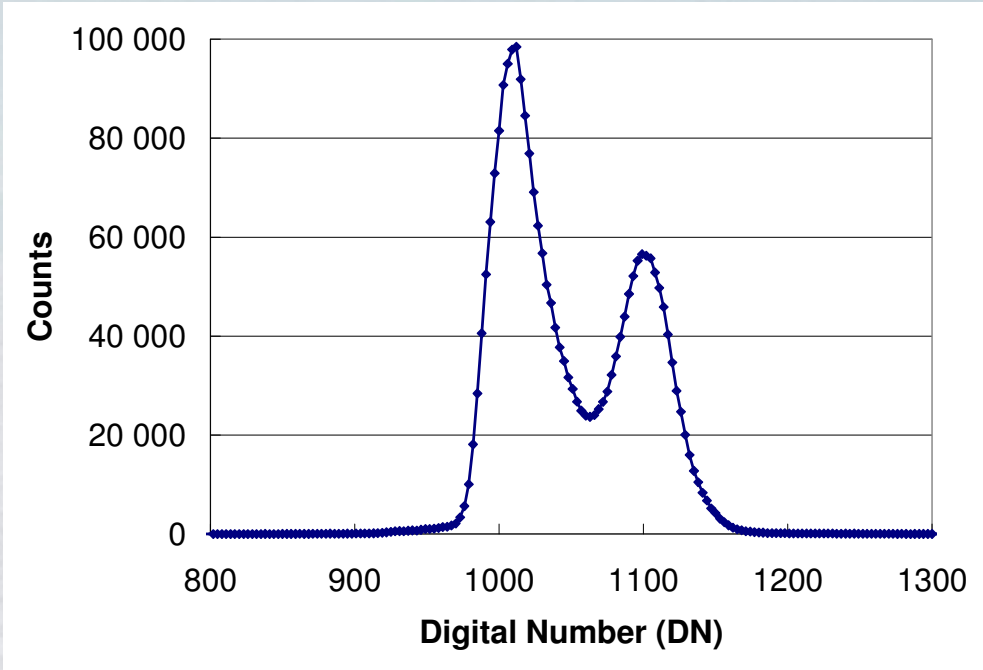
A big issue with the large-footprint results is whether four spatial samples is sufficient

- Cost limited deployment of more radiometers
- Use of high-resolution imagery can assess number of radiometers needed
- Single scene evaluated at this point



Spatial assessment

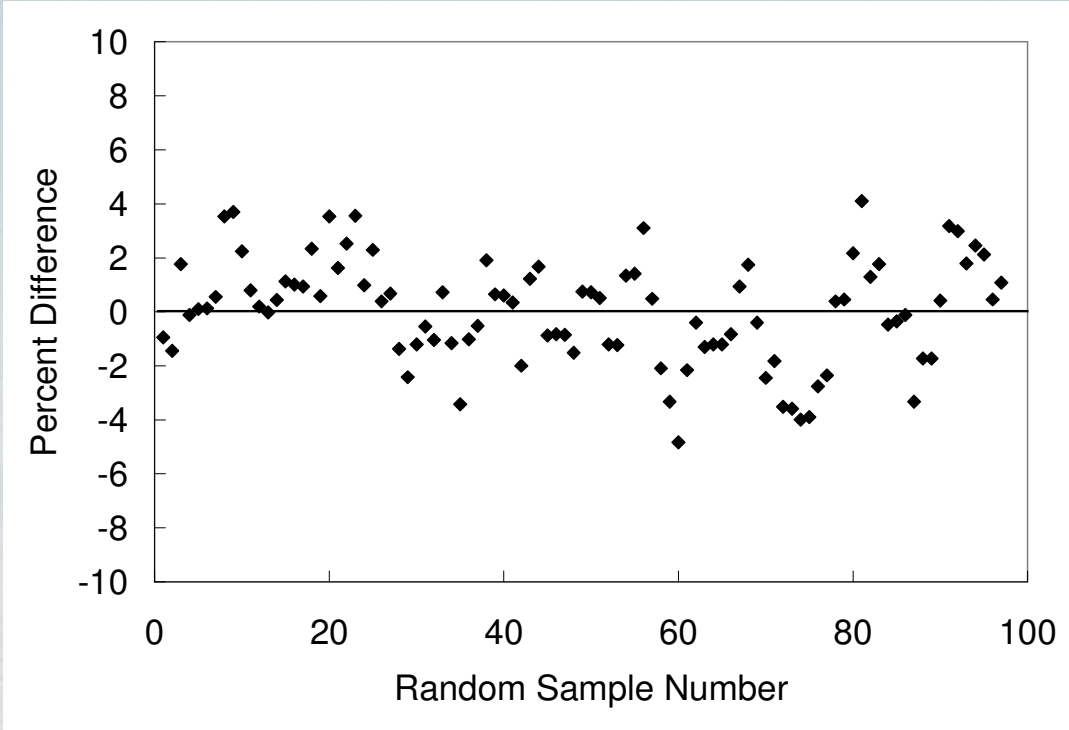
- Determine spatial average for 1-km^2 large-footprint site
  - QuickBird panchromatic image (60-cm spatial resolution)
  - Gives baseline, or best-case scenario
- Random sampling of imagery of large-footprint site
  - Current four ground-viewing radiometers
  - Four randomly-place ground-viewing radiometers
  - Varied number of radiometers (1-20)



