College of Optical Sciences THE UNIVERSITY OF ARIZONA

THE ABSOLUTE RADIOMETRIC CALIBRATION OF EARTH-OBSERVING SENSORS USING RADCATS

Jeffrey Czapla-Myers[1], Nikolaus Anderson[1], Joel McCorkel[2], and Kurtis Thome[2]

[1] Remote Sensing Group
College of Optical Sciences
University of Arizona
Tucson, Arizona, USA

[2] NASA GSFC
Greenbelt, Maryland, USA

JACIE 2015, 5–7 May 2015, Tampa, Florida, USA

TOPICS

- Vicarious calibration
- Radiometric Calibration Test Site (RadCaTS) at Railroad Valley
- Field work: 2012–2014
- CEOS WGCV Radiometric Calibration Network (RadCalNet)
- Future plans

VICARIOUS RADIOMETRIC CALIBRATION

- Vicarious calibration provides an independent assessment of sensors post launch
  - Radiometric calibration
  - Validation of data products such as surface reflectance
  - Validation of atmospheric correction codes
  - Methods: *in situ* measurements, PICS, moon, cross calibration
- Remote Sensing Group (RSG) at University of Arizona has traditionally used ground-based *in situ* measurements for vicarious calibration
- Reflectance-based approach
  - Measurements of surface reflectance
  - Measurements of atmosphere
  - Currently using MODTRAN 5.3.2 radiative transfer code
  - Prediction of TOA quantities (e.g. reflectance or spectral radiance)
  - Validation of surface reflectance product
- Focused effort to develop the Radiometric Calibration Test Site (RadCaTS)
  - Automated radiometric calibration
  - Goal: collect all clear-sky overpasses for sensors under test

THE RADIOMETRIC CALIBRATION TEST SITE (RADCATS)

- Concept similar to Lake Tahoe validation site
- Collection of data in absence of personnel
- Originally designed for large-footprint sensors (e.g. MODIS)
- Currently being used for sensors with 1–1000-m footprints

- Current status:
  - 4 ground-viewing radiometers
  - 1 Cimel sun photometer
  - 1 meteorological station

CURRENT RADCATS WORK

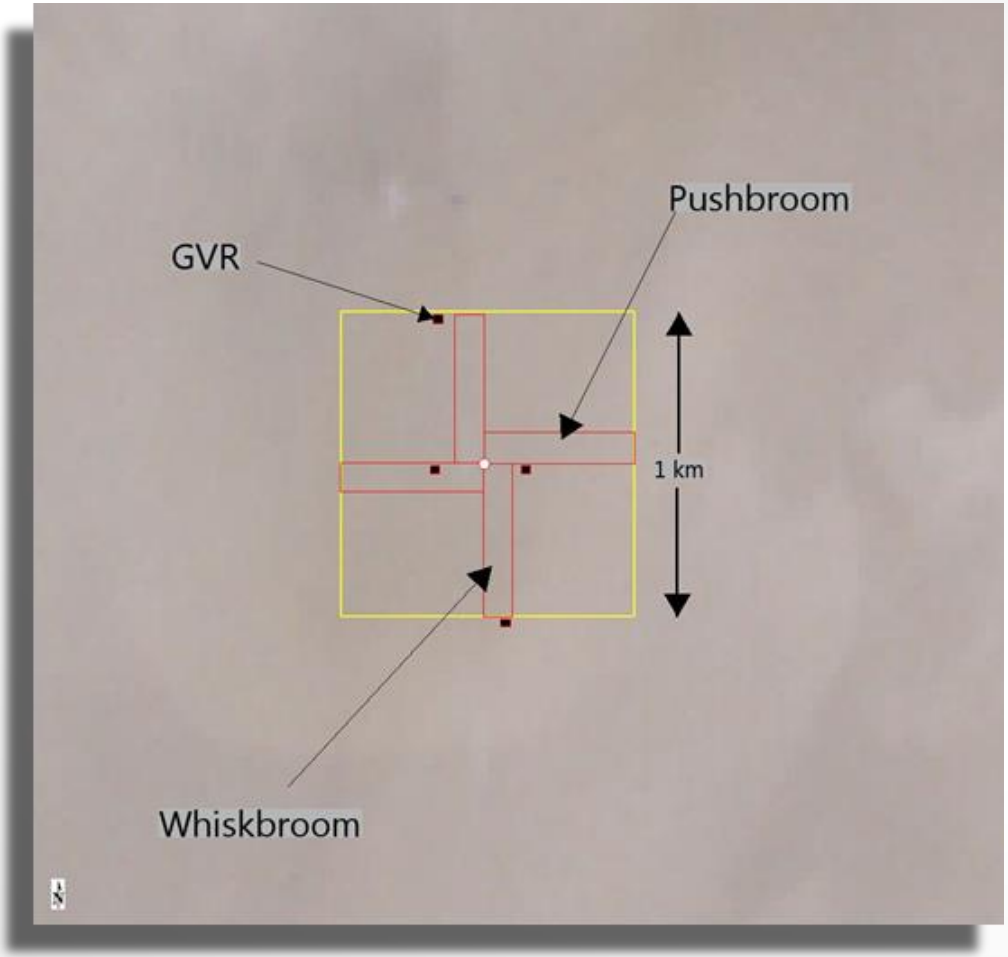
- Landsat 7 & 8, MODIS, MISR, ASTER, SNPP VIIRS
- RapidEye and WorldView (results next year…)

