College of Optical Sciences THE UNIVERSITY OF ARIZONA

THE ABSOLUTE RADIOMETRIC CALIBRATION OF EARTH-OBSERVING SENSORS USING GROUND-BASED TECHNIQUES

Jeffrey Czapla-Myers[1], Nikolaus Anderson[1], Kurtis Thome[2], and Stuart Biggar[1]

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

[2] NASA GSFC
Greenbelt, Maryland, USA

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TOPICS

- Vicarious calibration and reflectance-based approach
- Radiometric Calibration Test Site (RadCaTS) at Railroad Valley
- Field work: 2012–2013
- Results and discussion

VICARIOUS RADIOMETRIC CALIBRATION

- Remote Sensing Group at University of Arizona uses reflectance-based approach with on-site personnel
- Measurements of surface and atmosphere during sensor overpass
- Radiative transfer code to determine at-sensor quantities (e.g. spectral radiance or spectral reflectance)
- Dry lake beds typically used as test sites
  - Railroad Valley, Nevada
  - Ivanpah Playa, California
  - Alkali Lake, Nevada
  - Red Lake, Arizona
- Motivation: to provide independent measurements for calibration and validation of airborne and satellite sensors

REFLECTANCE-BASED APPROACH

Measure site: atmospheric data

Average site radiance derived from image data

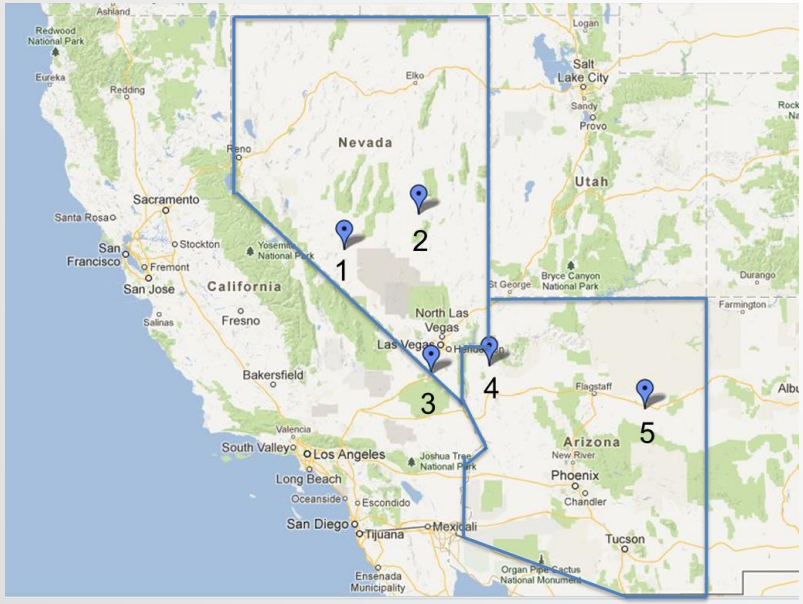
MODTRAN 5

Compute TOA spectral radiance (or reflectance)

Measure site: reflectance data

Comparison to sensor under test

VICARIOUS CALIBRATION TEST SITES



Alkali Lake (1)

RRV (2)

Ivanpah (3)

Red Lake (4)

RADIOMETRIC CALIBRATION TEST SITE (RADCATS)

- RadCaTS was developed to obtain data in absence of ground personnel
  - Located at Railroad Valley, Nevada
  - Modelled on reflectance-based technique
  - Attempt to retain accuracy of reflectance-based technique with flexibility of invariant sites
- Instrumentation includes ground-viewing radiometers (GVR), a Cimel sun photometer, and a meteorological station
- Recent improvements include deployment of new GVRs with greater radiometric stability
- Wireless data transmission upgrade in 2014
  - Data currently downloaded during routine field trips
  - Wireless data will transmit to Tucson throughout the day

