Radiometric Validation of Landsat 8 OLI and Sentinel-2A MSI Using the Radiometric Calibration Test Site (RadCaTS)

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Outline

- Vicarious radiometric calibration
  - Remote Sensing Group (RSG) progression from manned to automated measurements
  - Radiometric Calibration Test Site (RadCaTS) at Railroad Valley
- Atmospheric and surface reflectance instrument transition
- Results for Landsat 8 OLI and Sentinel-2A MSI
- Future work

Vicarious calibration

- Vicarious calibration
  - In situ measurements
  - Lunar observations
  - Pseudo-invariant calibration sites (PICS)
  - Cross calibration
- U. Arizona Remote Sensing Group has been using reflectance-based approach for ~25 years
  - Combination of surface reflectance and atmospheric measurements
  - Radiative transfer code to determine atmospheric transmission
- 'Recent' effort includes migration to automated test site approach
  - U. Arizona operates RadCaTS at Railroad Valley, Nevada
  - Member of RadCalNet working group for global instrumented cal sites

Reflectance-based approach

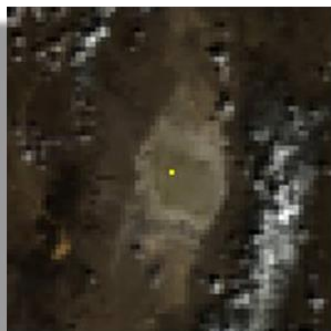
Measure site: atmospheric data

Measure site: reflectance data

MODTRAN5

Compute TOA spectral radiance

Average site radiance derived from image data
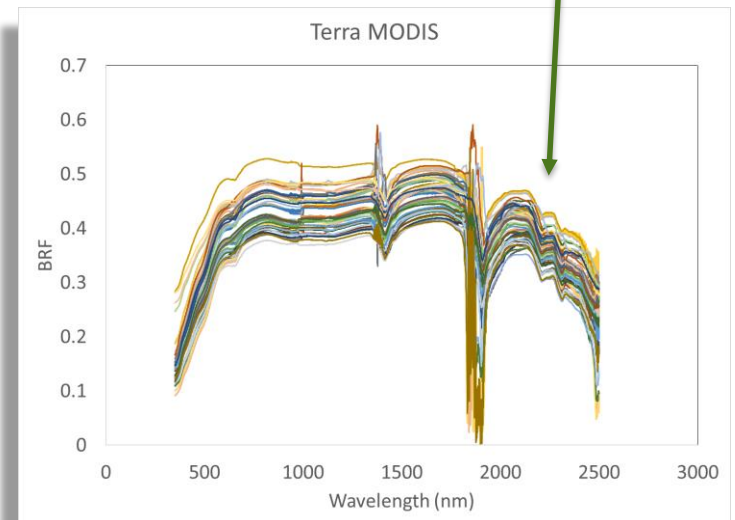
Calibration of sensor's spectral bands

Test sites

- **Recent test sites**
  - Alkali Lake, Nevada
  - Railroad Valley, Nevada
  - Ivanpah Playa, California
  - Red Lake, Arizona
- **Previously used test sites**
  - White Sands Missile Range
  - Pima County Fairgrounds (asphalt parking lot)

- **Typical Surface BRF**
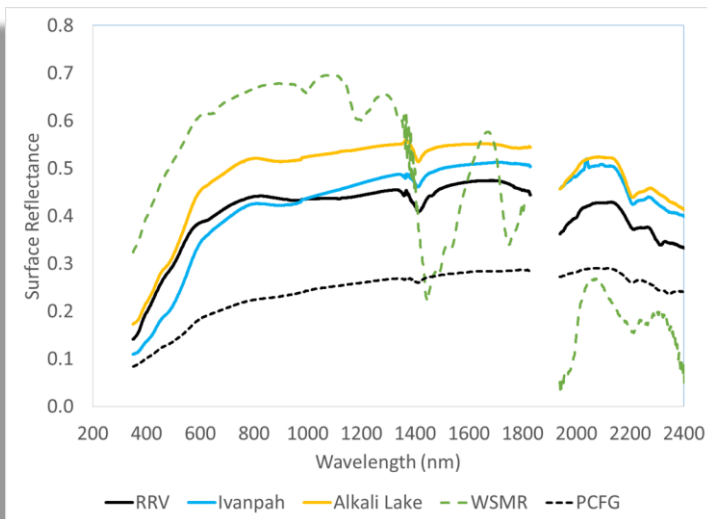
Not PICS, must be measured!
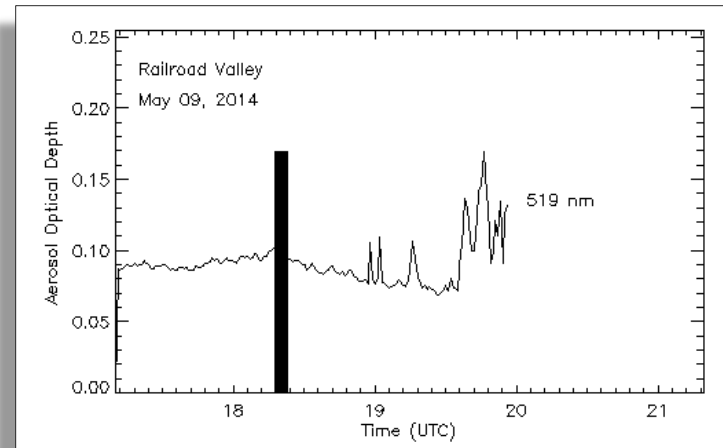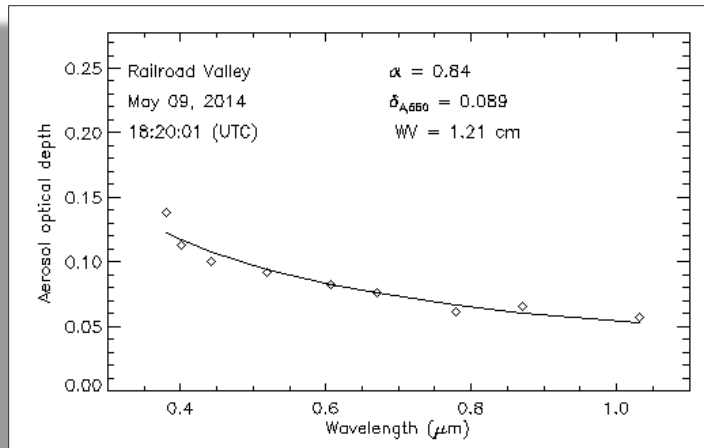
Seasonal variability

