

# Consistent Landsat Calibration: ETM+ to OLI

Landsat Science Team Meeting

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USGS EROS

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USGS OLI Cal/Val Lead



# The Team...

- South Dakota State University
  - Jim Dewald, Dave Aaron Larry Leigh
  - Rimy Malla, Cody Anderson, Sirish Uprety, Raj Bhatt, Dan Morstad
- USGS EROS
  - Ron Morfitt, Esad Micijevic, Gyanesh Chander, Obaidul Haque, Pat Scaramuzza
- NASA GSFC
  - Brian Markham, Julia Barsi, Ed Kaita, Lawrence Ong, Raviv Levy

# Outline

- ETM+ operational at launch/OIV of OLI
  - OLI Cal/Val plan
  - Image Assessment Systems ETM+/TM/OLI
  - Under-flight opportunity
- Bridging the gap: cross-calibration with other sensors
  - Overview of concept
  - Candidate sensors
  - Issues
  - Actions
- Bridging the gap: use of pseudo-invariant sites
  - Overview of concept
  - Candidate sites
  - Relationship to Vicarious Calibration
  - Issues
  - Actions
- Summary

# Calibration & Validation Overview

- Primary Mission:  
*Ensure accurate spectral, radiometric, spatial and geometric characterization and calibration of LDCM data products and instrument*
- Government Cal/Val Plan defines scope and roles and responsibilities of the joint Cal/Val Team
  - NASA leads through commissioning
  - USGS leads during operations
- Primary Cal/Val Team interactions
  - USGS ground system
  - Instrument vendor
  - Spacecraft vendor
  - Landsat Science Team



# Calibration & Validation Functions...

- Oversight and coordination of Cal/Val activities
  - Covers portions of ground system, spacecraft, instrument and other external entities
- Algorithm development
  - OLI data simulator
  - Cal/Val toolset/prototype
  - Algorithms delivered to ground system developers
    - Data processing, characterization and calibration
- Instrument performance characterization
  - OLI pre-launch, OIV and on-orbit operations
  - Supports instrument acceptance



# Calibration & Validation Functions

- Calibration parameter determination & validation
  - Pre-launch validation of vendor provided parameters
  - Validated parameters ensure quality products
- Product performance characterization
  - Reports for science and user community
- Independent calibration verification and calibration continuity
  - Ensures traceability and continuity with historical products
- Anomaly resolution
  - Includes anomalies in product generation and image assessment
  - Supports observatory and other anomaly resolution, as requested by FOT