MODELLED ON REFLECTANCE-BASED APPROACH

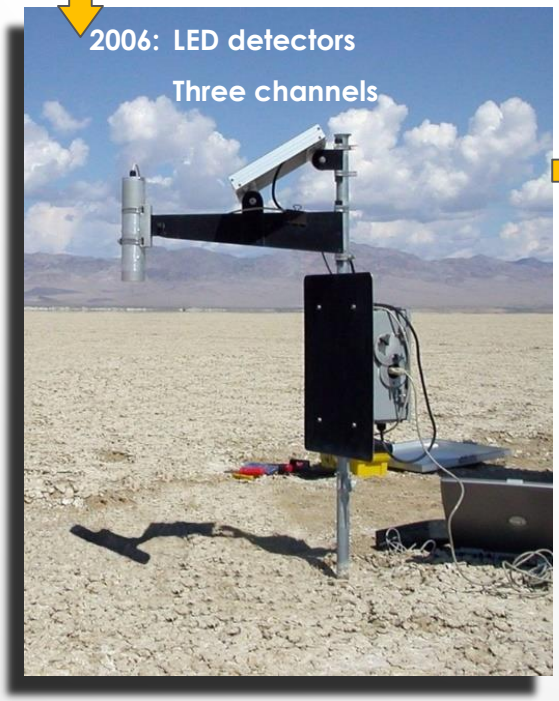
Measure site: atmospheric data

Measure site: reflectance data

Reflectance based

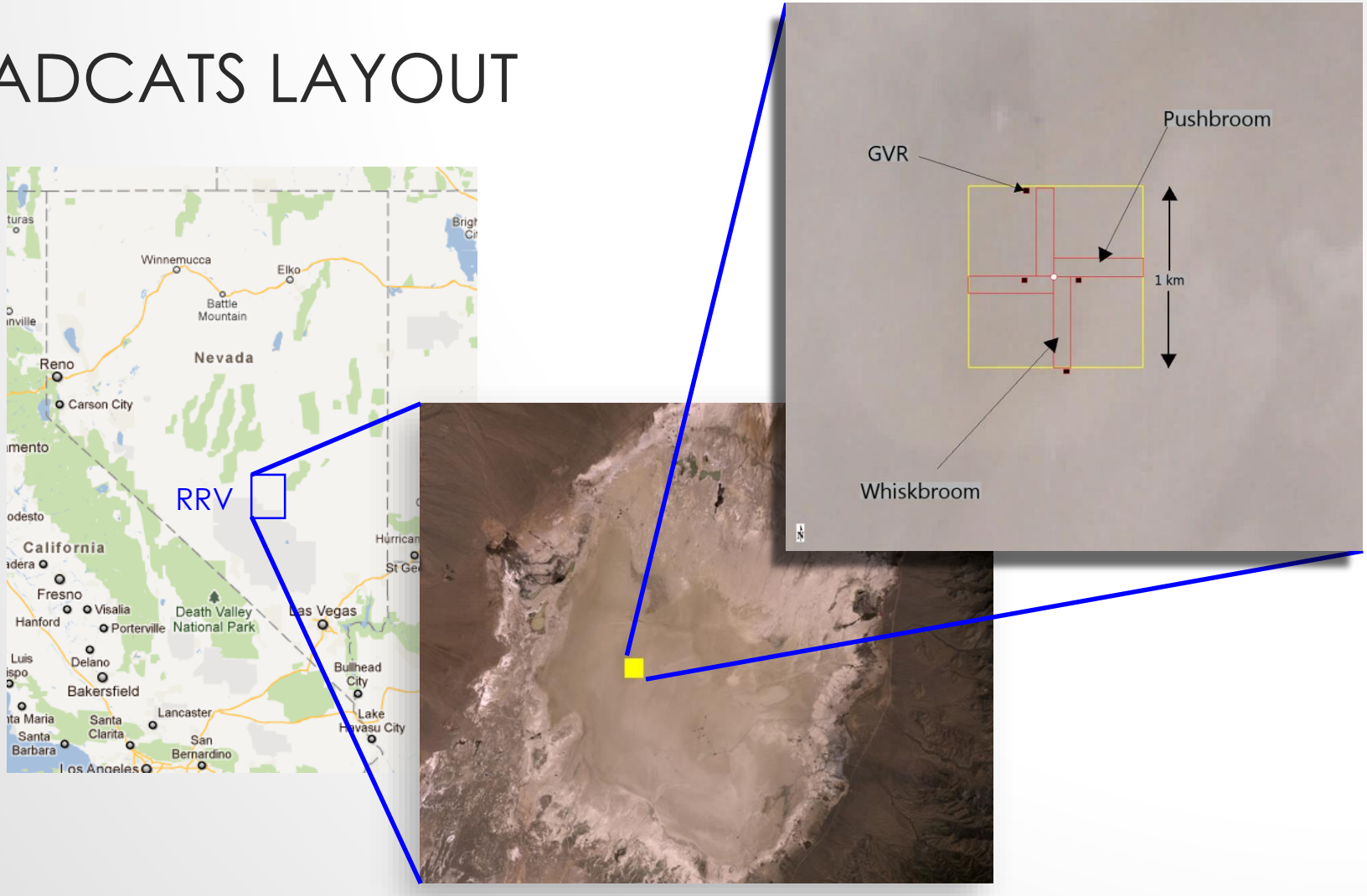
RadCaTS

GVR DEVELOPMENT



GLOBE Sun photometer

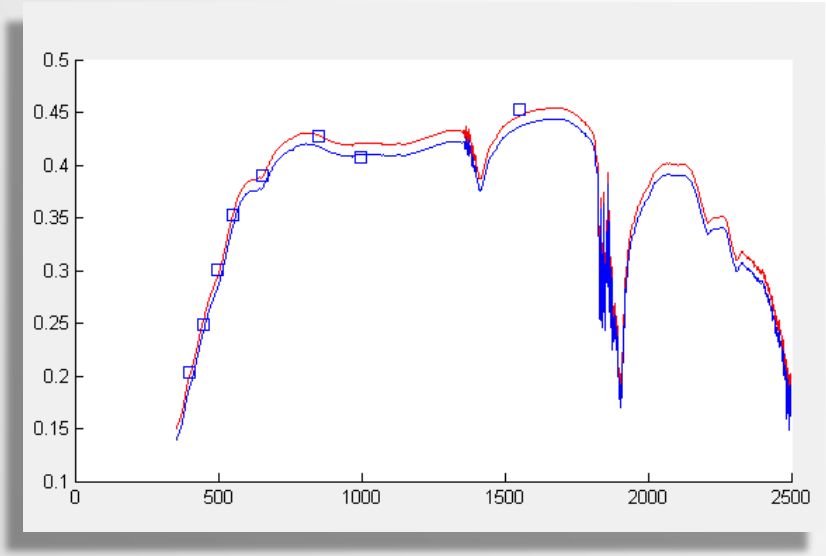
RADCATS LAYOUT



RADCATS SURFACE BRF RETRIEVAL

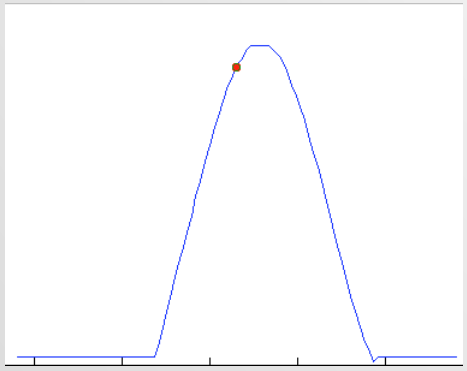
- GVR measurements used to scale reference hyperspectral data
- Hyperspectral data are from a ~10-year average
- Data are binned into separate months
- Data also categorized as AM or PM