Atmospheric measurements

- U. Arizona has traditionally used an Automated Solar Radiometer (ASR) to measure attenuated solar irradiance

- 10 channels (380, 400, 411, 520, 611, 670, 780, 870, 940, and 1030 nm)

- Auto tracking of sun throughout day

- Ancillary equipment

  - Global irradiance (VNIR and broadband)

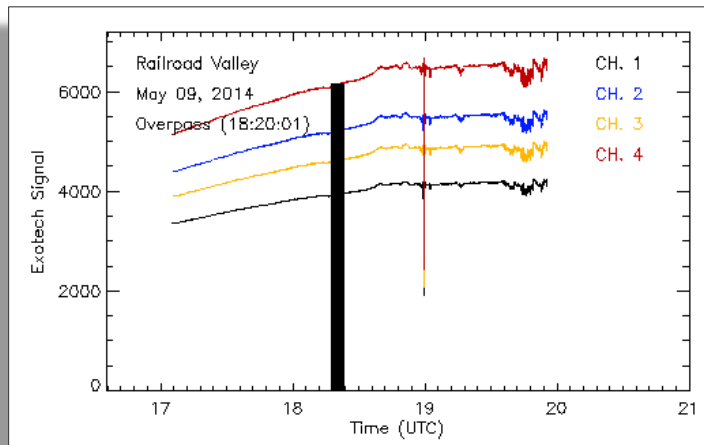 - Line-of-sight [to sensor] radiometer (LOSR)

  - Temperature and pressure

Atmospheric measurements

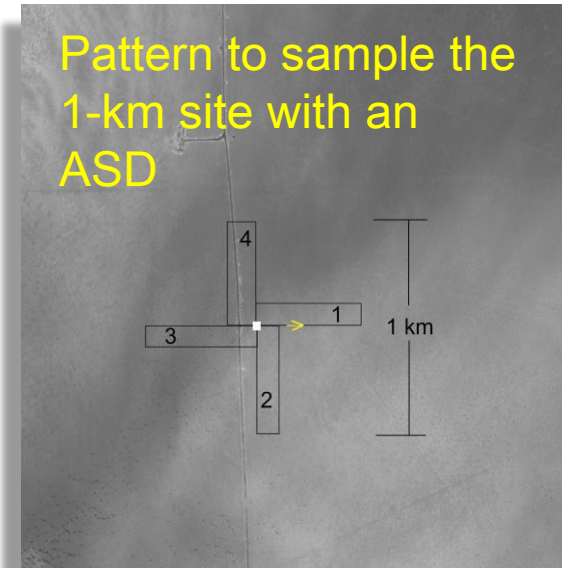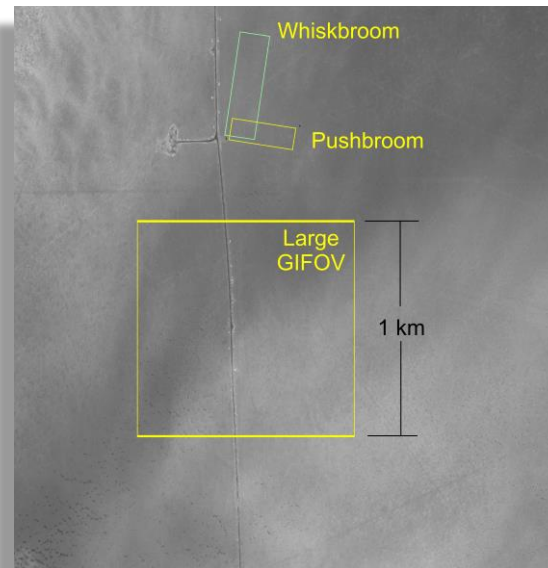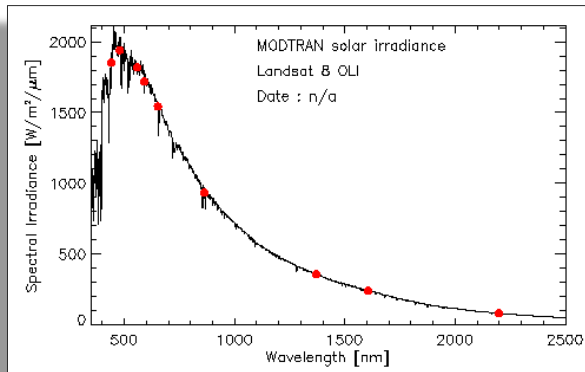- An example of a Landsat 8 OLI overpass at Railroad Valley