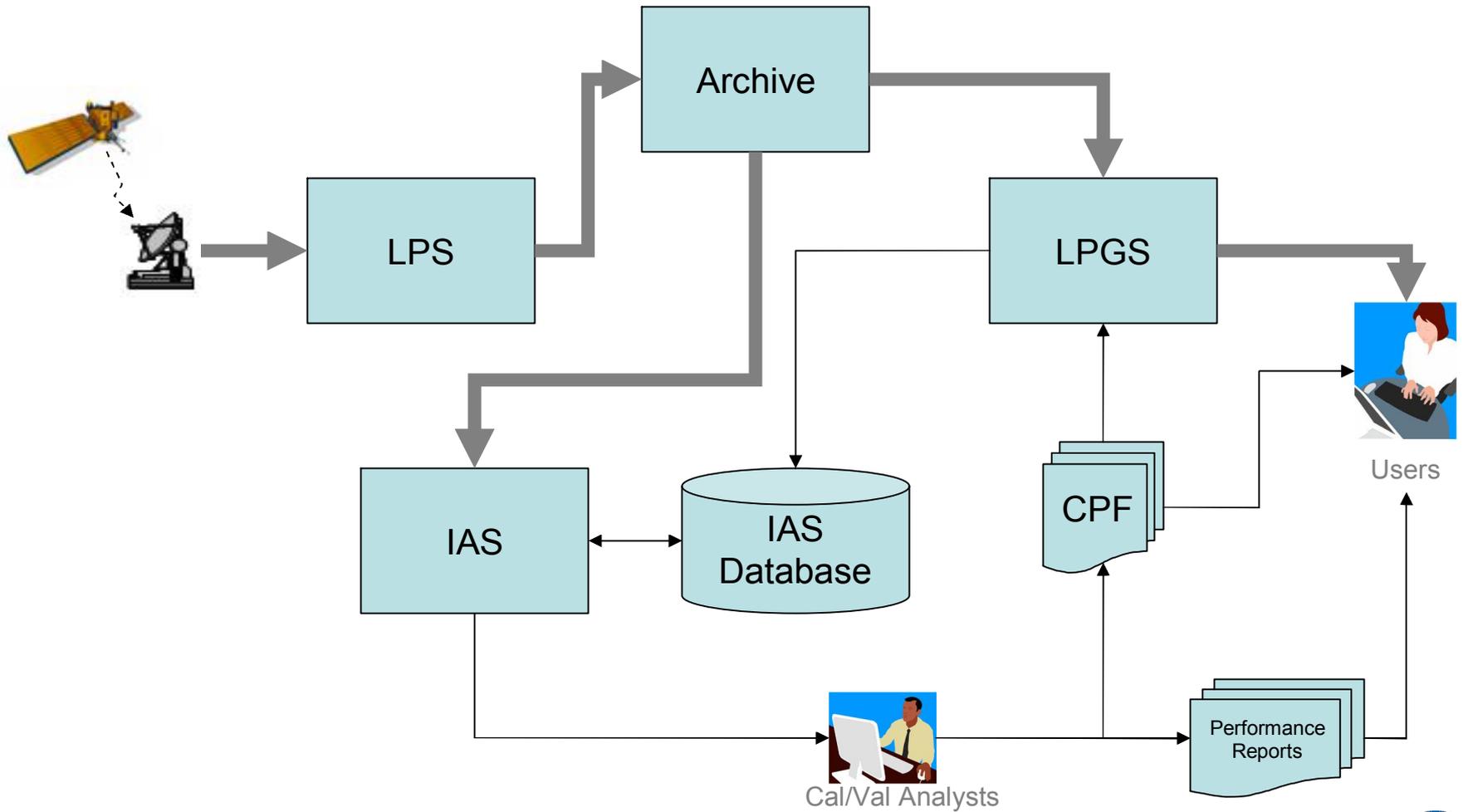


# Original Image Assessment System

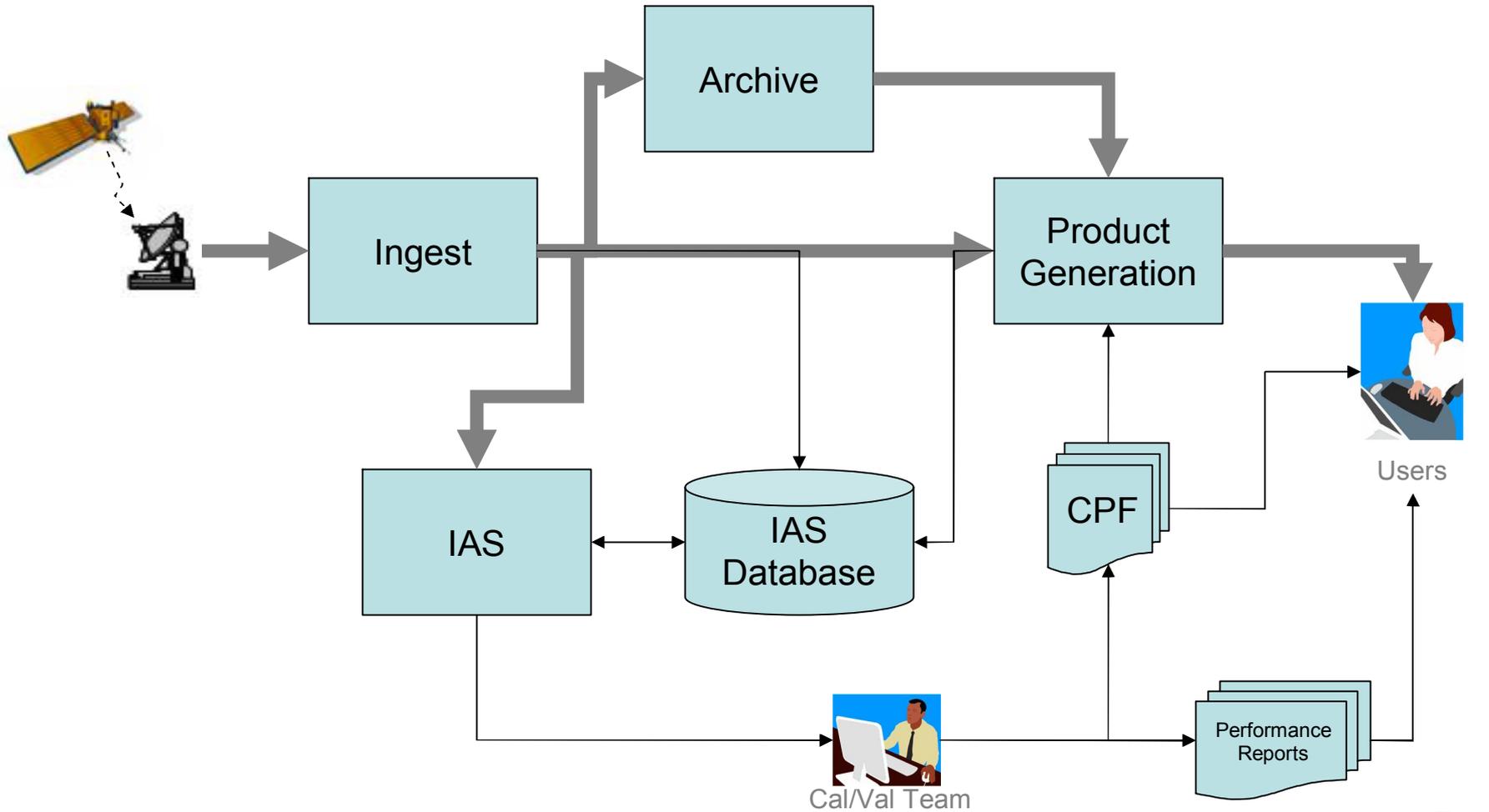
- Enables
  - Calibration updates
  - Report on instrument and product performance
  - Investigate anomalies
- Drawbacks of current implementation
  - Offline characterizations
  - Characterizes fraction of image acquisitions
  - Relies heavily on Calibration Analysts



# L7 Ground System Block Diagram



# LDCM Ground System Block Diagram



# LDCM Concept of IAS

- Perform characterizations on every scene acquired
  - Increased database size and processing requirements
- Increased automation
  - Required due to increase in number of detectors
- Provide immediate alerts
  - Calibration update needed
  - Instrument performance degradation
  - Product performance degradation
- Prototyped with ALIAS
  - Scene statistics used to reduce striping in ALI



# OLI Underflight of ETM+

- OLI will acquire near-simultaneous imagery with ETM+
  - Assuming Landsat-7 operational at launch
  - Enables cross-calibration
  - Other options possible
- Provides best opportunity for calibration continuity
  - Other options decrease accuracy of cross-calibration
- Landsat-7 underfly of Landsat-5 in 1999
  - Provided cross-calibration
  - Increased comparability of ETM+ with TM

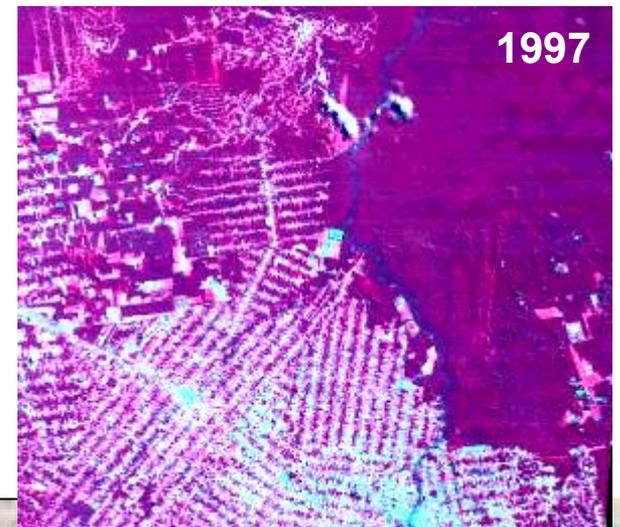


# Bridging the gap: cross-calibration with other sensors

- Overview of concept
  - A 'calibrated' radiometer can be used to transfer the calibration from one instrument to another, or from one source to another
    - Example: Landsat TM was used to transfer the calibration from NIST referenced integrating sphere to on-board cal lamps
  - Two issues/opportunities present in this scenario:
    1. Transfer of calibration from ETM+ to OLI from space platform
    2. Provide consistent Earth data from bridging instrument(s) during gap
  - Endpoints are critical
    - Cross-calibration of bridging sensor(s) with ETM+ (L5 TM?)
    - Cross-calibration of bridging sensor(s) with OLI
    - Trend of bridging sensor(s) must also be tracked

# Landsat Importance to Science

- Change is occurring at rates unprecedented in human history
- The Landsat program provides the only inventory of the global land surface over time
  - ◆ at a scale where human vs. natural causes of change can be differentiated
  - ◆ on a seasonal basis
- No other satellite system is capable/committed to even annual global coverage at this scale



Amazonian Deforestation  
100 km

# Landsat Cross-calibration Activities

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## ● On-going Cross-calibration Activities