	Center Wavelength (nm)				
Band	**L7 ETM+**	**L8 OLI**	**MODIS**	**MISR (An camera)**	**ASTER**
1	478.7	443.0	645.7	445.4	554.0
2	561.0	482.6	856.3	557.6	661.1
3	661.4	561.3	466.1	671.9	807.1
4	834.6	654.6	553.9	866.5	-
5	1650.3	864.6	1242.1	-	-
6	Thermal	1609.1	1628.6	-	-
7	2208.1	2201.2	2113.7	-	-
Pixel (m)	30	30	250, 500, 1000	375	15

	Center Wavelength (nm)	
Band	**SNPP VIIRS (I)**	**SNPP VIIRS (M)**
1	638.3	420.8
2	861.5	445.7
3	1601.1	489.5
4	-	552.0
5	-	671.1
6	-	745.0
7	-	861.7
8	-	1240.5
9	-	1375.2
10	-	1601.9
11	-	2257.2
Pixel (m)	375	750

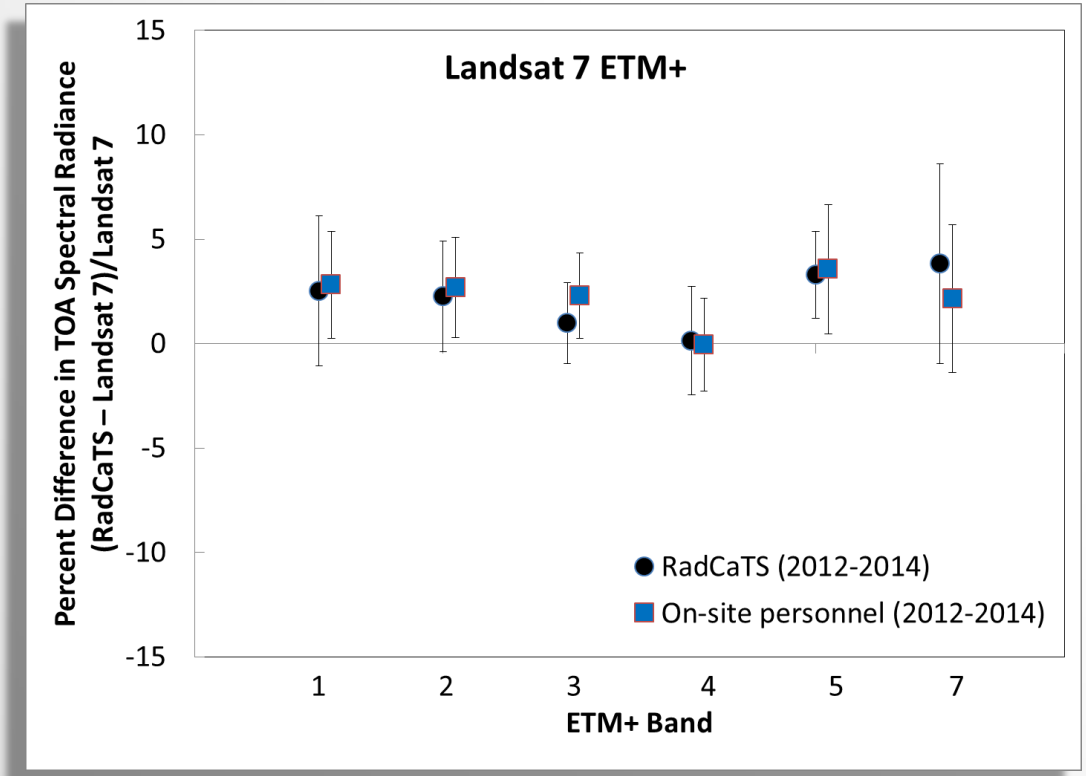
CURRENT RESULTS USING RADCATS

- Timeline: 2012–2014
- Successful collects:
  - Terra: 46
  - Aqua: 35
  - Landsat 7: 18
  - Landsat 8 (2013–2014): 9
  - SNPP VIIRS: 42
- Region of interest is 1 km^2



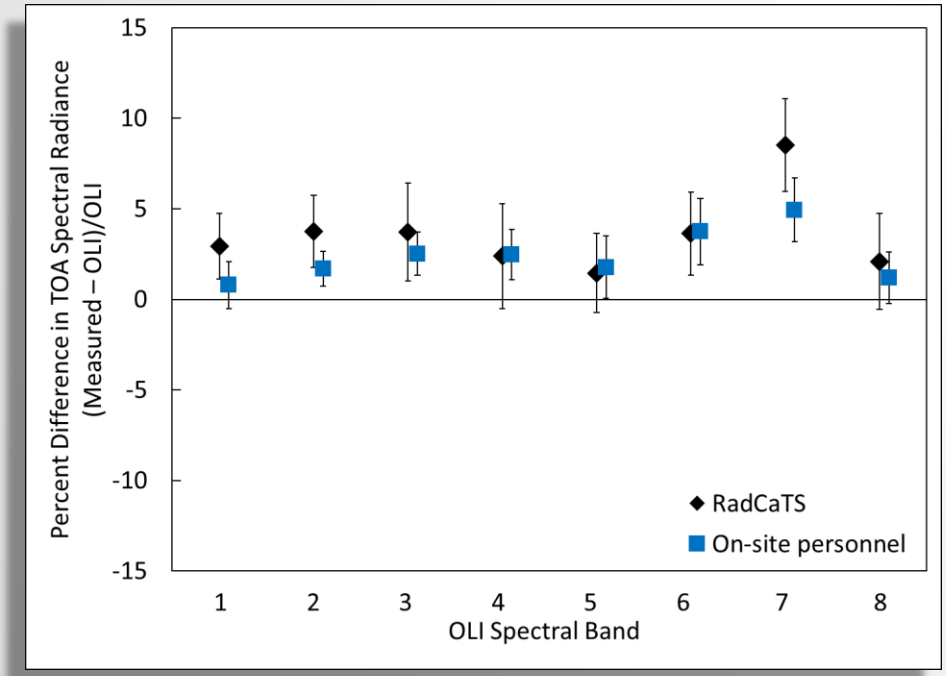
LANDSAT 7 ETM+

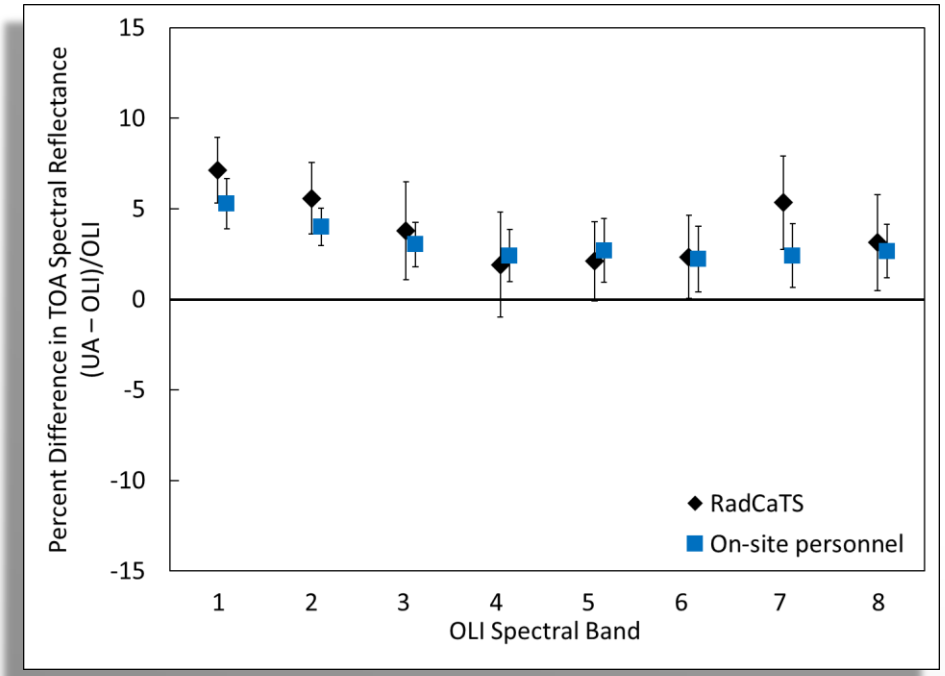
- RadCaTS and in situ results
- L1T product from USGS