AOD at overpass

Railroad Valley
May 09, 2014
18:20:01 (UTC)
$\alpha = 0.84$
$\delta_{A550} = 0.089$
WV = 1.21 cm

AOD$_{520}$ vs. time

Railroad Valley
May 09, 2014
519 nm

Global irradiance

Railroad Valley
May 09, 2014
Overpass (18:20:01)
CH. 1
CH. 2
CH. 3
CH. 4

18:20 UTC

Surface reflectance

- Performed during overpass time
- User walks in predetermined pattern based on site and sensor
- ASD carried in nadir-viewing configuration
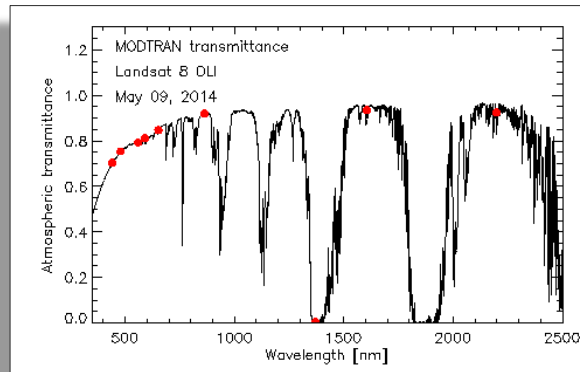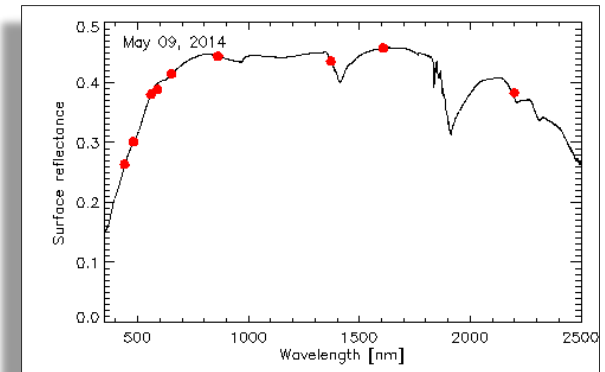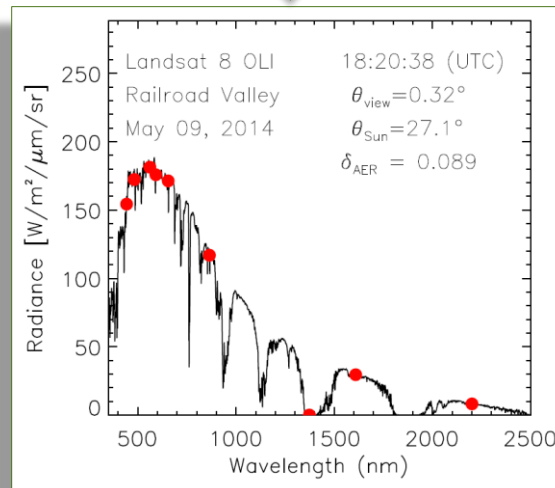- Panel measurements are made every few transects

Whiskbroom

Pushbroom

Large GIFOV

1 km

Pattern to sample the 1-km site with an ASD

4

3   1

2

1 km

MODTRAN

E_0

Atmo. Trans.

Surface Refl.

At-sensor
spectral radiance

MODTRAN

Automation of vicarious calibration

- Recent emphasis of U. Arizona work has been to further develop the Radiometric Calibration Test Site (RadCaTS) concept

- Development began ~2002

- Modelled on reflectance-based approach

- No on-site personnel required

- Requires measurements of surface reflectance and atmosphere
  - AERONET Cimel sun photometer
  - Ground-viewing radiometers (GVRs)
    - Developed by RSG
    - 8 channels (Si and InGaAs detectors)
    - Temperature-controlled detectors
  - Currently 4 GVRs on site, more in development
  - Previous studies to determine number/location of GVRs