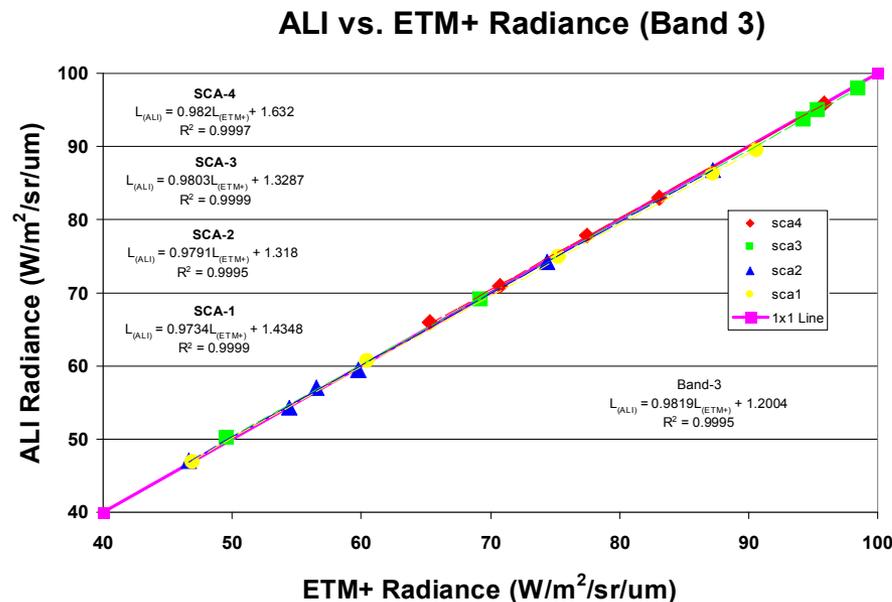
- ◆ L7 ETM+ and L5 TM sensor
- ◆ L5 TM and L4 TM sensor
- ◆ L7 ETM+/L5 TM and EO-1 ALI sensor
- ◆ L7 ETM+/L5 TM and Terra MODIS sensor
- ◆ L7 ETM+/L5 TM and IRS-P6 AWiFS/LISS-III sensor
- ◆ L7 ETM+/L5 TM and CBERS-2 CCD sensor
- ◆ L7 ETM+/L5 TM and ALOS AVNIR-2 sensor

## ● Planned Cross-calibration Activities

- ◆ TM and MSS sensors
- ◆ L7 ETM+/L5 TM and CBERS-2B CCD sensor
- ◆ L7 ETM+/L5 TM and ENVISAT MERIS sensor
- ◆ L7 ETM+/L5 TM and AVHRR MetOP sensor

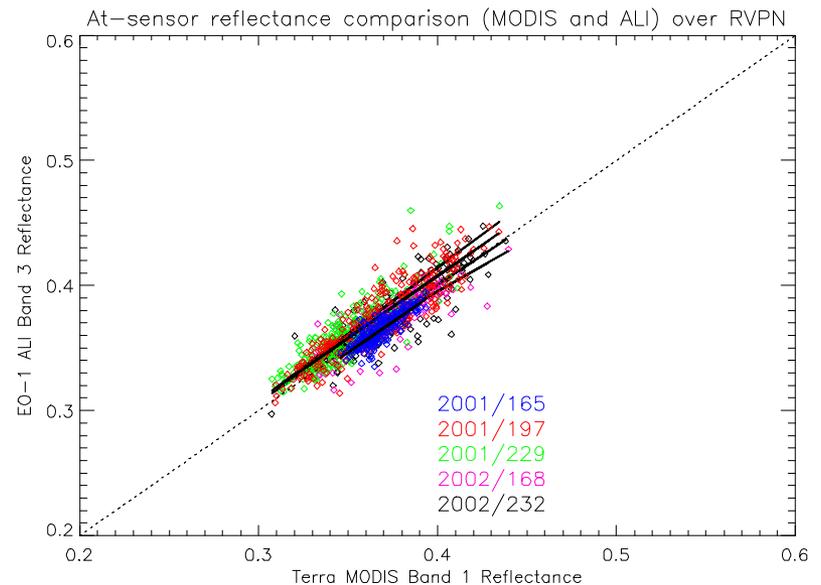
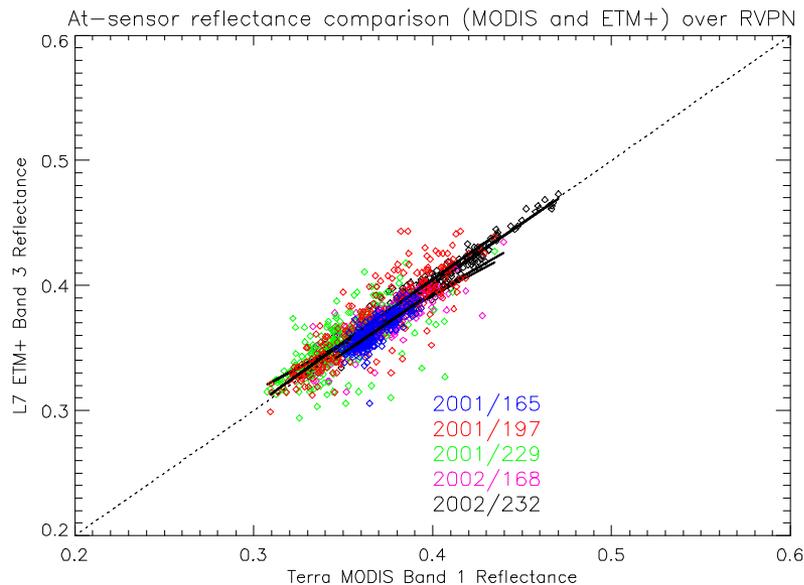
# Cross-calibration of the L7 ETM+ and EO-1 ALI sensors

- ✓ Chander, G., Meyer, D.J., Helder, D.L., "Cross-Calibration of the Landsat-7 ETM+ and EO-1 ALI sensors," IEEE Transactions on Geoscience and Remote Sensing, vol. 42, No. 12, pp. 2821-2831, Dec, 2004. (Invited paper)



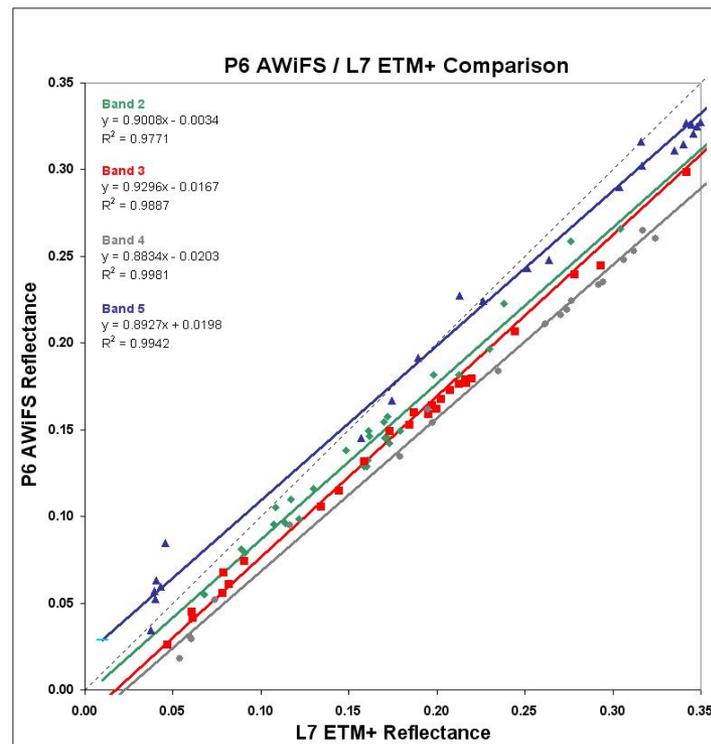
# Cross-calibration of the Terra MODIS, L7 ETM+ and EO-1 ALI sensors

