Investigation of the LSpec autonomous ground calibration site using MODIS, Landsat ETM+, and IKONOS

Civil Commercial Imagery Evaluation Workshop

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LOCKHEED MARTIN

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Outline

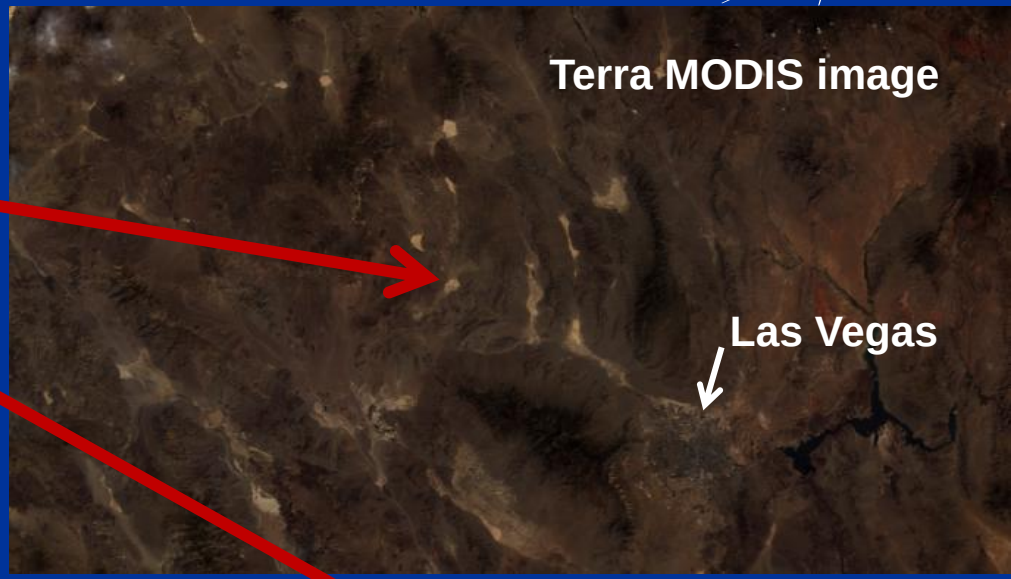
- Purpose
- LSpec
  - LSpec Site
  - Sensor Comparison
  - Data
  - Data Analysis
  - LSpec Calibration Results
- Railroad Valley Calibration Results
- IKONOS Observations
- Summary

Purpose

- Quantify how well LSpec (LED Spectrometer) is performing as an unattended vicarious calibration site

LSpec Site

- LSpec is an autonomous vicarious calibration site
  - Located on a dry lakebed on Frenchman Flat at the Nevada Test Site
  - Began operations in Nov 2006
- LED spectrometers monitor surface brightness
  - Converted to reflectance
- Weather station and sun photometer monitor atmosphere
  - Part of AERONET network

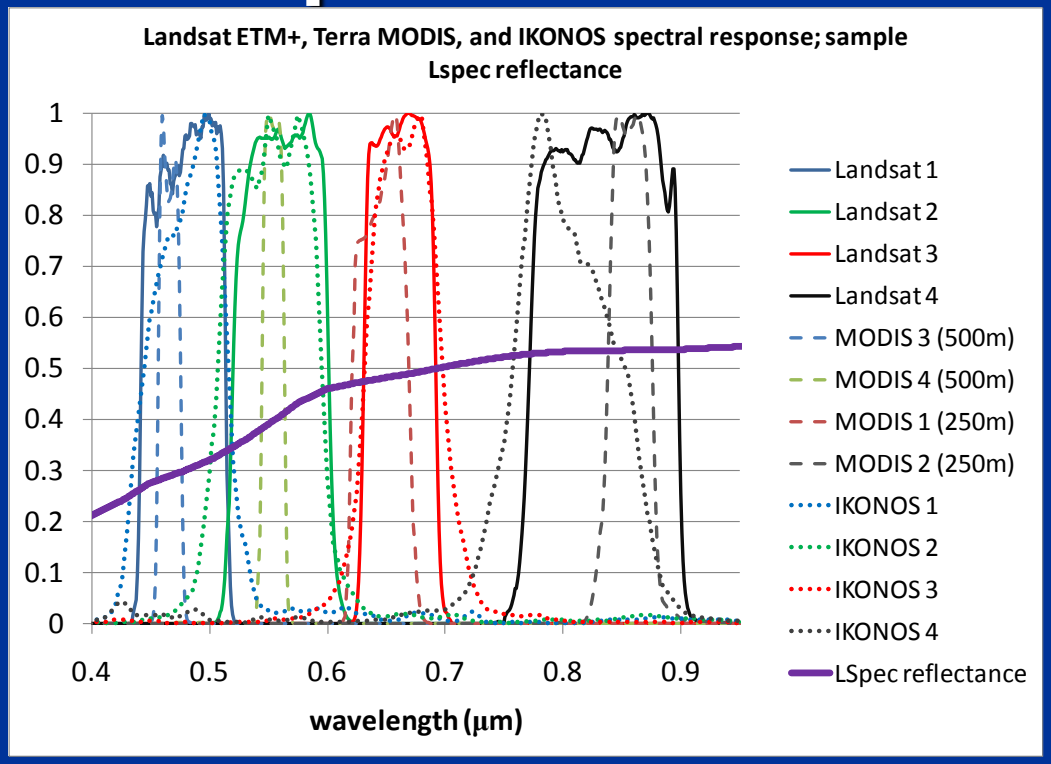


All necessary instrumentation on site

Approach

- Quantify LSpec vicarious calibration performance
  - Metric is NASA Landsat 7 ETM+ and Terra MODIS sensor performance using LSpec
  - Cross-site comparison with Railroad Valley provides additional validation
  - Show utility of LSpec as a calibration site for commercial sensors (e.g. IKONOS)