GVR channels
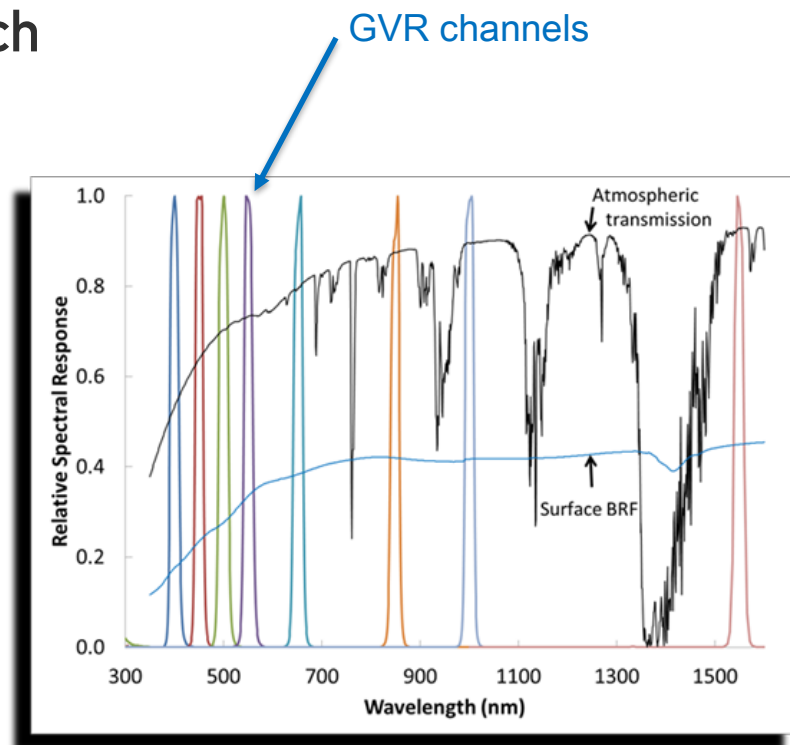
RadCaTS atmospheric measurements: Cimel sun photometer

- U. Arizona has operated an AERONET Cimel sun photometers at Railroad Valley for ~15 years
  - #15 and #314
  - Swapped for calibration at NASA GSFC
- RadCaTS uses AERONET data products
  - Aerosol optical depth
  - Angstrom exponent
  - Water vapor
- Assume spectral aerosol optical depths can be described using Junge distribution
- Ozone: OMI
- Met station: temperature, pressure, humidity, wind, global irradiance
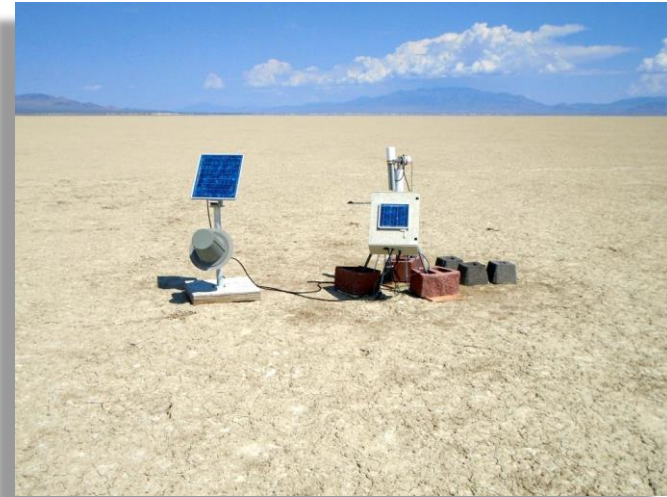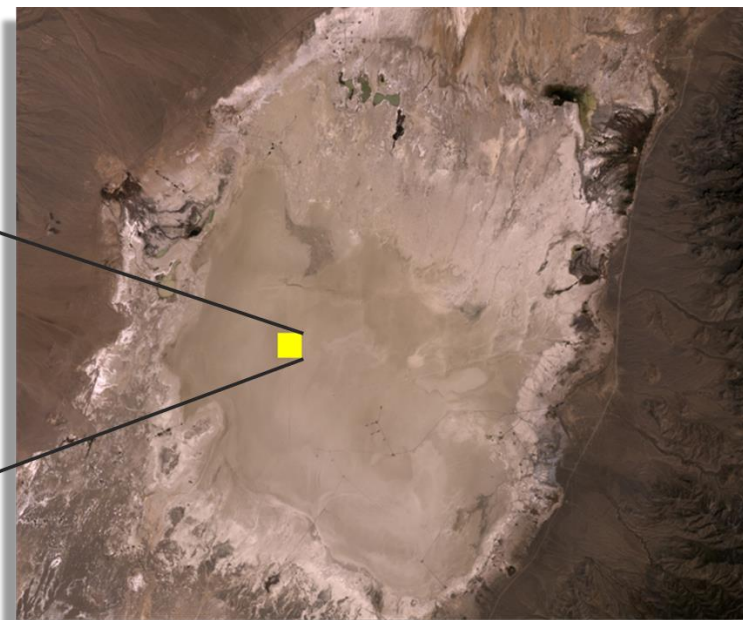
Surface reflectance: RadCaTS