- ✓ Chander, G., Angal, A., Choi, T., Meyer, D. J., Xiong, X., Teillet, P.M., “Cross-calibration of the Terra MODIS, Landsat-7 ETM+ and EO-1 ALI sensors using near simultaneous surface observation over Railroad Valley Playa, Nevada test site,” in Proc. SPIE Int. Symp. , Vol 6677, 6677-34, San Diego, CA, 2007.
- ✓ Meyer, D.J., Chander, G., “Cross-calibration of MODIS with ETM+ and ALI sensors for long-term monitoring of land surface processes,” in Proc. SPIE Int. Symp., Vol 6296, 62960H, San Diego, CA, 2006.



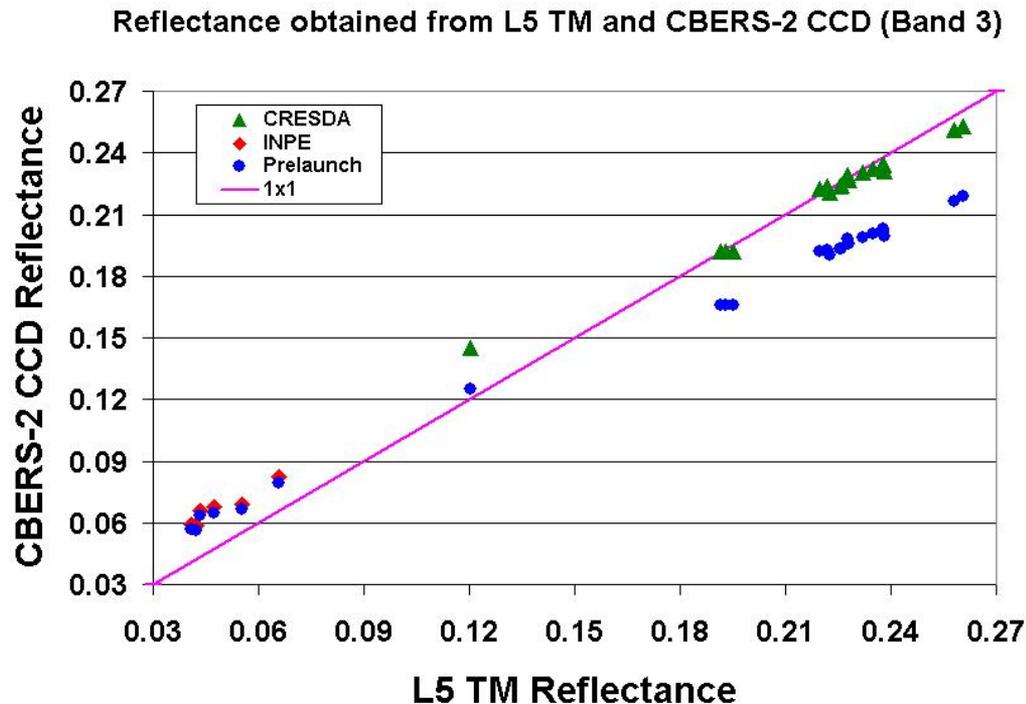
# Cross-calibration of the L7 ETM+, L5 TM and IRS-P6 AWiFS/LISS-III sensors

- ✓ Chander, G., Coan, M.J., Scaramuzza, P.L., "Evaluation and Comparison of the IRS-P6 and the Landsat Sensors," IEEE Transactions on Geoscience and Remote Sensing. (accepted)
- ✓ Chander, G., Scaramuzza, P.L., "Cross Calibration of the Landsat-7 ETM+ and Landsat-5 TM with the ResurceSat-1 (IRS-P6) AWiFS and LISS-III Sensors," in Proc. SPIE Int. Symp., Vol. 6407, 64070E, Goa, 2006.



# Cross-calibration of the L7 ETM+, L5 TM and CBERS-2 CCD sensors

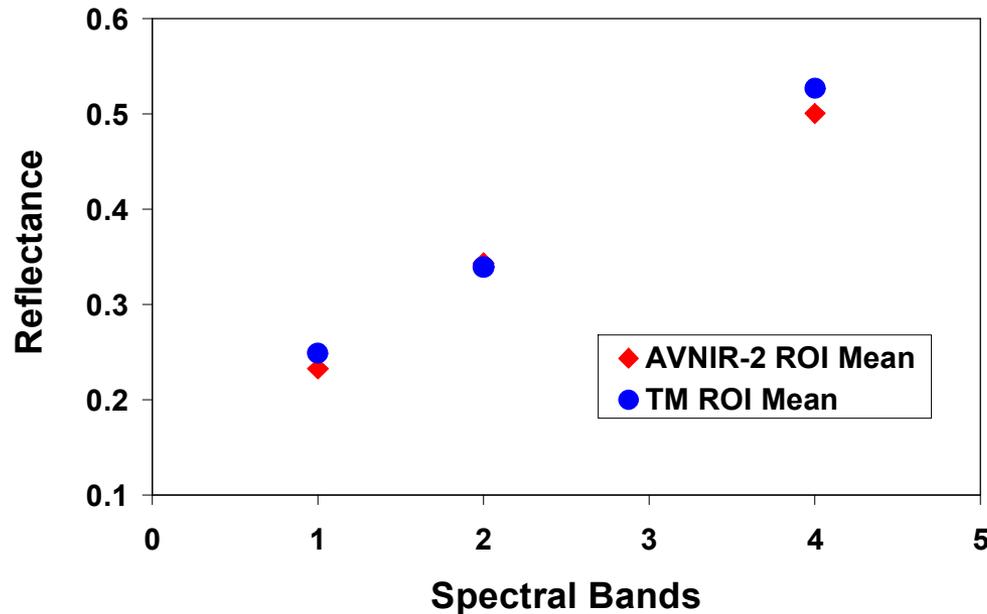
- ✓ Chander, G., "An overview of the CBERS-2 satellite and comparison of the CBERS-2 CCD data with the L5 TM data," in Proc. JACIE, 2006.