ETM+/MODIS/IKONOS Comparison

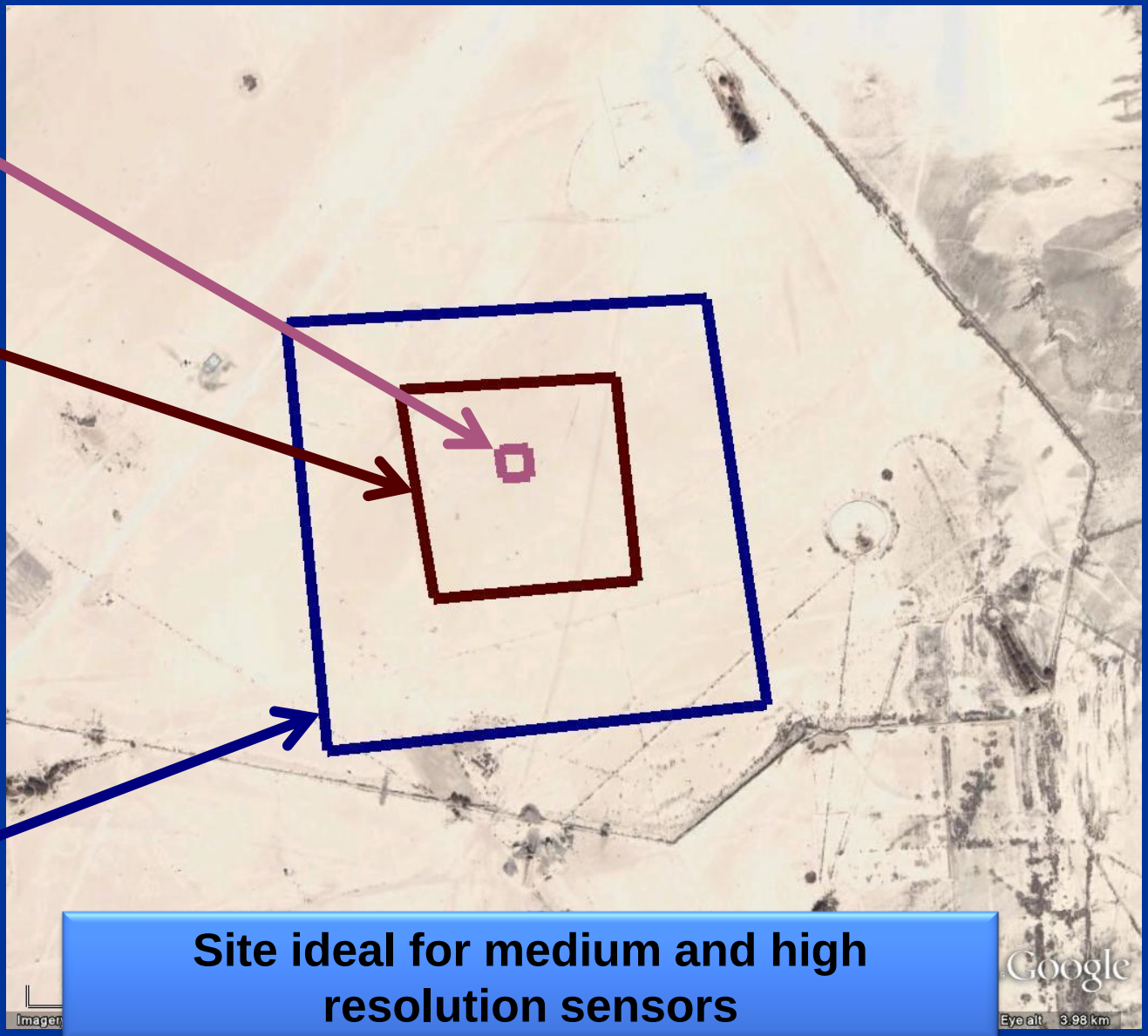


Satellite	Sensor	GSD	Local Time Descending Node	Revisit Time
Terra	MODIS	250-500m	10:30 a.m.	16 days (nadir)
Landsat	ETM+	30m	10:00 a.m.	16 days
IKONOS	MSI	3.2m	10:30 a.m.	3 days