- **Radiometric Calibration Test Site (RadCaTS)**
- **Surface reflectance**
  - 4 ground-viewing radiometers (GVRs)
  - 8-channel multispectral instrument
  - Temperature controlled
  - Full laboratory calibration and characterization

Atmosphere
- AERONET Cimel
- Meteorological station

GVR channels

1 km

Road

GVR
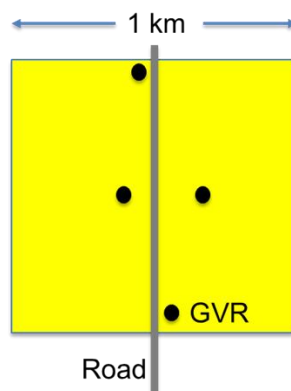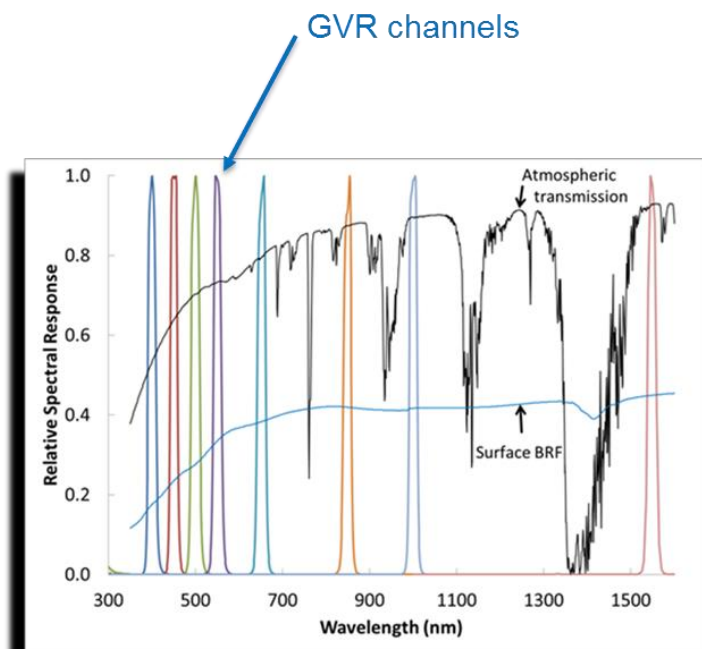
GVR Development

GVR 23
1320 m to base station

GVR 24
775 m to base station

WiFi

Head weatherproofing

WiFi
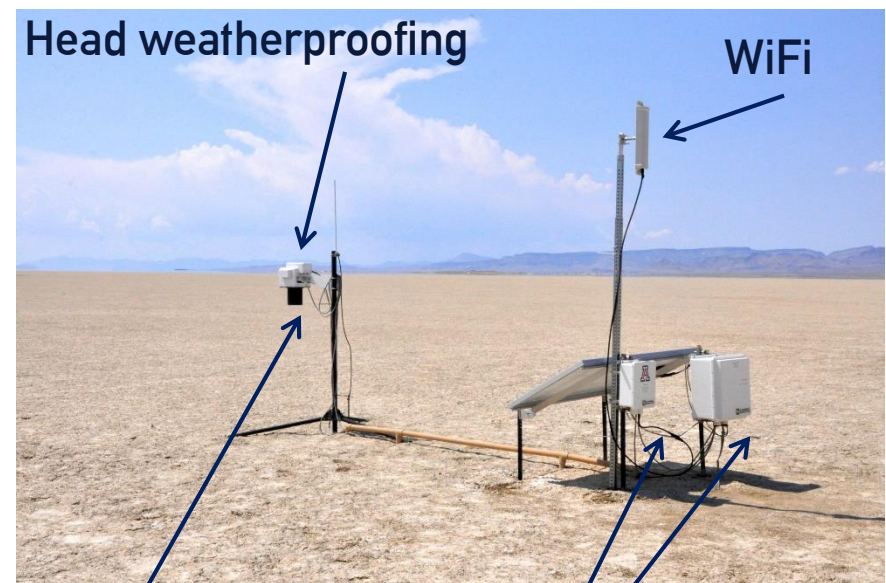
Scattered light reduction

Protective nose

Satellite uplink: daily data

- GVRs collect data every 2 minutes throughout the day and night
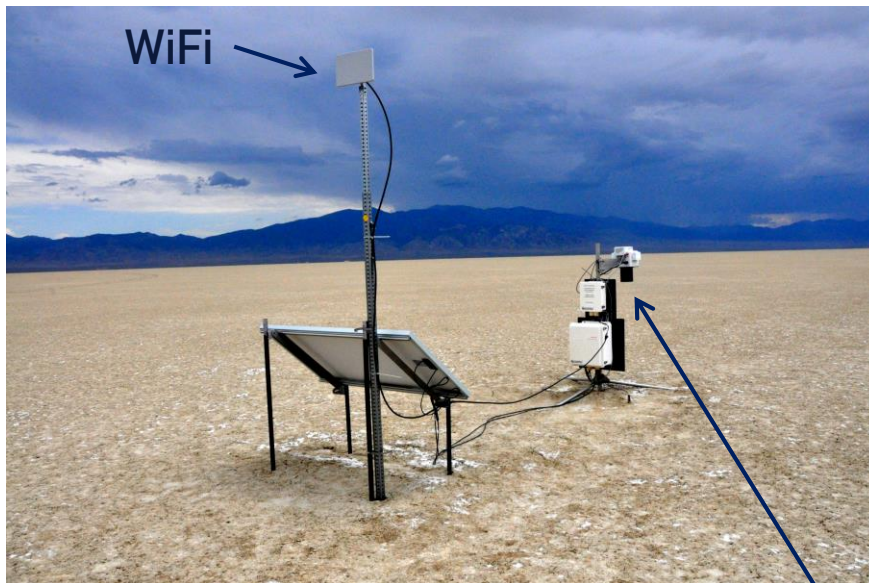
- TE controller operates during clear-sky conditions