# Cross-calibration of the L5 TM and ALOS AVNIR-2 sensor

- ✓ Bouvet, M., Goryl, P., Chander, G., Santer, R., Saunier, S., "Preliminary radiometric calibration results of ALOS AVNIR-2 performance," in Proc. IGARSS, Barcelona, Spain, 2007.

## AVNIR2 & TM Reflectance Comparison



# Landsat Data Gap Study Team

- "The Study Team assessed the basic characteristics of multiple systems and identified sensors aboard the China/Brazil Earth Resources Satellite (CBERS-2), and the Indian Remote Sensing (IRS-P6) ResourceSat-1 satellite as the most promising sources of Landsat-like data."
- "The data qualities evaluated and summarized by the Data Characterization Working Group (DCWG) included:
  - Spectral Characterization
  - Radiometric characterization
  - Geometric Characterization
  - Spatial Characterization"
- "The DCWG concluded that preliminary results for IRS-P6 AWiFS and LISS-III or CBERS-2 HRCCD datasets do not indicate any unresolvable issues. The IRS-P6 satellite is a more mature system and better able in the near-term to provide useful datasets."
- Full details of this work can be found in:

## **LANDSAT DATA GAP STUDY**

### **Technical Report**

#### **Initial Data Characterization, Science Utility and Mission Capability Evaluation of Candidate Landsat Mission Data Gap Sensors**

**Version 1.0**

**January 31, 2007**

- **Currently located at**  
[http://calval.cr.usgs.gov/documents/LDGST\\_Technical\\_Report6.pdf](http://calval.cr.usgs.gov/documents/LDGST_Technical_Report6.pdf)

# ResourceSat-1 (IRS- P6) Overview

- The IRS-P6 satellite was launched into a polar sun-synchronous orbit on Oct. 17, 2003, with a design life of 5 years
- IRS-P6 carries three sensors
  - ◆ High Resolution Linear Imaging Self-Scanner (LISS-IV)
  - ◆ Medium Resolution Linear Imaging Self-Scanner (LISS-III)
  - ◆ Advanced Wide Field Sensor (AWiFS)
- All three sensors are “Pushbroom” scanners using linear arrays of CCDs
- IRS-P6 also carries an onboard SSR with a capacity of 120 GB

IRS-P6 Orbit and Coverage Details	
Orbit Altitude	817 km
Orbit Inclination	98.69 deg
Orbit period	101.35 min
Number of Orbits per day	14.2083
Equatorial crossing time	10.30 a.m.
Repeat Cycle (LISS-III)	24 days
Repeat Cycle (LISS-IV)	5 days
Distance between adjacent paths	117.5 km
Distance between successive ground tracks	2,820 km
Lift-off Mass	1360 kg
Ground trace velocity	6.65 km/sec
Orbits/cycle	341
Semimajor axis	7195.11
Eccentricity	0.001
Mission Life	5 years

IRS-P6 Sensor Specifications			
	LISS-IV	LISS-III	AWiFS
Resolution (m)	5.8	23.5	56
Swath (km)	23.9 km (Mx)	141km	740 km
Spectral Bands (µm)	B2: 0.52-0.59	B2: 0.52-0.59	B2: 0.52-0.59
	B3: 0.62-0.68	B3: 0.62-0.68	B3: 0.62-0.68
	B4: 0.77-0.86	B4: 0.77-0.86	B4: 0.77-0.86
		B5: 1.55-1.70	B5: 1.55-1.70
Quantization (bits)	7	7	10
Repeat Cycle (days)	5	24	5
Integration Time (msec)	0.877714	3.32	9.96
No. of gains	Single gain	Four for B2,3,4	Single gain
Sensor	Pushbroom	Pushbroom	Pushbroom
CCD Arrays	1 * 12288	1 * 6000	2 * 6000
CCD Size (µm)	7 µm x 7 µm	10 µm x 7 µm	10 µm x 7 µm
Focal Length (mm)	982	347.5	139.5
Cross-track FOV for pixel (radian)	0.0000071	0.0000288	0.0000717
Power (W)	216	70	114
Weight (kg)	169.5	106.1	103.6
Data Rate (MBPS)	105	52.5	52.5

# Header File Information (Lmax & Lmin)

## LISS-IV Mono Band 3:

Onboard gain number for band 3 ..... 3  
 Minimum / maximum radiance for band 3 [mw/cm2/str/um] ... 0.00000 9.92230

## LISS-III:

Onboard gain number for band 2 ..... 3  
 Onboard gain number for band 3 ..... 3  
 Onboard gain number for band 4 ..... 3  
 Onboard gain number for band 5 ..... 2  
 Minimum / maximum radiance for band 2 [mw/cm2/str/um] ... 0.00000 12.06400  
 Minimum / maximum radiance for band 3 [mw/cm2/str/um] ... 0.00000 15.13100  
 Minimum / maximum radiance for band 4 [mw/cm2/str/um] ... 0.00000 15.75700  
 Minimum / maximum radiance for band 5 [mw/cm2/str/um] ... 0.00000 3.39700

## AWiFS-A camera (A&C quadrant scenes):

Onboard gain number for band 2 ..... 8  
 Onboard gain number for band 3 ..... 9  
 Onboard gain number for band 4 ..... 8  
 Onboard gain number for band 5 ..... 9  
 Minimum / maximum radiance for band 2 [mw/cm2/str/um] ... 0.00000 52.34000  
 Minimum / maximum radiance for band 3 [mw/cm2/str/um] ... 0.00000 40.75000  
 Minimum / maximum radiance for band 4 [mw/cm2/str/um] ... 0.00000 28.42500  
 Minimum / maximum radiance for band 5 [mw/cm2/str/um] ... 0.00000 4.64500

## AWiFS-B camera (B&D quadrant scenes):

Onboard gain number for band 2 ..... 8  
 Onboard gain number for band 3 ..... 9  
 Onboard gain number for band 4 ..... 8  
 Onboard gain number for band 5 ..... 9  
 Minimum / maximum radiance for band 2 [mw/cm2/str/um] ... 0.00000 52.34000  
 Minimum / maximum radiance for band 3 [mw/cm2/str/um] ... 0.00000 40.75000  
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 Minimum / maximum radiance for band 5 [mw/cm2/str/um] ... 0.00000 4.64500