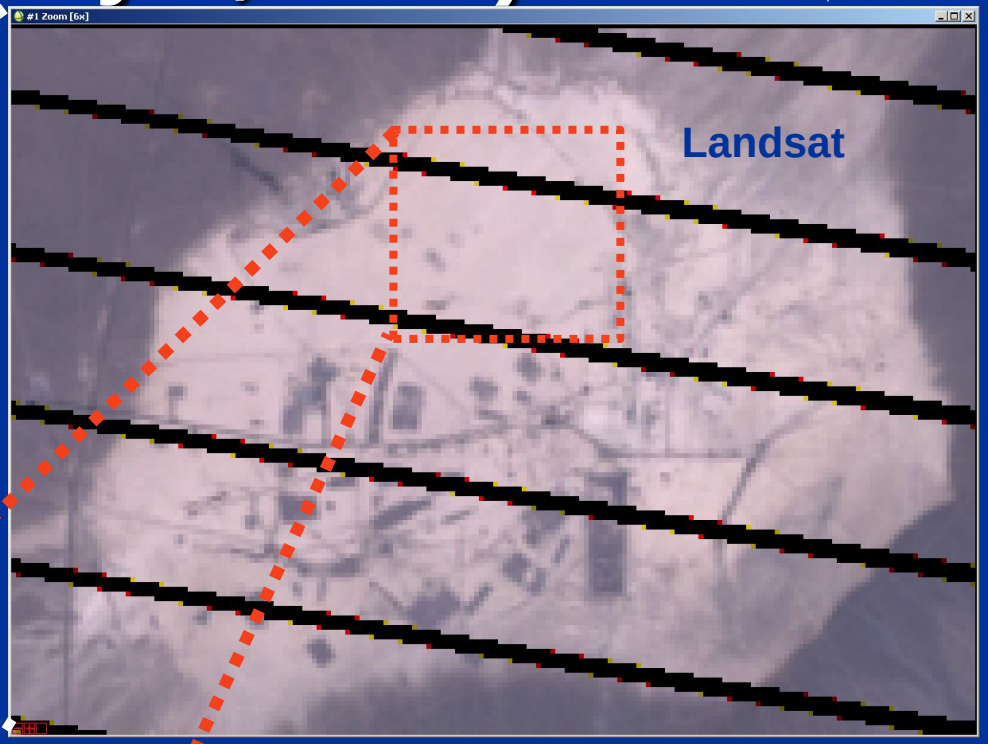
- Sensors are spectrally similar, aside from narrower MODIS bands
- Sensor GSDs differ, but extended playa mitigates the difference
  - LSpec site nominally 300m x 300m
    - Homogeneous to about 500m x 500m
    - 30m x 30m area enclosed by LED Spectrometers
      - Ideal for commercial satellites

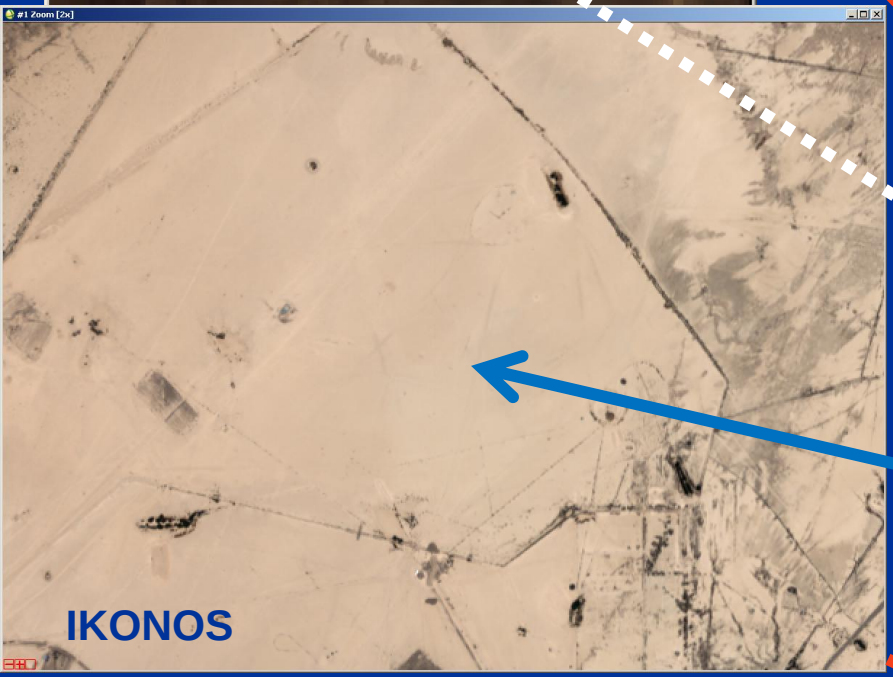
Sensor Footprint Comparison

- 30m x 30m
  - LSpec characterized area; Landsat)
- 250m x 250m
  - MODIS red and NIR bands
- 300m x 300m
  - LSpec site
    - cleared of loose debris, small bushes, and other detritus
- 500m x 500m
  - MODIS blue and green bands



Sample Images (July 6, 2009)