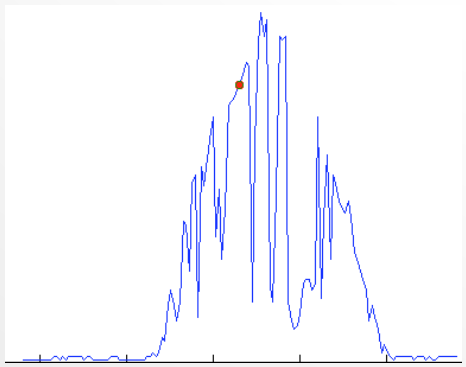
$$\rho = \frac{\pi \, C_{GVR} \, V_{GVR}}{E_0 \, \tau_{solar} \cos\theta + E_{sky}}$$

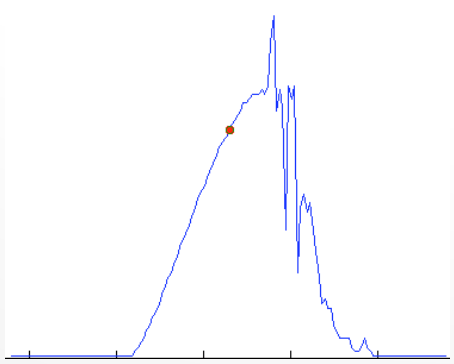


- ρ = surface BRF
- C_{GVR}= GVR calibration coefficient
- V_{GVR} = GVR output voltage
- E_0 = exoatmospheric solar irradiance
- τ_{solar} = direct solar beam transmission
- θ = solar zenith angle
- E_{sky} = diffuse sky irradiance