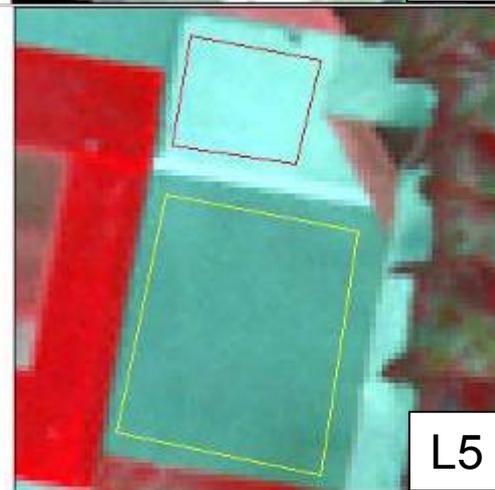
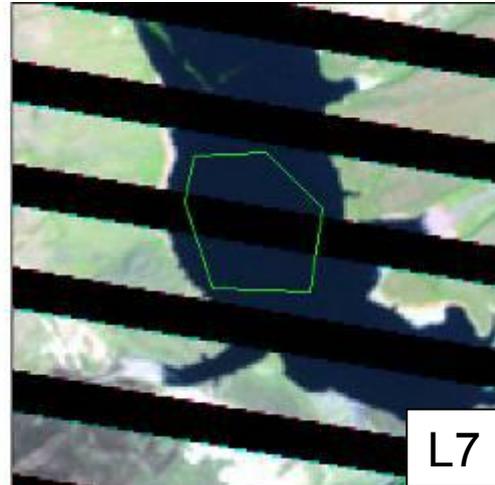
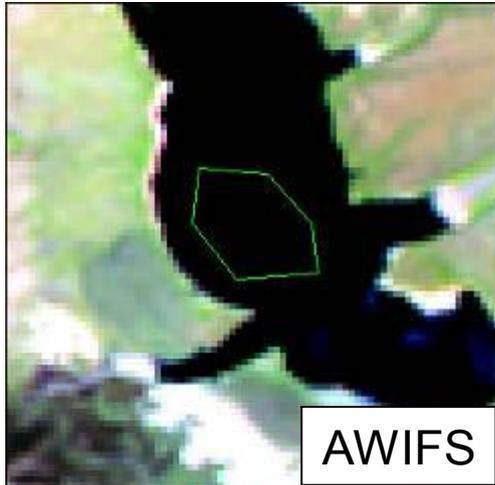
## Conversion to Reflectance

$$\rho_p = \frac{\pi \cdot L_\lambda \cdot d^2}{ESUN_\lambda \cdot \cos \theta_s}$$

ESUN values using the CHKUR  
 MODTRAN 4.0 spectrum  
 (UNITS = W/m<sup>2</sup> μm)

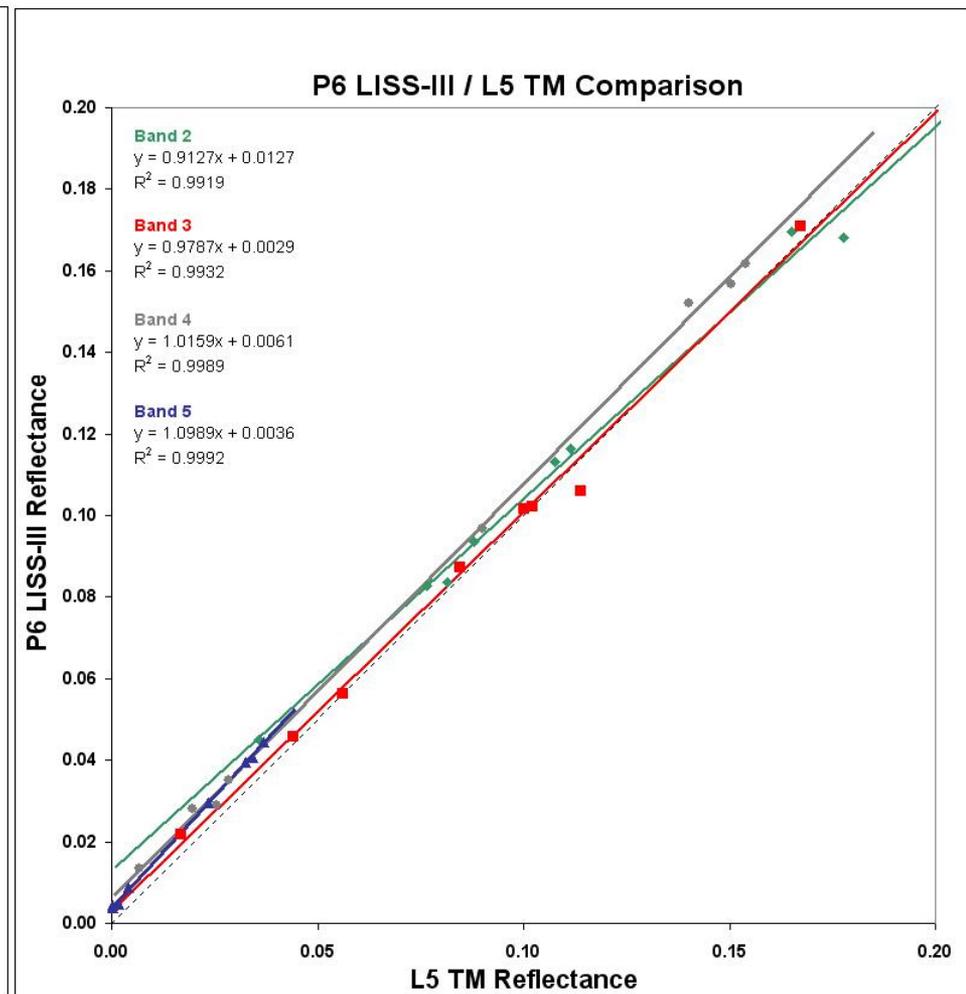
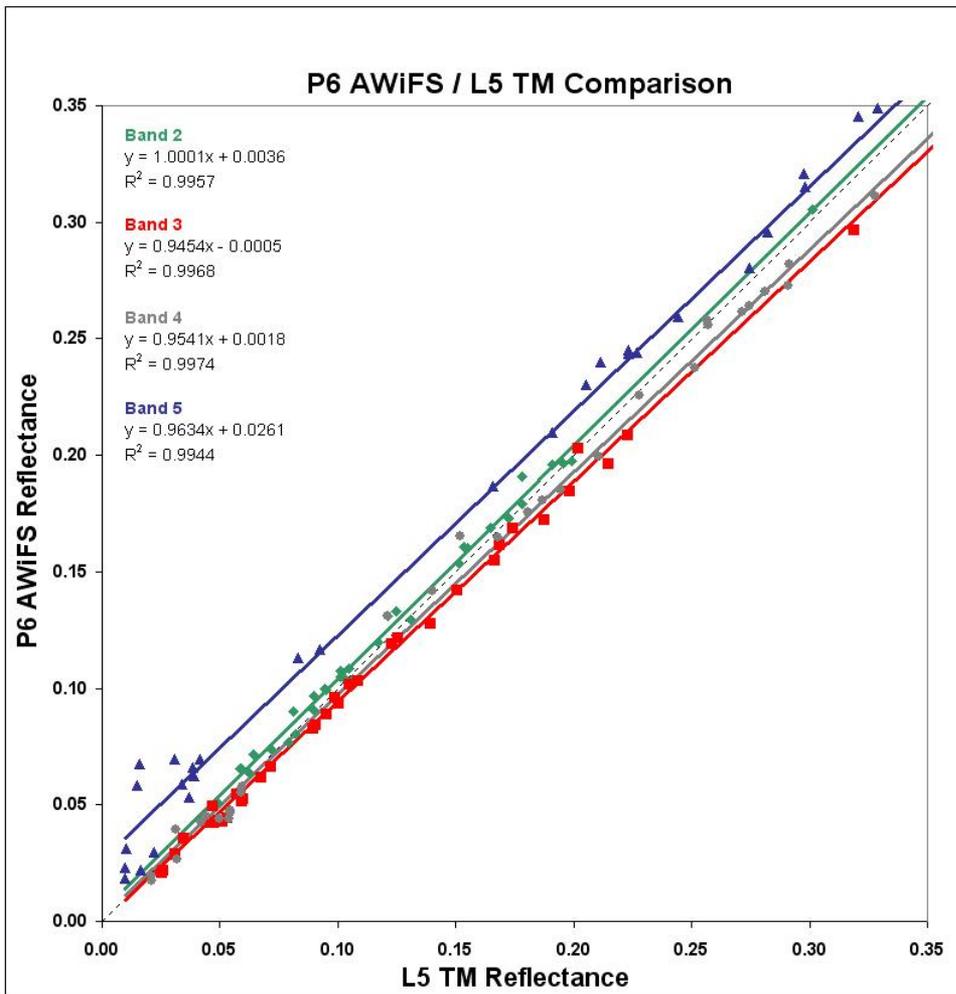
Bands	L5 TM	L7 ETM+	P6 LISS-III	P6 AWiFS
2	1826.000	1840.000	1846.770	1849.820
3	1554.000	1551.000	1575.500	1579.370
4	1036.000	1044.000	1087.340	1075.110
5	215.000	225.700	236.651	235.831