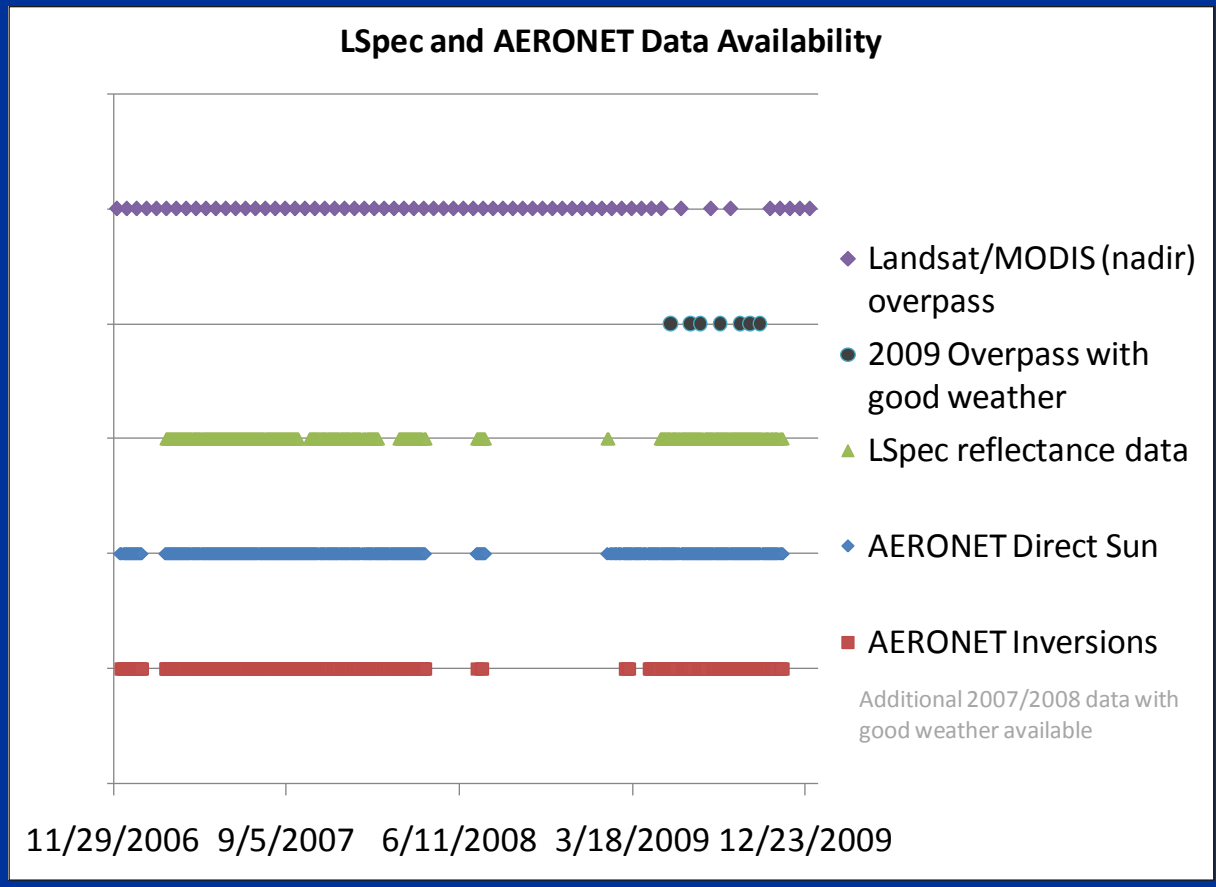




LSpec

LSpec Data Availability

- Playa reflectance measured every 5 minutes
- Direct sun measurements reported every ~15 minutes
  - Spectral aerosol optical thickness
  - Angstrom parameter
  - Column water vapor
- AERONET Inversions reported every hour for solar elevations < 51°
  - Direct sun data plus:
    - Extinction, scattering, absorption coefficients
    - Scattering phase functions



Autonomous collection enables capture of *all* satellite overpasses with good weather

AERONET Data Extrapolation

1:41 PM
1:47 PM
1:57 PM Full AERONET inversion
1:56 PM
2:03 PM
2:05 PM
2:09 PM
2:15 PM
2:21 PM
3:14 PM
3:44 PM
4:41 PM
4:47 PM
5:41 PM
5:56 PM
6:11 PM
6:12 PM Landsat Overpass
6:26 PM
6:35 PM MODIS Overpass
6:41 PM
6:56 PM
7:11 PM
7:26 PM
7:41 PM
8:11 PM
8:26 PM
8:41 PM
9:26 PM
9:41 PM
9:56 PM
10:11 PM
10:26 PM
10:56 PM
11:11 PM
11:26 PM
11:37 PM

05/19/2009

- **Near summer solstice, AERONET Inversions are available only in the morning before the sun gets too high**
- **Extrapolating the inversions with Direct Sun data incurs little error and temporally extends calculated spectral extinction, scattering, absorption coefficients, and scattering phase functions to time of overflight for input parameters into MODTRAN**
- **Earlier and later months have Inversions both before and after imaging, allowing for interpolation**