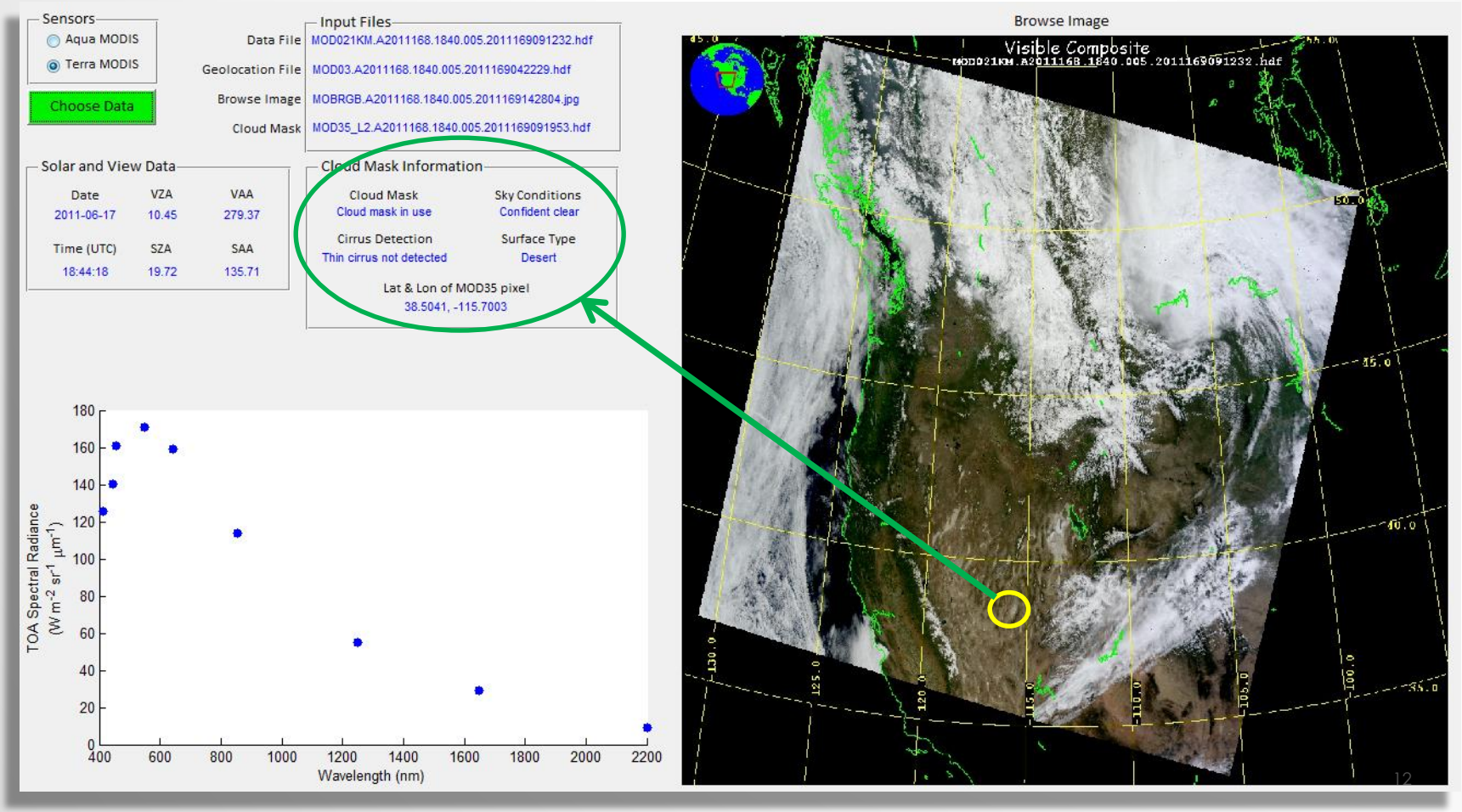
DATA QUALITY DETERMINATION: GVR VOLTAGE







DATA QUALITY DETERMINATION: MODIS CLOUD MASK

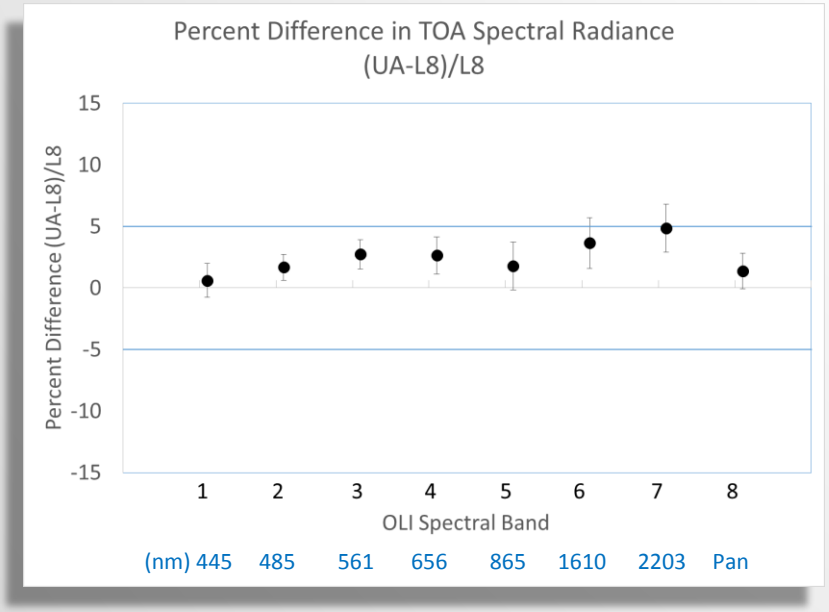


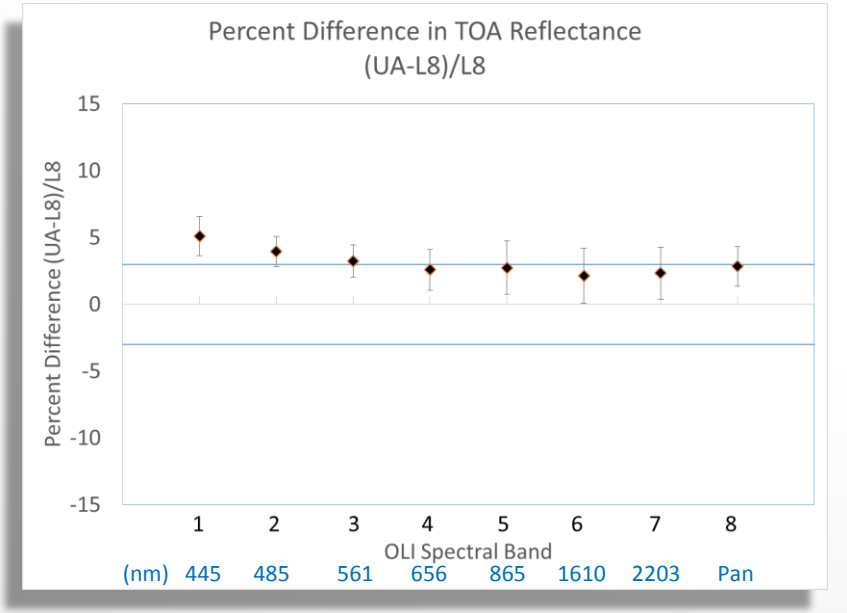
LANDSAT 8 OLI WORK

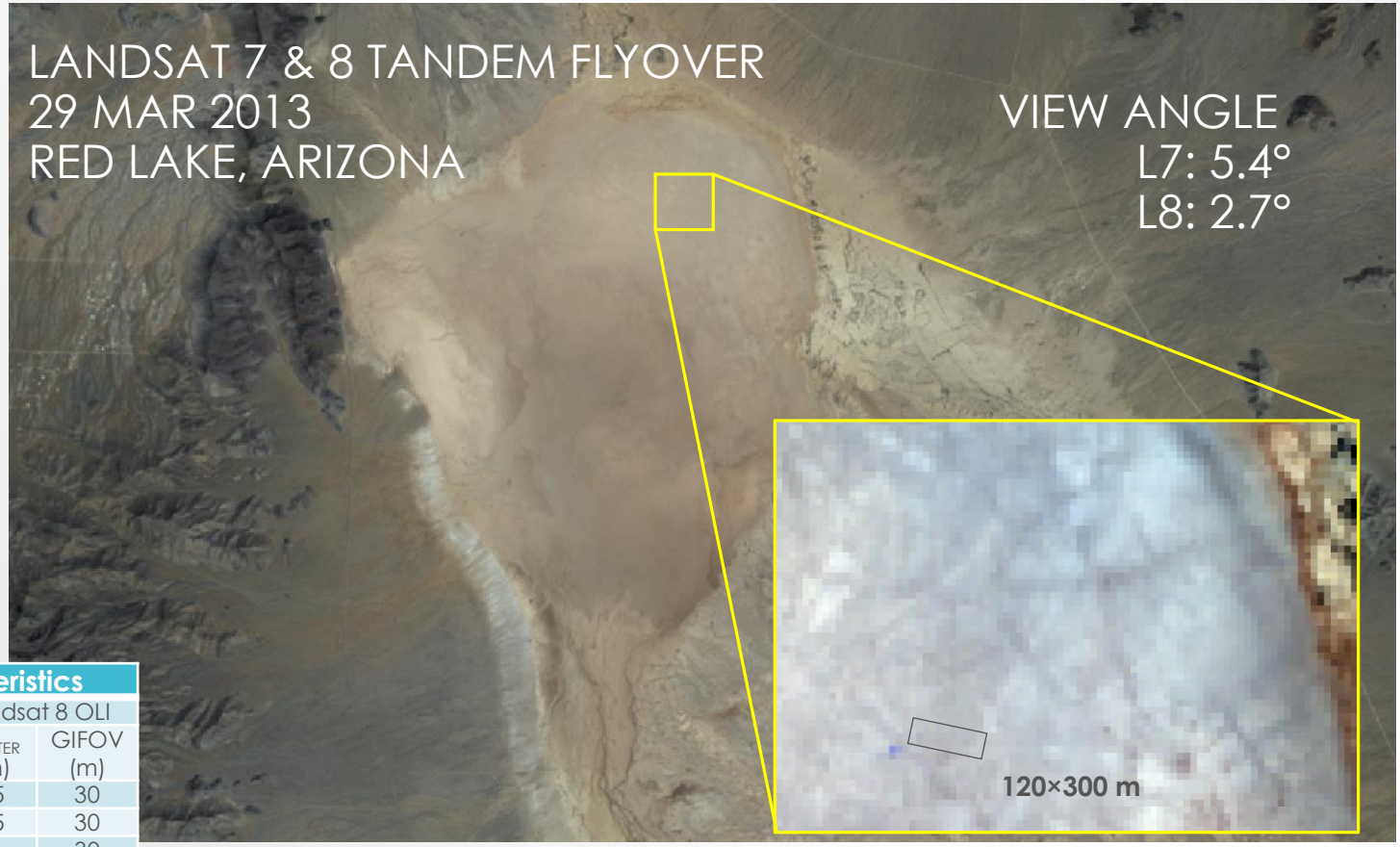
- Remote Sensing Group at University of Arizona involved in preflight calibration of Operational Land Imager (OLI)
  - Transmittance measurements of heliostat facility at Ball Aerospace
  - Round-robin campaign to determine preflight radiometric calibration of OLI
- Work continues with post-launch radiometric calibration
  - In situ measurements
  - RadCaTS
  - Cross calibration during tandem overflight with Landsat 7
- Landsat 8 launch: 11 Feb 2013
  - Intensive field campaigns focused on the two-month commissioning phase
  - 11 Mar – 11 May 2013
  - Routine field campaigns after commissioning phase