LANDSAT 8 OLI

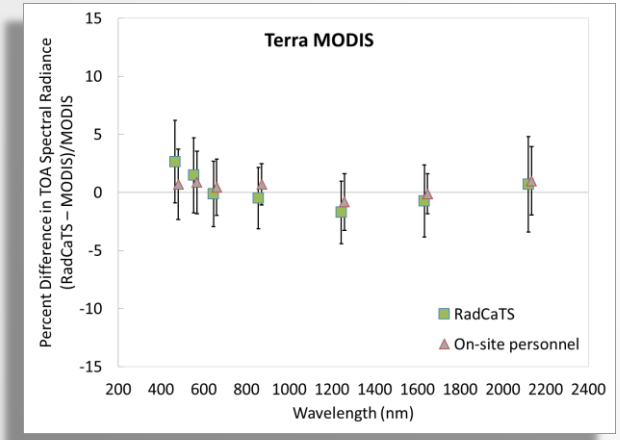
- RadCaTS and in situ results for TOA spectral radiance and reflectance
- L1T product from USGS

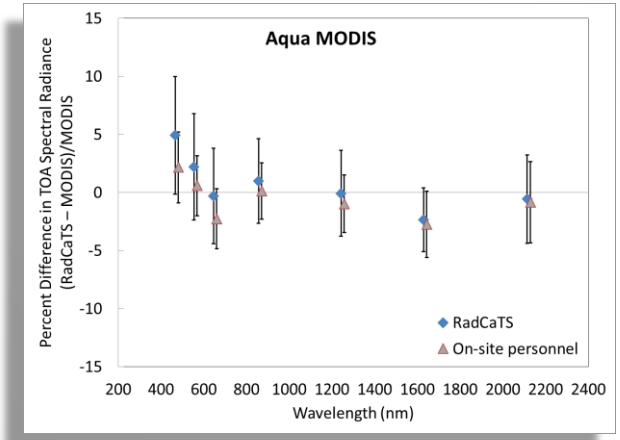


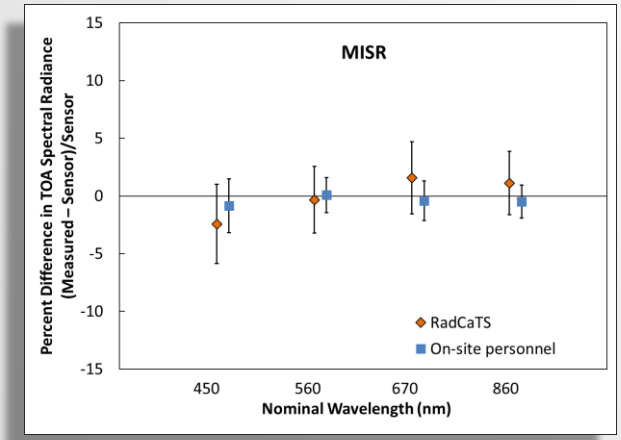


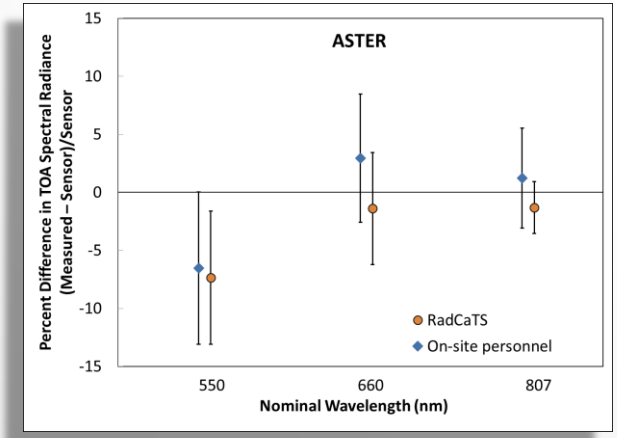
TERRA AND AQUA IMAGING SENSORS