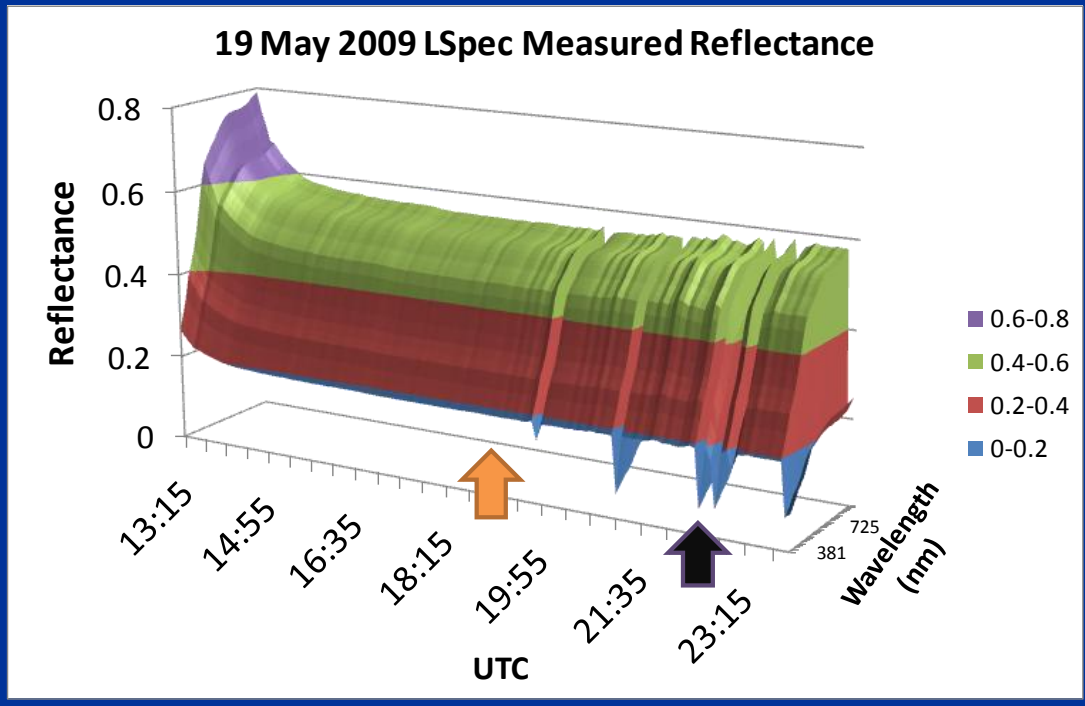
Yellow times (UTC) are AERONET Direct Sun Measurements

08/07/2009

3:17 PM
3:32 PM
3:33 PM Full AERONET Inversion
4:02 PM
4:35 PM
4:50 PM
4:51 PM Full AERONET Inversion
4:56 PM
5:35 PM
5:50 PM
6:05 PM
6:11 PM Landsat Overpass
6:20 PM
6:35 PM
6:35 PM MODIS Overpass
6:50 PM
7:05 PM
7:20 PM
7:35 PM
7:50 PM
8:20 PM
8:35 PM
8:50 PM
9:20 PM
9:35 PM
9:50 PM
10:05 PM
10:35 PM
10:50 PM
10:51 PM Full AERONET Inversion
10:56 PM
11:39 PM
11:40 PM Full AERONET Inversion

LSpec Reflectance – Daily Variations

- All days with spectral reflectance curves were examined to insure no anomalous events
  - Orange arrow indicates time of imaging
  - Black arrow indicates possible clouds occurred later in the day



- Left edge of graph shows increase in reflectance at low solar elevations (<30°)

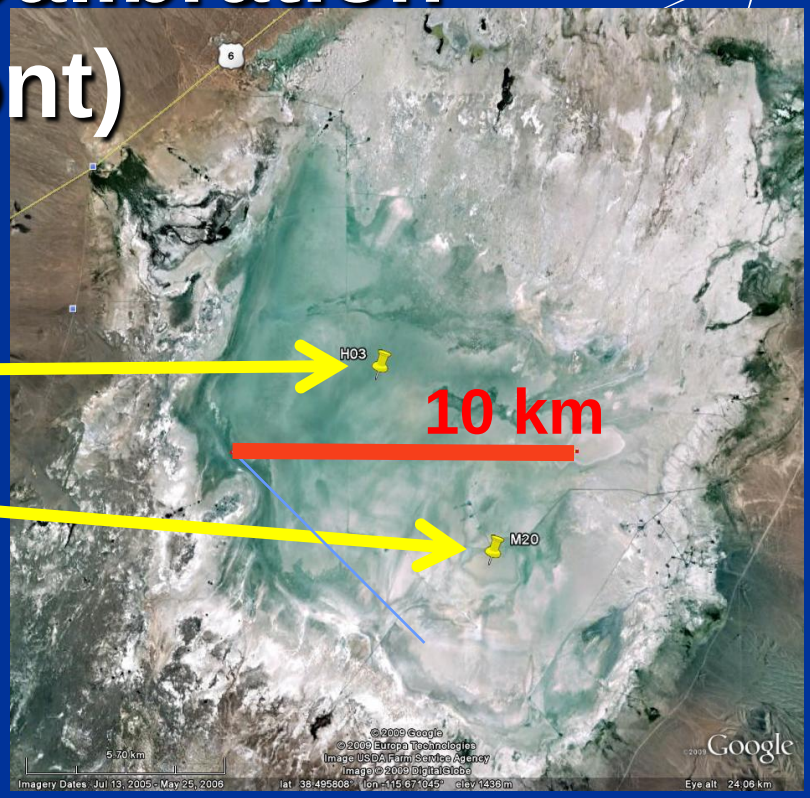
Daily reflectance variations minimal in good weather