SUMMARY OF LANDSAT 8 FIELD WORK MAR 2013 – MAR 2014

- Attempted ground collects with on-site personnel: 15
- Successful collects: 9
- Results compared to TOA radiance and reflectance products
- Uncertainty bars are the 1-σ standard deviation of the measurements



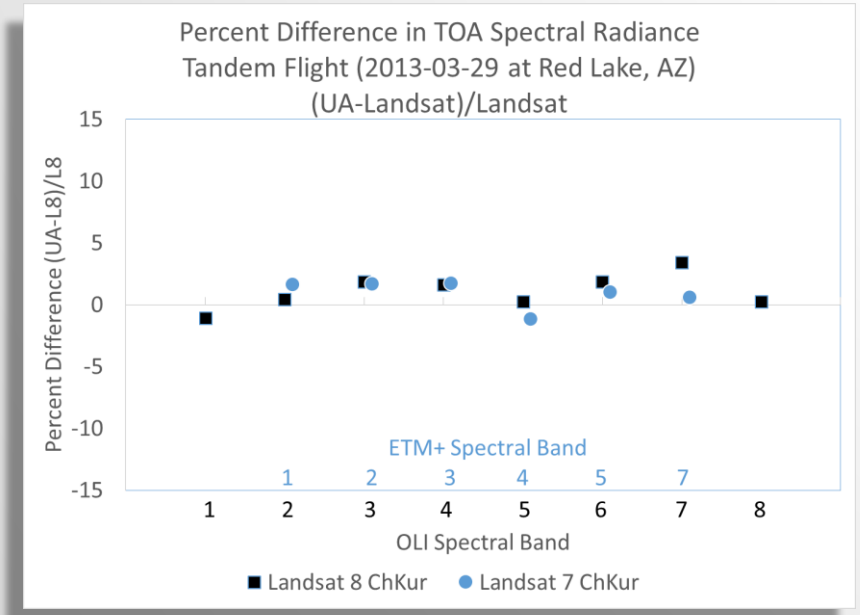


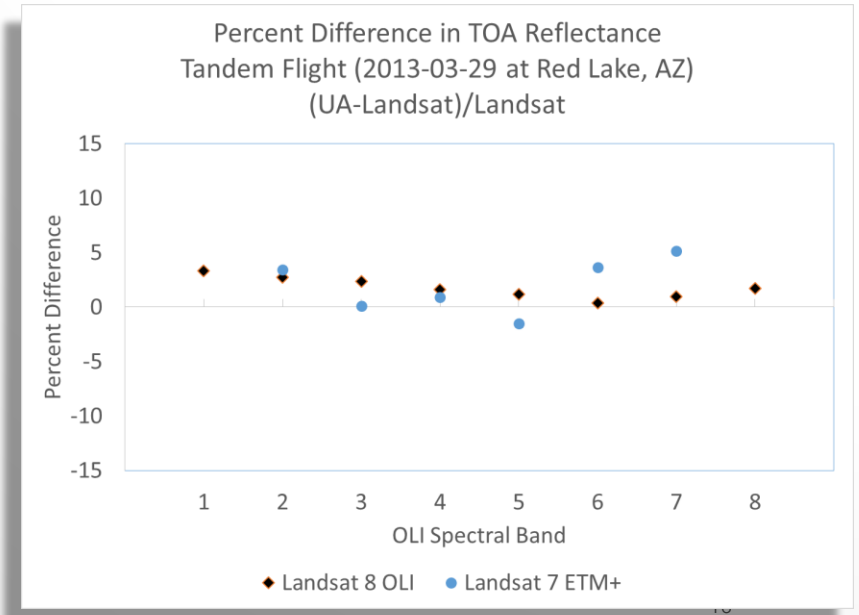


	Sensor Characteristics			
	Landsat 7 ETM+		Landsat 8 OLI	
Band	λ_{CENTER} (nm)	GIFOV (m)	λ_{CENTER} (nm)	GIFOV (m)
1	479	30	445	30
2	561	30	485	30
3	661	30	561	30
4	835	30	656	30
5	1650	30	865	30
6	-	-	1610	30
7	2208	30	2203	30
8	Pan	15	Pan	15
9	-	-	1372	30