- RadCaTS TOA spectral radiance



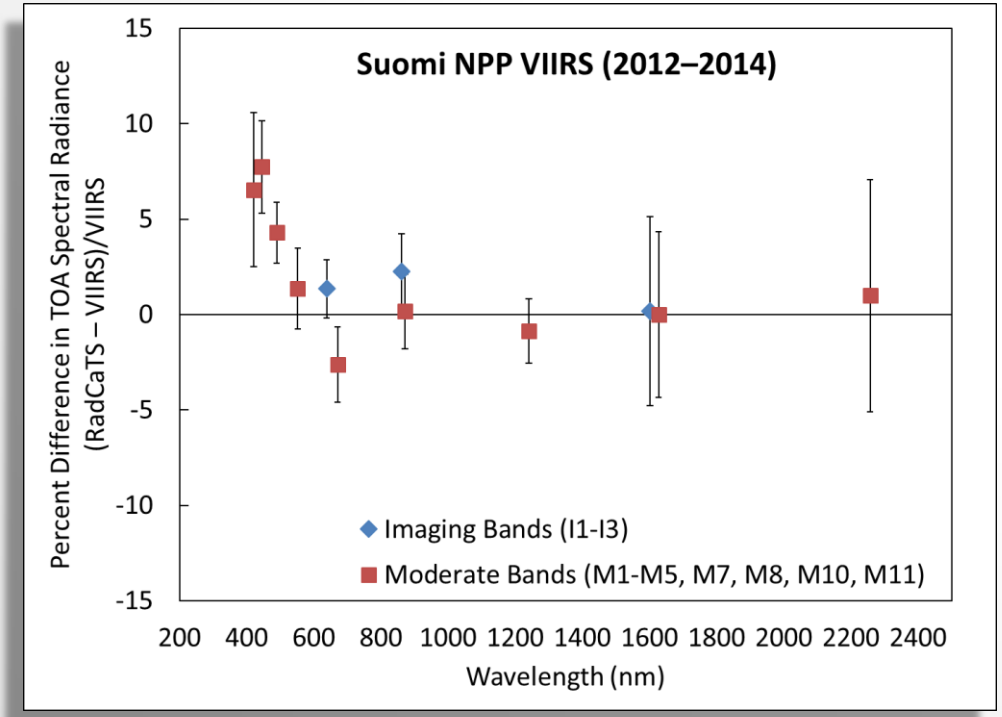






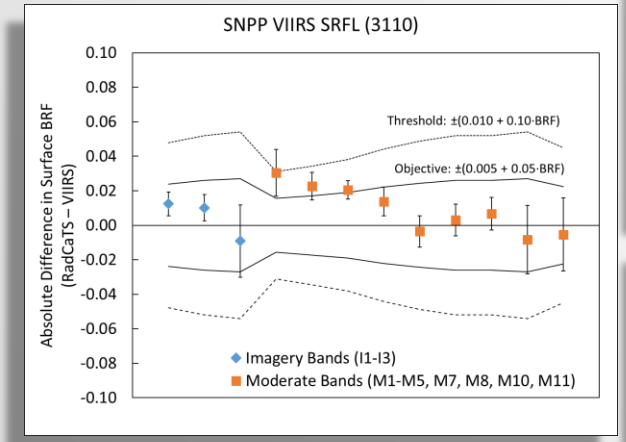
SUOMI NPP VIIRS

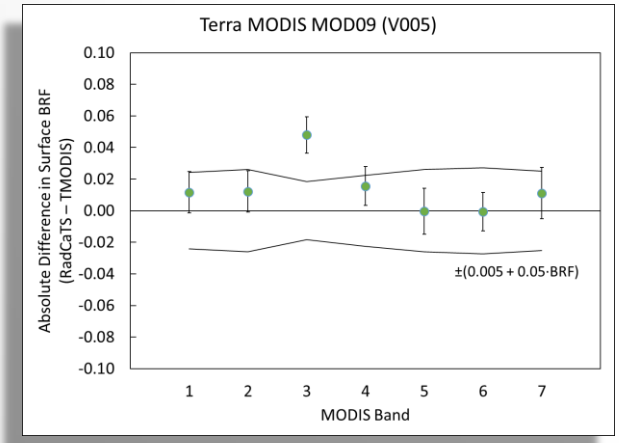
- Imaging (I) band: 375 m
- Moderate (M) band: 750 m
- Unfortunately, no *in situ* measurements for comparison