GOSAT Vicarious Calibration Field Campaign

- The Railroad Valley (RRV) field campaign was conducted in order to provide a Vicarious Calibration of the GOSAT sensor
  - The Greenhouse gases Observing SATellite (GOSAT) by JAXA, Japan, was built in order to measure global distributions of carbon dioxide from space
  - GOSAT satellite launch: January 23, 2009
  - RRV field campaign dates: June 22-July 6, 2009
  - The field team included members of the JAXA and NASA communities
- Vicarious calibration measurements included
  - Surface reflectance from 350-2500 nm, using three ASD FieldSpecPro spectrometers
  - Atmospheric (aerosol) characterization using Cimel, Reagan, and microtops sunphotometers
  - Water vapor, pressure, and temperature profiles using radiosonde

GOSAT Vicarious Calibration Field Campaign (cont)

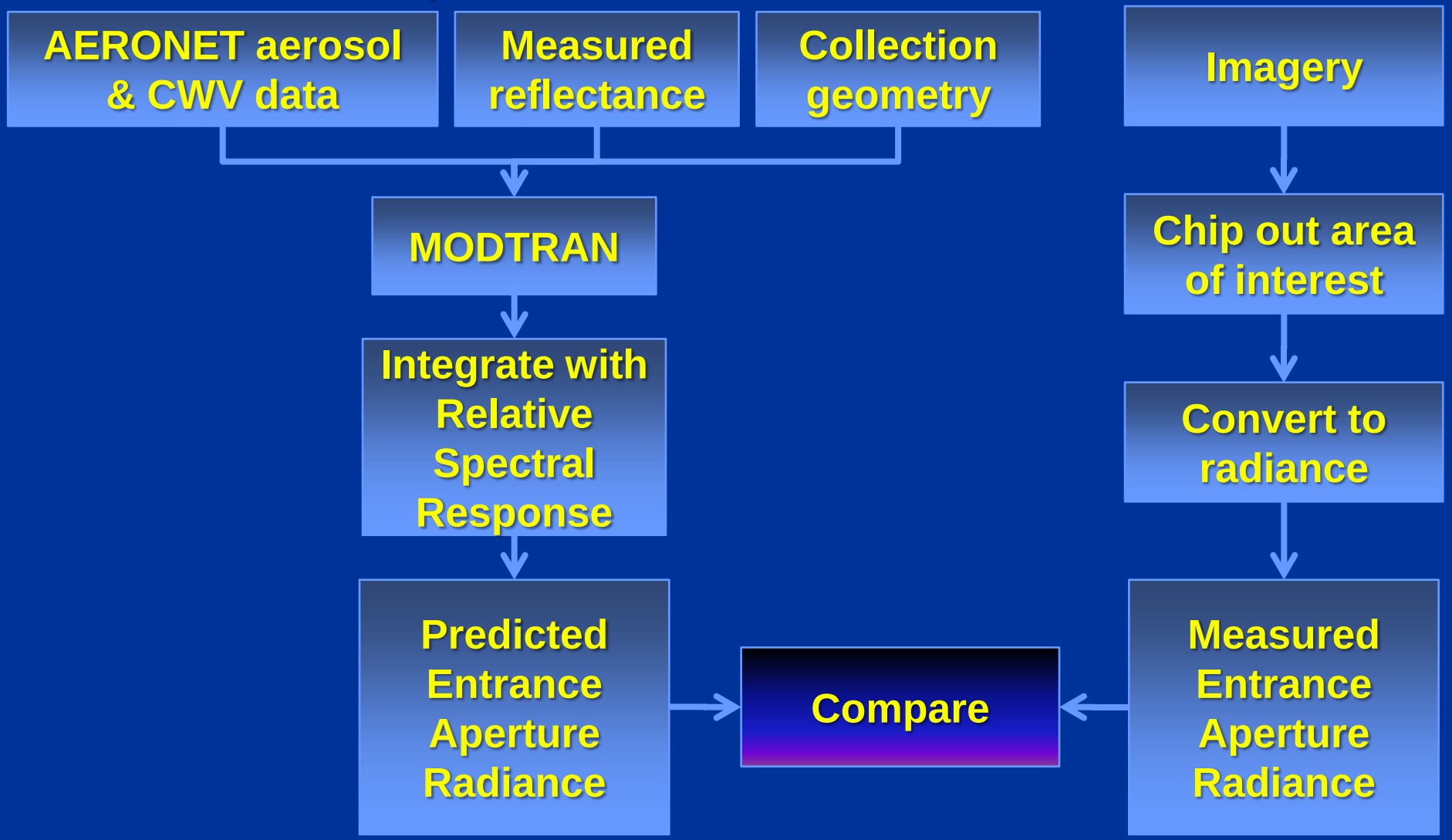
- Reflectance data taken at two sites on July 5, 2009
  - H03
  - M20
- Landsat 7, Terra MODIS, and IKONOS all collected images morning of July 6