LANDSAT 7 AND 8 TANDEM FLIGHT RESULTS

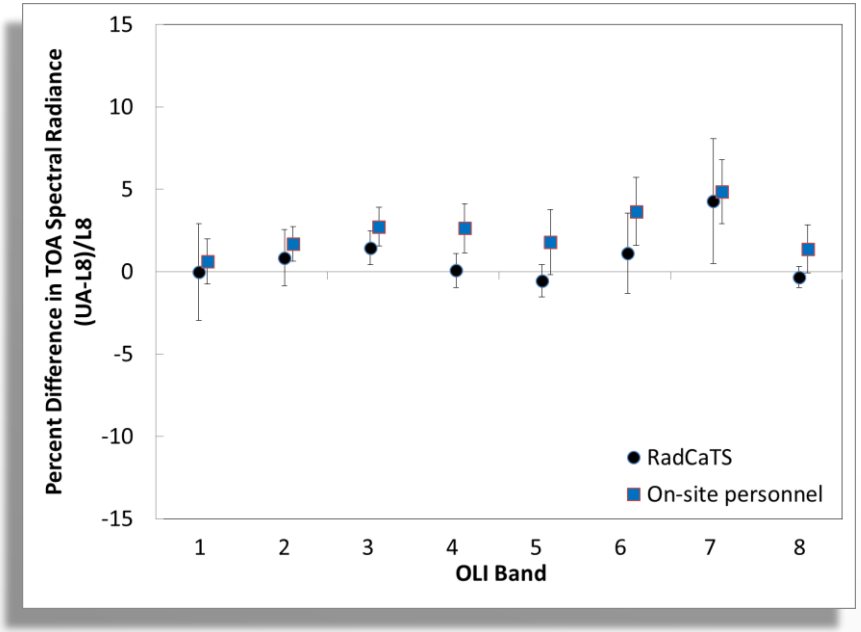
- Ground measurements used as 'transfer radiometer'
- Overpasses ~7 minutes apart
- Radiance results <2.5% difference, TOA reflectance <4% diff.





RADCATS AND LANDSAT 8

- ~16 overpasses at RadCaTS in 2013
- 7 successful data collects (2 were considered outliers due to salt on surface)
- On-site personnel site size:
  - 90×500 m (Railroad Valley)
  - 120×300 m (Ivanpah, Red Lake, Alkali)
- RadCaTS size
  - 1-km^2

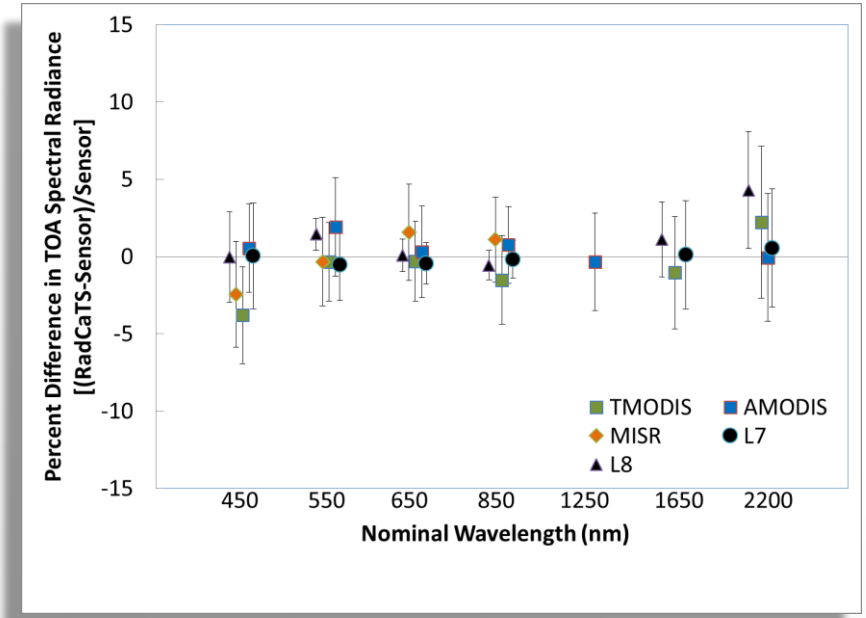


RADCATS AND OTHER EARTH-OBSERVATION SENSORS (2012–2013)

- Sensors compared to 1-km^2 area at RadCaTS
- Uncertainty bars are 1-σ standard deviation of measurements