# Regions of Interest (ROI)

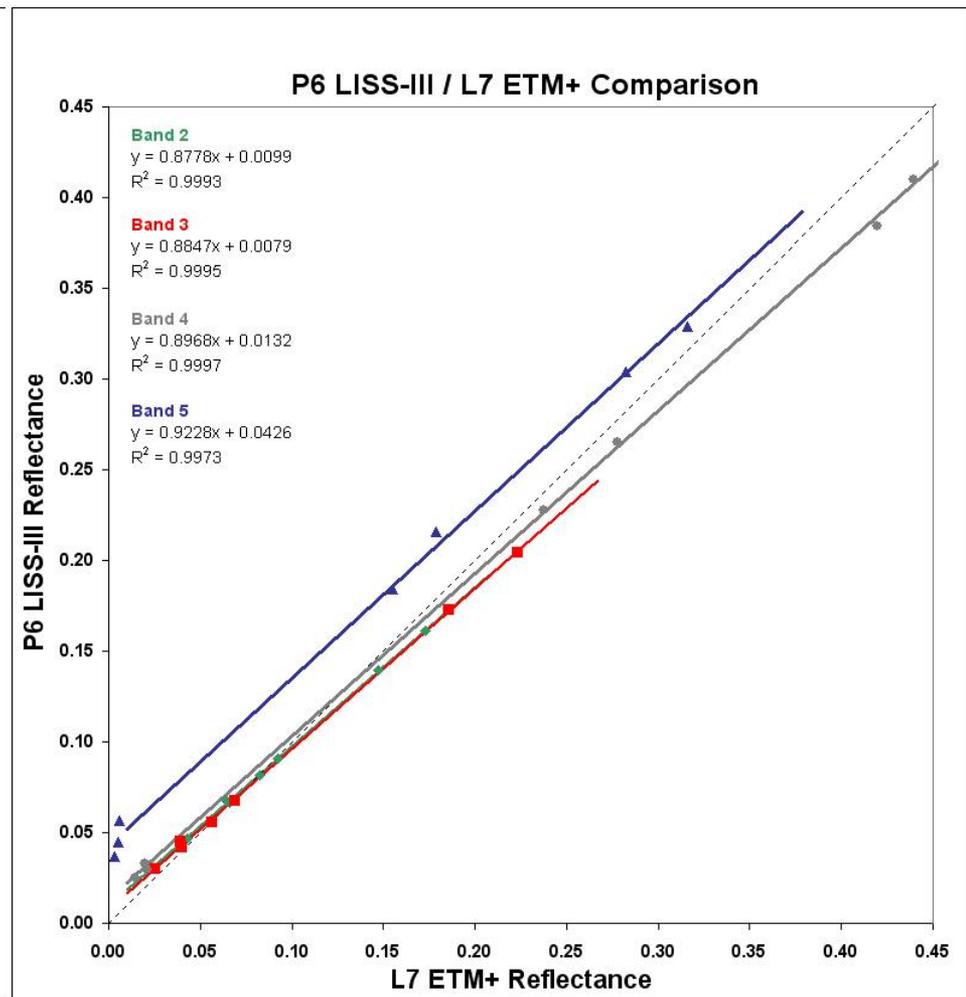
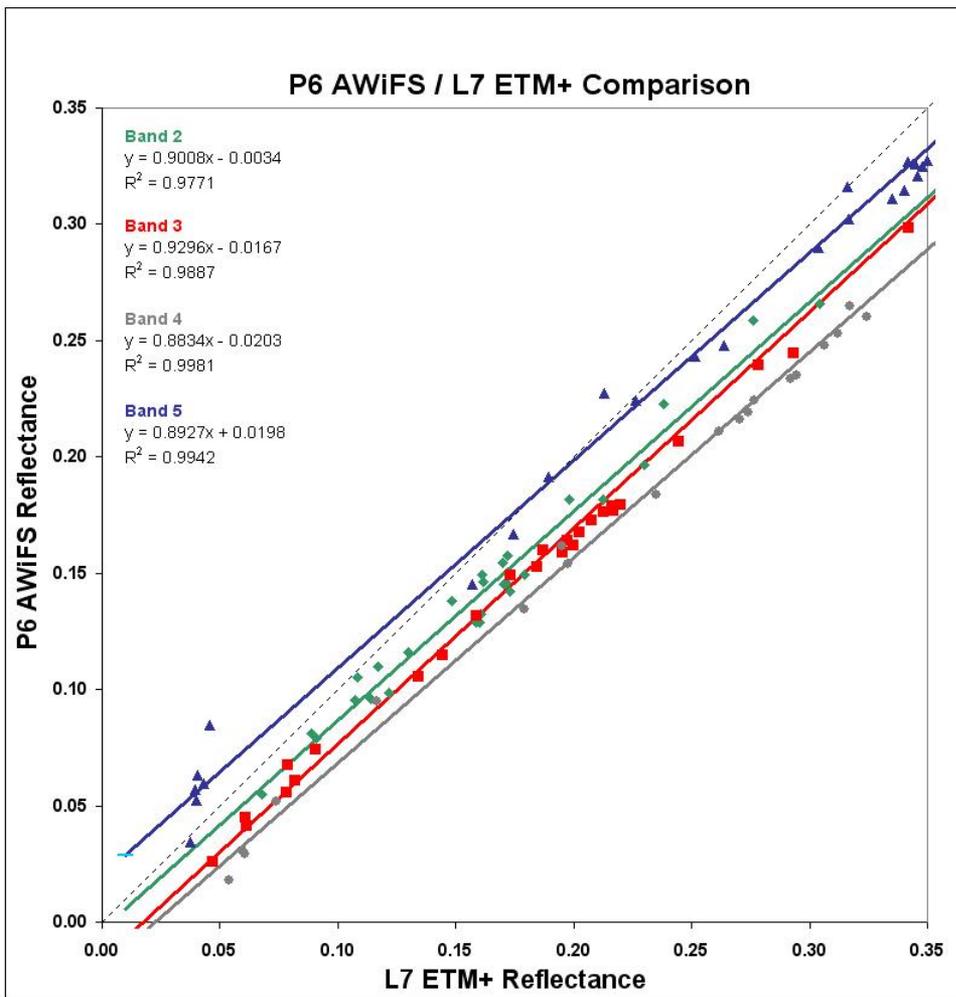