  - Landsat and MODIS were nadir collects
  - IKONOS 15° off nadir
- University of Arizona RRV AERONET site data used
  - Inversion data extrapolated to time of imaging using Direct Sun data

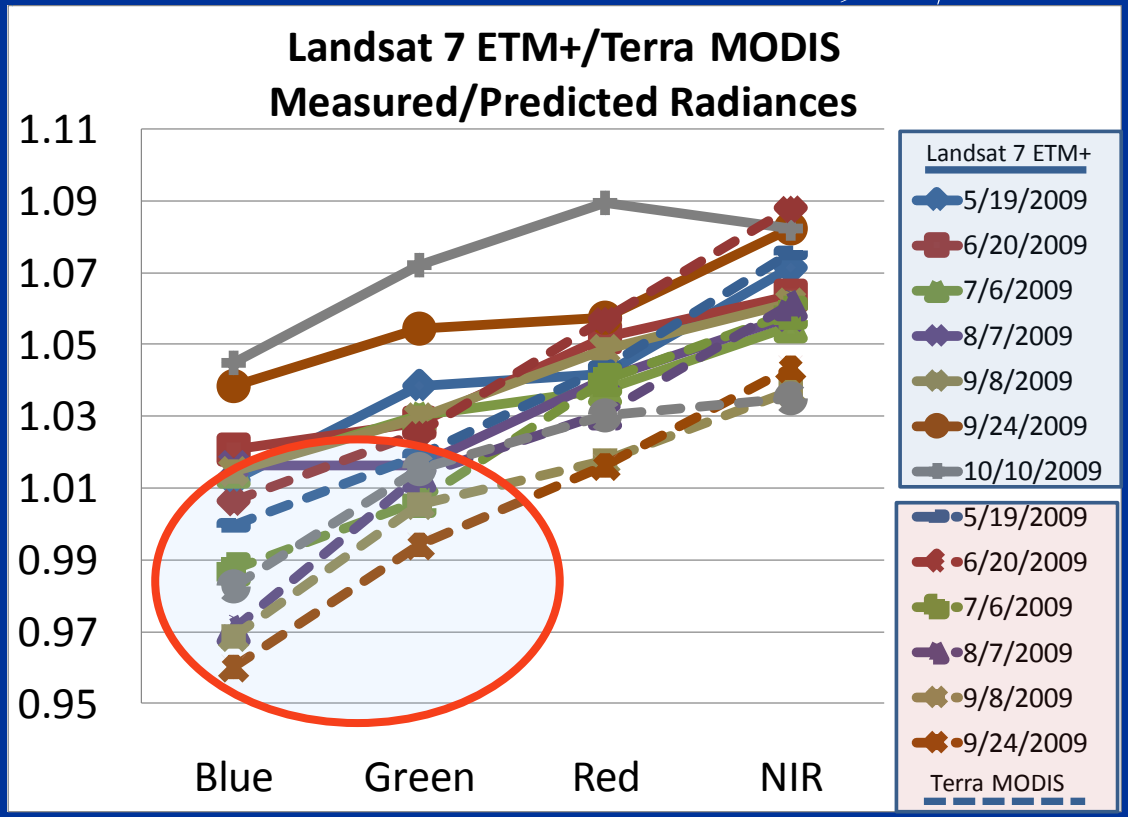
Data Analysis

- For each sensor, for each band:



LSpec Results

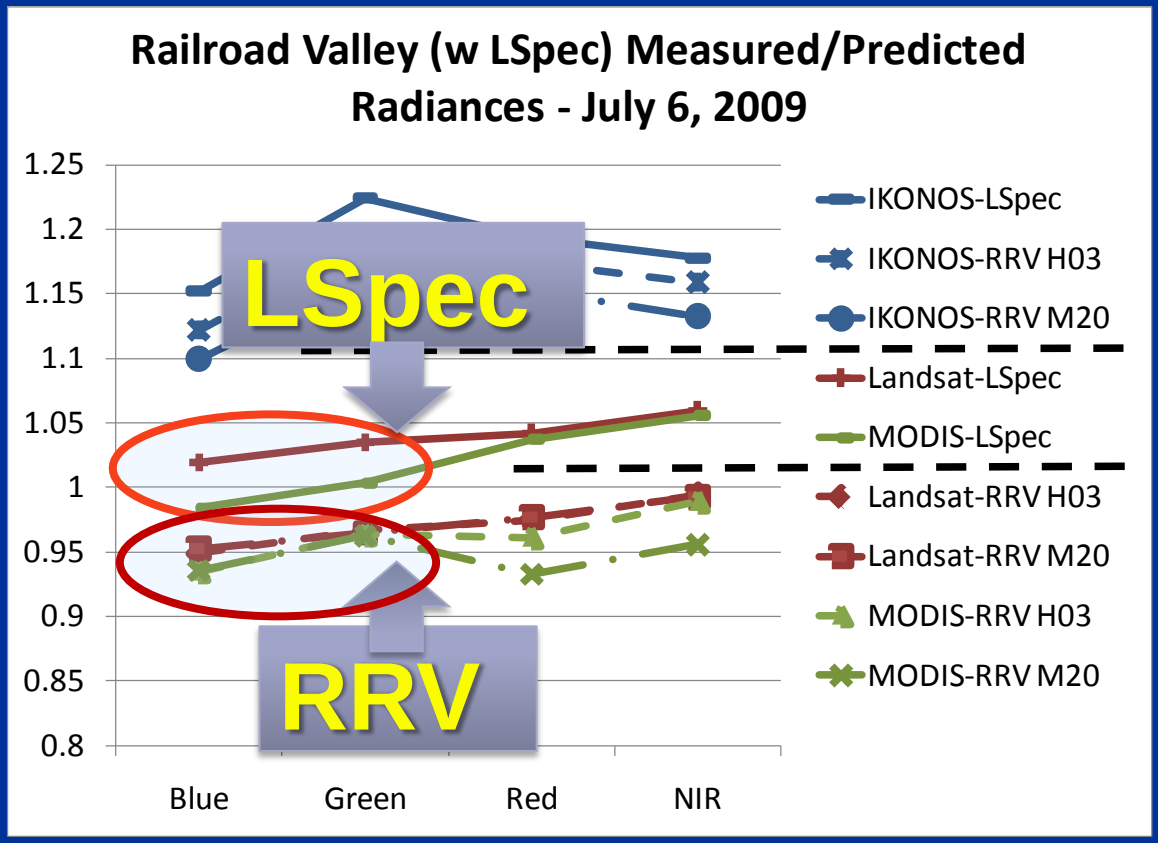
- Spread in dates introduces meteorological diversity
  - Reduces random error in the mean
- Similar, consistent spectral shape for Landsat and MODIS
  - Suggests slope is significant
  - Assessing reflectance versus atmospheric data as source