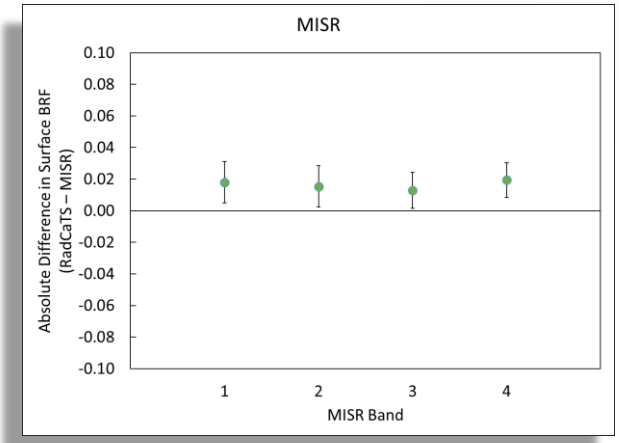


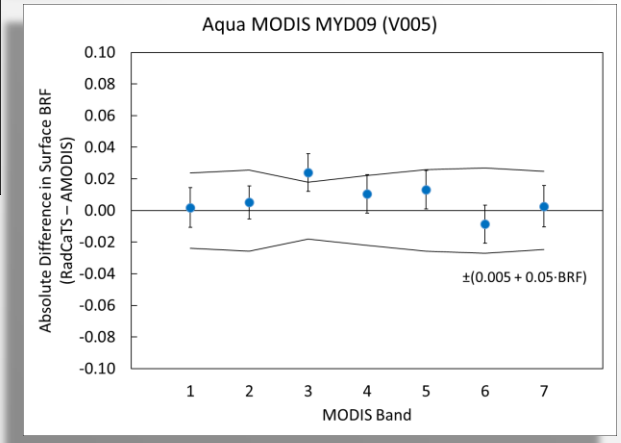
SURFACE REFLECTANCE PRODUCT VALIDATION

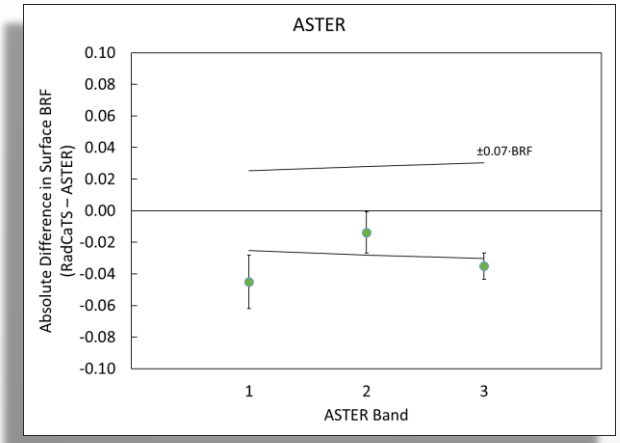
- Surface reflectance products:
  - MODIS: MOD09 (MYD09)
  - MISR: MIL2ASLS
  - ASTER: AST_07
  - VIIRS: NPS_SRFLIIP_L2 and NPS_SRFLMIP_L2











RADCATS UNCERTAINTY ANALYSIS

- Completed as part of Landsat 8 OLI work
- Uncertainty sources:
  - Radiometric calibration of GVRs
  - Output voltage from each GVR
  - Exoatmospheric solar irradiance
  - Atmospheric transmission
  - Solar position
  - Diffuse sky irradiance
  - Surface reflectance retrieval
- Current estimation:

Surface reflectance

Source of Uncertainty	Surface BRF Uncertainty			
	GVR Band			
	450 nm	650 nm	850 nm	1550 nm
Individual GVR measurement	2.7%	2.4%	2.5%	2.2%
Scaling hyperspectral reference data	2.6%	1.7%	2.8%	3.3%
Total BRF uncertainty	**3.7%**	**2.9%**	**3.8%**	**4.0%**

TOA Spectral Radiance

RadCaTS TOA Spectral Radiance Uncertainty			
GVR Band			
450 nm	650 nm	850 nm	1550 nm
4.1%	3.1%	4.1%	4.1%

RADIOMETRIC CALIBRATION NETWORK (RADCALNET)