Four-radiometer case

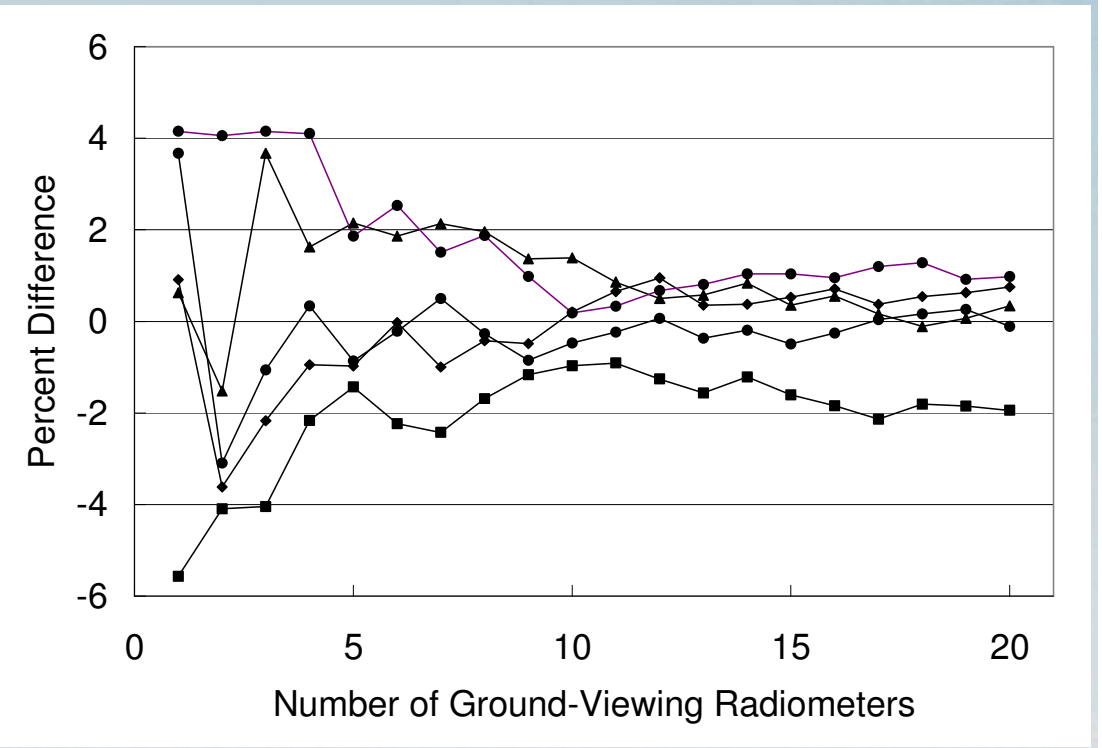
Analysis of location of present four radiometers show an average that is 3.4% lower than full site

- Average value for 100 sets of four randomly placed radiometers
  - Average percent difference is 0.04% from average of entire site
  - Standard deviation (1 σ) is 1.9%
- All cases were within ±5% of full-site average



Optimal radiometer number

Vary number of radiometer locations from 1 to 20



- Randomly selected pixel agrees with entire site to better than 10%
- Four radiometers produces the same uncertainty as 20 radiometers
- Evaluation only examined the panchromatic band
- Further work with more scenes and multispectral data

Summary

Automated ground measurement approaches are excellent means for radiometric calibration

- Other groups have also succeeded in developing sites
  - Stennis Space Center facility
  - JPL facility at Lake Tahoe
- Method has been applied at RRV Playa
  - High and low spatial resolution
  - BRDF correction
- Benefits high spatial resolution sensors
  - Vicarious calibration data can be collected at the convenience of the sensor scheduler
  - Will allow intercomparisons between sensors without need for coincident data collections

Summary

Evaluation of approach for collecting ground data has benefited from high resolution data

- Determine optimal placement of sensors
  - Indicates number of sensors needed
  - 4 sensors is sufficient, but not where we have them
- Allows determination of the limits of the approach
  - Largest error source at this time is the instrumentation
  - New funding allowing development of new radiometers
- Further evaluation with more scenes will improve the confidence of these results
- Results here give confidence that an automated system can provide results with similar accuracy as on-site measurements