- Cross-calibration excellent in Red and NIR for first five dates
  - <2.5%, sensor-to-sensor, by date
  - Slight Landsat divergence on last two dates
  - Lower measured responses in MODIS Blue and Green bands may be due to larger GSD

Railroad Valley Results

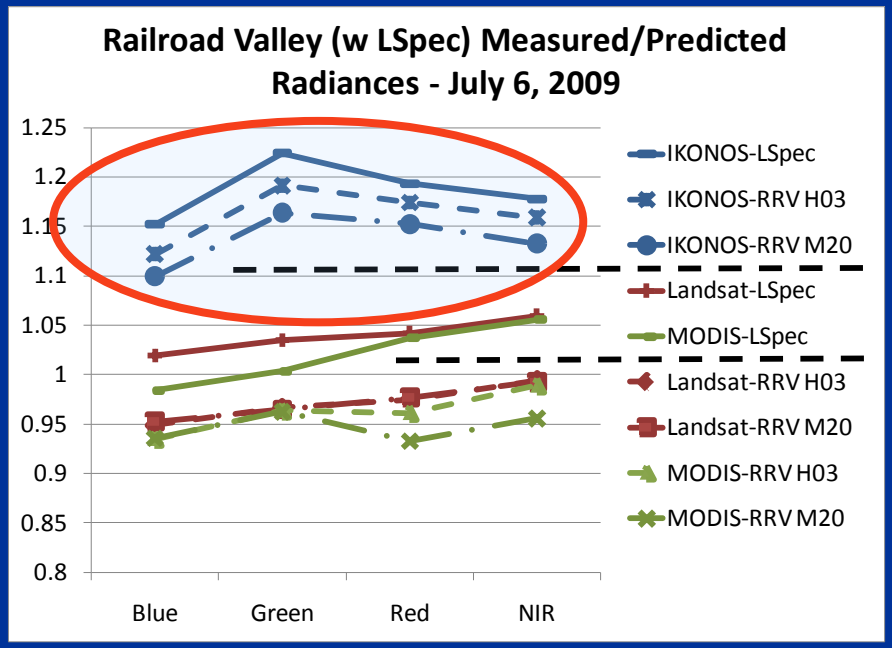
- LSpec consistently calibrates about 5% higher than Railroad Valley
  - Unable to definitively say which is better
  - Larger data set for LSpec being acquired



- Divergence in MODIS Blue and Green bands for LSpec not seen in larger surface of Railroad Valley
  - Different divergence seen in Red and NIR bands

Railroad Valley Results - IKONOS

- Stennis calibration results (2001-2004)[1] had positive bias in NIR band
  - about 6% of background
    - Possibly due to extended vegetative background
- Comparison of University of Arizona RRV results to Stennis and SDSU results show positive radiometric biases (up to 7%, primarily in the green and red)[2]
- This study showed positive biases relative to ground truth, MODIS and ETM+ of up to 20%
  - Bias had same spectral shape as above, earlier study



- GeoEye (Martin Taylor) reports large positive radiometric bias in darker areas of an image when adjacent to large bright areas.
- Current hypothesis is stray light
  - Definitive confirmation requires calibration experiments specifically designed to find such interference

Summary

- LSpec autonomous concept shows promise as a vicarious calibration site
  - Cross-calibration within 2.5% uncertainty
  - 5% bias above Railroad Valley results
    - Continuing to investigate
- Methodology used is applicable to aircraft and other commercial remote sensors
  - Can augment existing calibration studies
- Path forward is to continue to validate site with well-calibrated sensors
  - Data continues to be acquired and analyzed