- Met station collects temperature and pressure data every 2 minutes, other data collected every 60 minutes

- Data are uploaded to Tucson every afternoon

- Processing done on case-by-case basis (RadCaTS) and automatically (RadCalNet)

Landsat 8 OLI and Sentinel-2A MSI

- ## Landsat 8 OLI period of study
  - (2013 – 2015) Overpasses: 61
  - (2013 – 2015) Successful collects: 13
  - View angle: ~nadir

- ## Sentinel-2A MSI period of study
  - (2015) Overpasses: ~18
  - (2015) Successful collects: 5 (RadCaTS), 1 (on-site personnel)
  - View angles: 6° and 11°

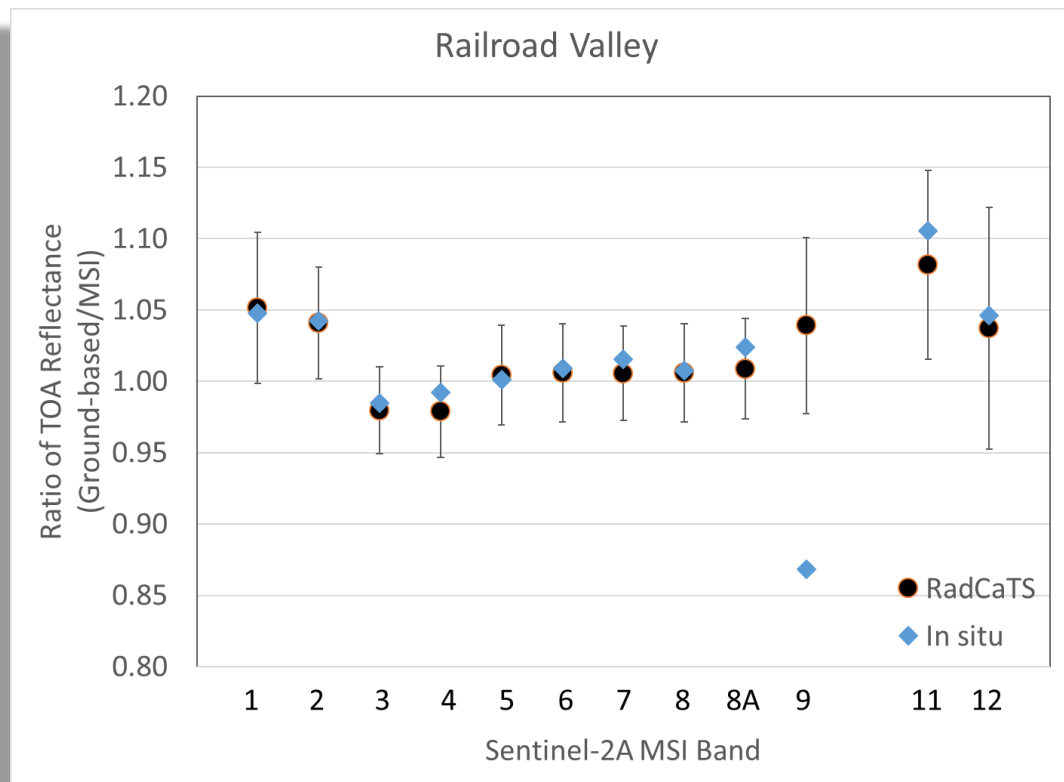- Ground results compared to TOA reflectance from each sensor