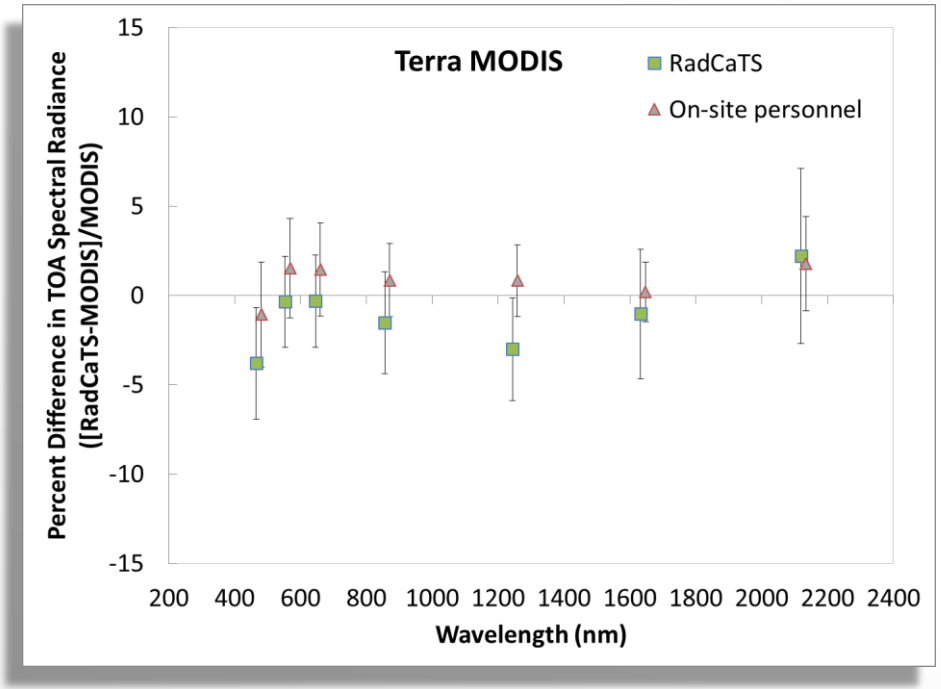
Near-Nadir Overpasses

- Terra (3 view angles) : 36 (.261)
- Aqua (2 view angles) : 22 (.239)
- Landsat 7 (nadir) : 10 (.218)
- Landsat 8 (nadir) (2013): 5 (.278)



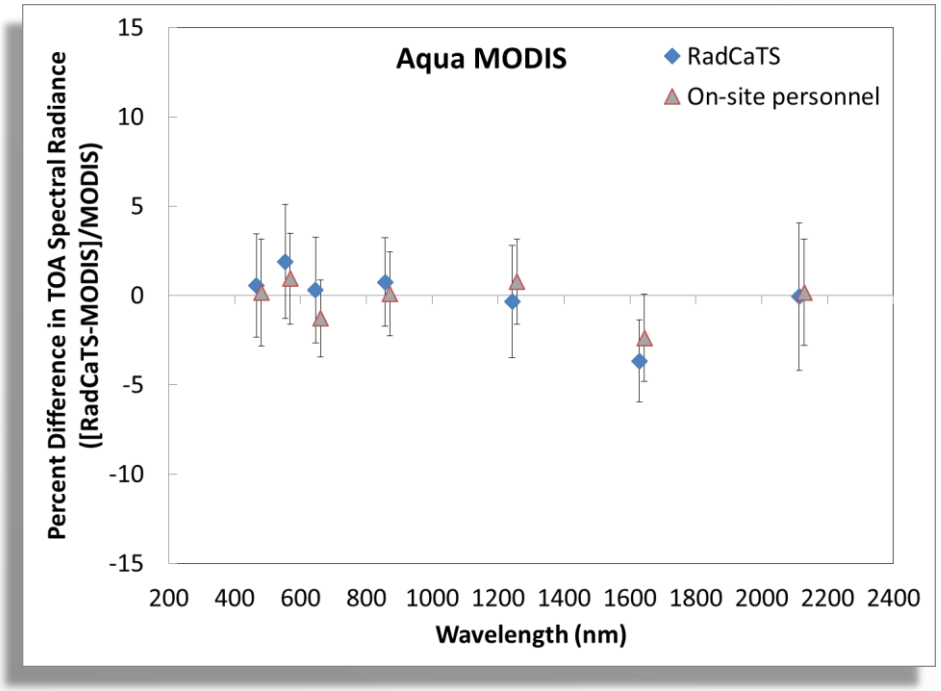
RADCATS AND OTHER EARTH-OBSERVATION SENSORS: TERRA MODIS

- Comparison of RadCaTS results to in situ measurements using on-site personnel
- Both methods use 1-km^2 site
- RadCaTS:
  - 2012–2013
  - Average of 36 dates
- On-site personnel:
  - 2000–2011
  - Average of 23 dates



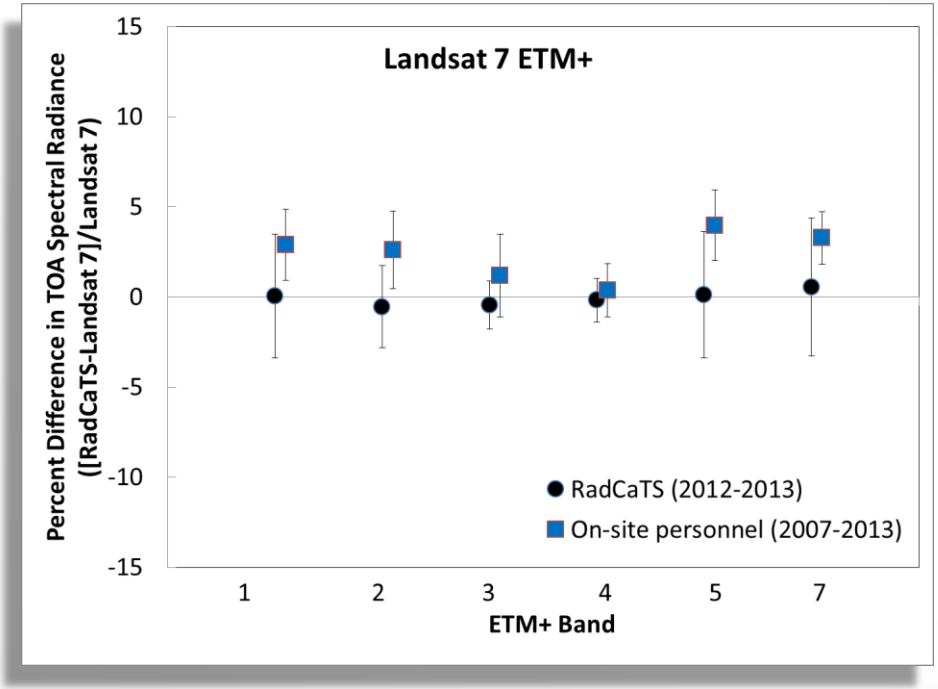
RADCATS AND OTHER EARTH-OBSERVATION SENSORS: AQUA MODIS

- Comparison of RadCaTS results to in situ measurements using on-site personnel
- Both methods use 1-km^2 site
- RadCaTS:
  - 2012–2013
  - Average of 22 dates
- On-site personnel:
  - 2002–2011
  - Average of 17 dates