- RadCalNet is a small working group that is part of CEOS WGCV IVOS
  - Previously known as Landnet
  - Creation of standardized network of sites and data processing protocols
  - Two-year prototyping project
- International collaboration: members from France, Italy, Netherlands, UK, USA, and China
- Composed of four sites in the US, France, China, and Namibia
- Objectives
  1. Define the architecture of RadCalNet
  2. Demonstrate the operational concept using current sensors
  3. Provide recommendations to CEOS WGCV for the evolution of RadCalNet
- Deliverable product
  - TOA reflectance at 30-min intervals
  - 400 – 2500 nm
  - 9:00 – 15:00 local time
  - Nadir view
- Current work uses Landsat 8 OLI results for site intercomparison

RADCALNET SITES

- Current three sites in US, France, and China

Site Name	Site Location	Latitude	Longitude	Altitude (m)	Surface Type
La Crau	France	43.559°	4.864°	18	Sparse vegetation
Railroad Valley	United States	38.497°	–115.690°	1435	Dry lake
Baotou	China	40.852°	109.629°	1270	Artificial targets

Figure 1. The three current RadCalNet sites: La Crau (left), Railroad Valley (center), and Baotou (right).

- A fourth site has been identified in Namibia
  - Located near Gobabeb Training and Research Centre (lat: –23.562°, lon: 15.041°)
  - Instrumentation has yet to be installed

FUTURE WORK

- Satellite uplink installation at Railroad Valley (summer/fall 2015)
  - Installation of semi-permanent mobile lab
    - Network equipment
    - Satellite antenna
    - Wireless data loggers
- Automated processing of RadCaTS data on a daily basis
  - Processed at U. Arizona to surface reflectance
  - Quality control completed at U. Arizona
  - Upload to NASA Goddard for further processing to TOA reflectance
  - Data portal for distribution
- Continued participation in RadCalNet
  - IGARSS presentation in Milan (July 2015)

ACKNOWLEDGEMENTS

- This research is supported by NASA and USGS grants:
  - NNX11AG28G
  - NNX14AE20G
  - NNX14AJ19G
  - NNX14AP68A
  - G14AC00371
- The authors would like to thank:
  - Bureau of Land Management (BLM) Tonopah, Nevada, office for their assistance and permission in using Railroad Valley
  - Brent Holben (PI) and AERONET for processing and distribution of the Railroad Valley data

THANKS!

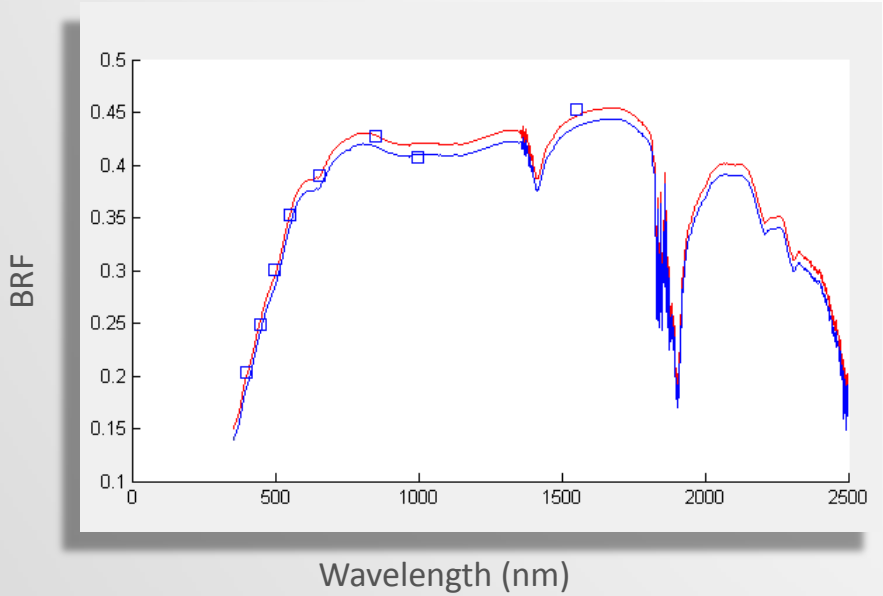
- www.optics.arizona.edu/rsg

EXTRA SLIDES

RADCATS SURFACE BRF RETRIEVAL

- GVR measurements used to scale reference hyperspectral data
- Hyperspectral data are from a ~10-year average
- Hyperspectral data set: ~85 measurements

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



- 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