Results

- **Comparison to TOA reflectance**
- **Uncertainty bars are 1σ standard deviation of measurements**
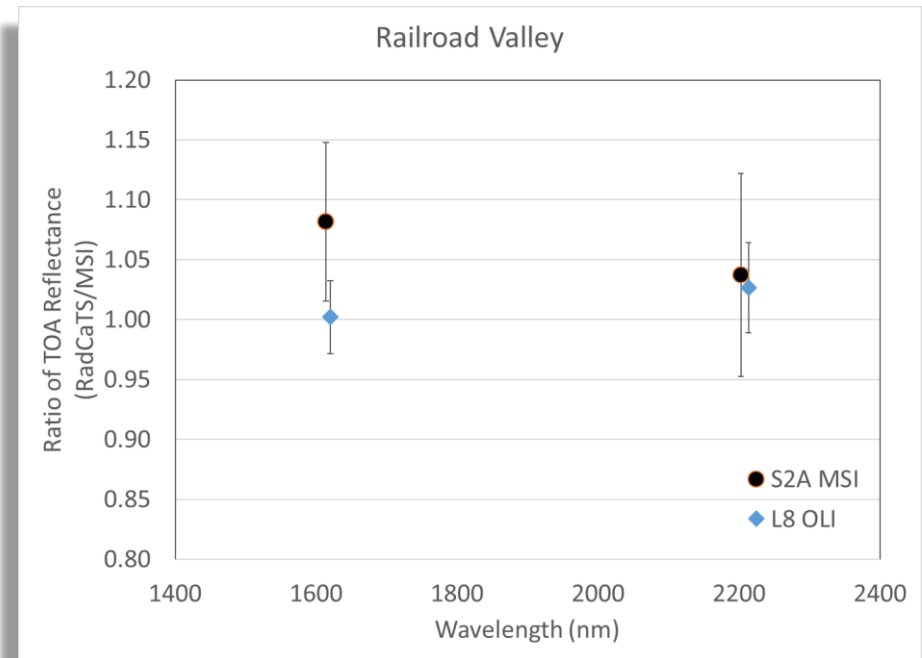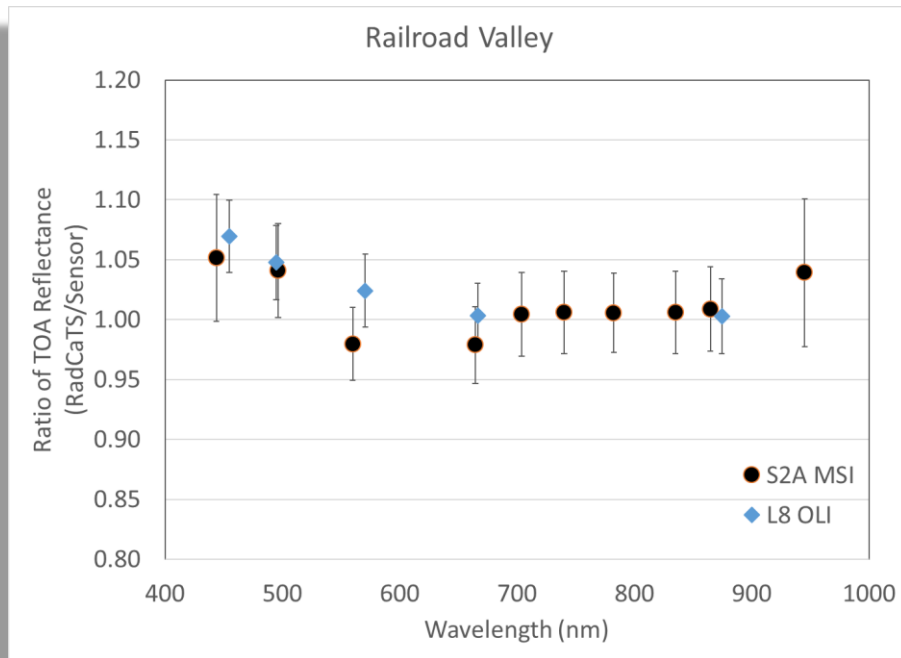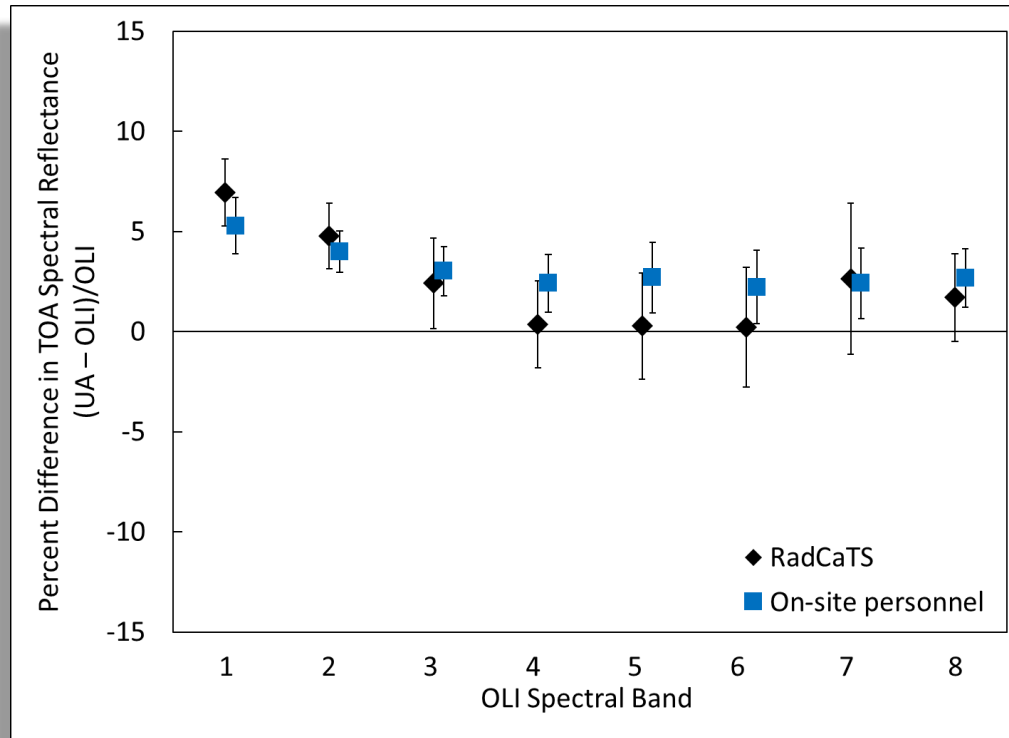
S2A MSI Results