RADCATS AND OTHER EARTH-OBSERVATION SENSORS: LANDSAT 7 ETM+

- Comparison of RadCaTS results to in situ measurements using on-site personnel
- RadCaTS:
  - 1-km^2 site
  - 2012–2013
  - Average of 10 dates
- On-site personnel:
  - 120×480-m site
  - 2007–2011 (for graph at right)
  - Average of 19 dates (RRV only)

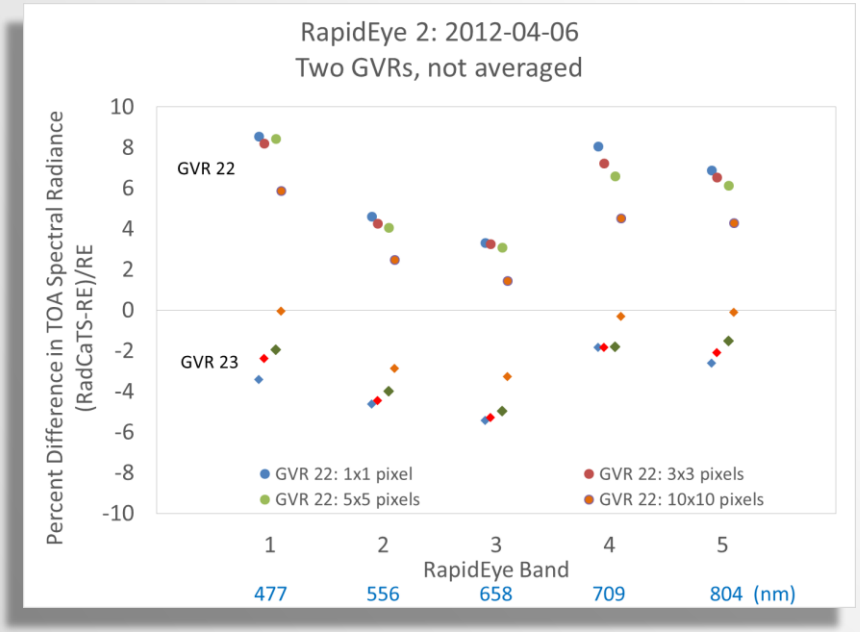


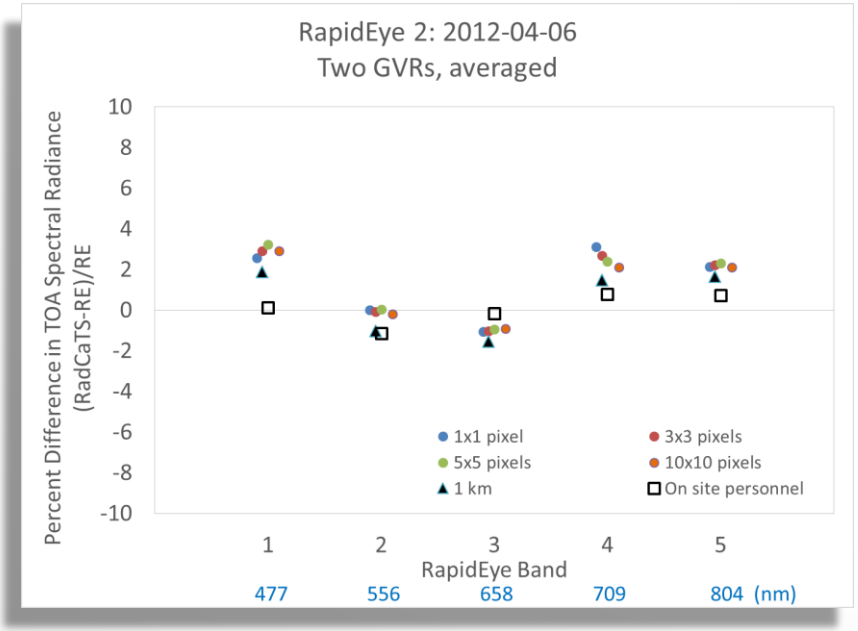
RADCATS SPATIAL SCALE STUDY

- Study to determine sampling area effect around each GVR
- Depends on uniformity of site
- RadCaTS can be thought of as:
  - Four individual data points for such sensor platforms as RapidEye, WorldView, Landsat, ASTER, and similar sensors
  - A 1-km^2 area that is the average of four GVR measurements
- Analysis using RapidEye Ortho Product
  - Resampled to 5-m spatial resolution
  - Orthorectified

RADCATS SPATIAL SCALE STUDY

- RapidEye pixel: 5 m (L3A)
- On-site personnel site size: 90×300 m





SUMMARY AND FUTURE WORK

- RadCaTS provides results similar to those obtained using on-site personnel
  - Salt on site will generally create a bias in the results because of decreased spatial uniformity, and it may affect the sampling of a GVR
  - Current results indicate that site should be treated as average of all GVRs
- RadCaTS has effectively supplemented data collection of on-site personnel
- Effective with sensors ranging from 5–1000 m spatial resolution
- Scaling effect study still requires more work
  - Upcoming RapidEye and Worldview 3 work in 2014
  - Comparison with Landsat 8 and on-site personnel results
- Work in progress to define uncertainty of RadCaTS product
- Work in progress to automate the quality control of RadCaTS
- Plans to make data available on web (~2015)

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- www.optics.arizona.edu/rsg