- 4 RadCaTS dates   (1-km^2 site)
- 1 reflectance-based date   (80 x 300-m site)
- Uncertainty bars are 1σ standard deviation of measurements

Railroad Valley

Results

- Landsat 8 OLI results using two methods: RadCaTS and on-site personnel with ASD, solar radiometer, etc.

Future work

- Development of new GVR
- Development of portable transfer radiometer for automated test site radiometer calibration
- Analysis of diffuse irradiance retrieval
- Continue to assist NPL with RadCaTS uncertainty analysis
- Automated processing and integration with NASA web portals
- RadCaTS will continue to be used to cal/val:
  - Landsat 8 OLI and Landsat 7 ETM+
  - Terra and Aqua MODIS, MISR, and ASTER
  - RapidEye
  - SNPP VIIRS
  - Sentinel-2A
  - GeoEye, WorldView-2, -3 (and -4...)
- Participation in CEOS WGCV RadCalNet
  - Intercomparison of instrumented test sites (USA, France, China, and Namibia)
  - Harmonization of ground-based radiometric calibration

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- We would also like to thank Brent Holben and AERONET for processing the Railroad Valley Cimel data

Thanks!

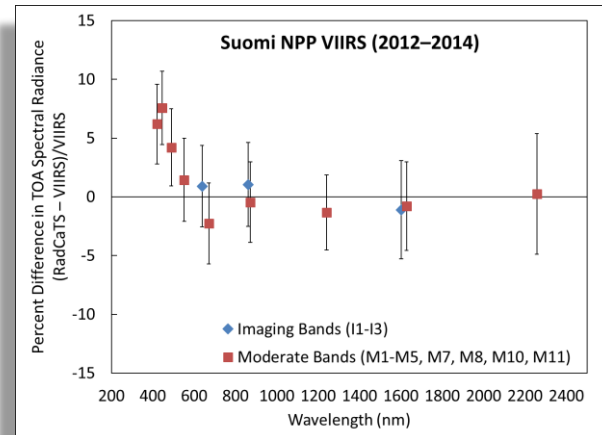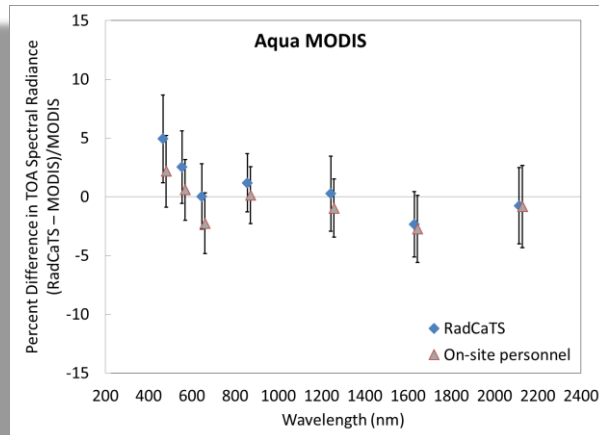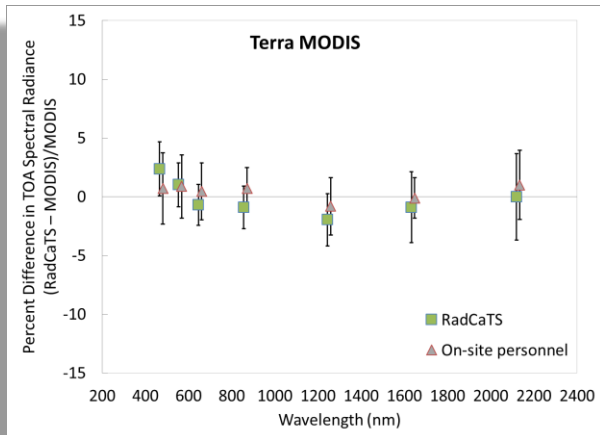- Questions?

Extra slides

Other Examples of RadCaTS results

- MODIS and VIIRS: automated RadCaTS (2012–2014)
  - Terra MODIS   Aqua MODIS   SNPP VIIRS
  - 30 overpasses   24 overpasses   42 overpasses

TOA Spectral Radiance Comparison

MODIS land bands (1–7)

RadCaTS surface reflectance validation results

- Landsat 8 OLI, MODIS, and VIIRS surface reflectance validation: automated RadCaTS (2012–2014)

Surface Reflectance Comparison