- ROI were selected in both AWiFS and Landsat data
- ROI were selected over homogenous regions (standard deviation  $< 10$  DN)
- Gaps in L7 data were discarded
- Mesa, AZ collection --
  - ◆ Five WRS-2 L7 scenes
  - ◆ 27 ROIs
- SLC, UT collection --
  - ◆ Three WRS-2 L5 scenes
  - ◆ 34 ROIs
- All AWiFS quadrants were represented in both collections

# L5 TM versus P6 AWiFS/LISS-III Salt Lake City, UT



# L7 ETM+ versus P6 AWiFS/LISS-III Mesa, AZ



# IRS-P6 Results

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- These preliminary results indicate that the IRS-P6 sensors can be cross-calibrated to the Landsat sensors to within an accuracy of 13 percent
- The IRS-P6 AWiFS and LISS-III sensors are within 5.5 percent of each other in all bands except Band 2, which has a 16.4 percent difference

## Cross-calibration results normalized to the AWiFS sensor

Sensor	Band			
	2	3	4	5
L5 TM	1.00	1.06	1.05	1.04
L7 ETM+	1.11	1.08	1.13	1.12
P6 AWiFS	<b>1.00</b>	<b>1.00</b>	<b>1.00</b>	<b>1.00</b>
P6 LISS-III (Mesa)	0.90	0.96	0.97	1.00
P6 LISS-III (SLC)	0.86	0.95	0.97	0.97

# China Brazil Earth Resources Satellite - CBERS

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- CBERS-1 was launched on Oct. 14, 1999
  - ◆ The spacecraft was operational for almost 4 years
  - ◆ The CBERS-1 images were not used by user community
  - ◆ On Aug. 13, 2003, CBERS-1 experienced an X-band malfunction causing an end of all image data transmissions
- CBERS-2 was launched on Oct. 21, 2003
  - ◆ The spacecraft carries the identical payload as CBERS-1
  - ◆ The IRMSS stopped working in Apr. 2005 due to power supply failure
- CBERS-2B was launched on Sept. 19, 2007
- CBERS-3: launch planned for 2009
- CBERS-4: launch planned for 2011

# CBERS-1/2 Sensor Compliment

- CBERS-1 and 2 carried three sensors
  - ◆ High Resolution CCD Camera (HRCCD)
  - ◆ Infrared Multispectral Scanner (IRMSS)
  - ◆ Wide-Field Imager (WFI)
- The CCD & the WFI camera operated in the VNIR regions, while the IRMSS operated in the SWIR and thermal region

CBERS-2 Specifications			
Parameter	HRCCD	IRMSS	WFI
Spectral Bands (µm)	0.51 - 0.73 (PAN)	0.50 - 1.10 (PAN)	0.63 - 0.69
	0.45 - 0.52	1.55 - 1.75 (SWIR)	0.76 - 0.90
	0.52 - 0.59	2.08 - 2.35 (SWIR)	
	0.63 - 0.69	10.4 - 12.5 (TIR)	
	0.77 - 0.89		
Spatial Resolution	20 m	80 m (PAN & SWIR) 160 m (TIR)	260 m
Swath Width (FOV)	113 km (8.32°)	120 km (8.78°)	885 km (60°)
Temporal Resolution	26 days	26 days	3-5 days
Cross-Track Pointing	±32°		
Data Rate	2 x 53 Mbit/s	6.13 Mbit/s	1.1 Mbit/s
Carrier Frequency (X-band)	8.103 and 8.321 GHz	8.216 GHz	8.203 GHz
EIRP	43 dBm	39.2 dBm	31.8 dBm
Modulation	QPSK	BPSK	QPSK
Tracking Beam Frequency	8.196 GHz	8.196 GHz	8.196 GHz

# CBERS-2B

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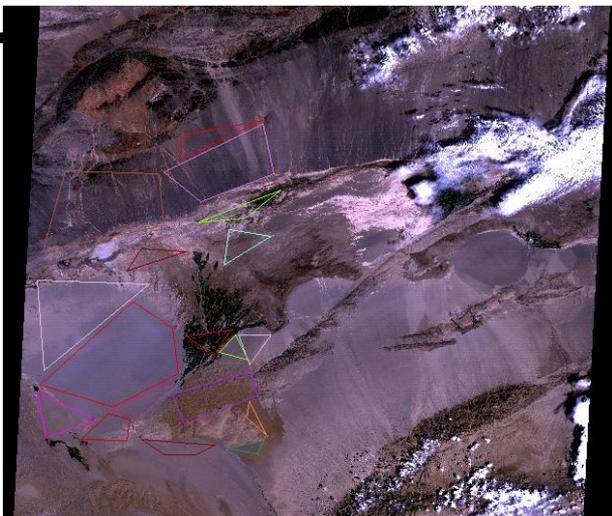
- **Same bus as CBERS-2**
- **Three onboard cameras (CCD, WFI, HRC)**
  - ◆ CCD and WFI cameras are the same as in CBERS-2
  - ◆ HRC is a high-resolution 2.5 m camera
  - ◆ No IRMSS sensor
- **HRC Camera**
  - ◆ 0.45 – 0.85  $\mu\text{m}$  (pan)
  - ◆ TDI CCD technology (Three CCD arrays of 4096 x 36 detectors)
  - ◆ Resolution : 2.5 m
  - ◆ Swath : 27 km
  - ◆ Bit rate : 432 Mbps (w/o compression)
- **Two onboard solid-state recorders**
  - ◆ Transmission of CCD camera data is identical to CBERS-2
  - ◆ Transmission of WFI and HRC is made on one downlink channel
  - ◆ HRC data is compressed before transmission
- **One GPS receiver and two star sensors**

# High Resolution CCD (HRCCD)

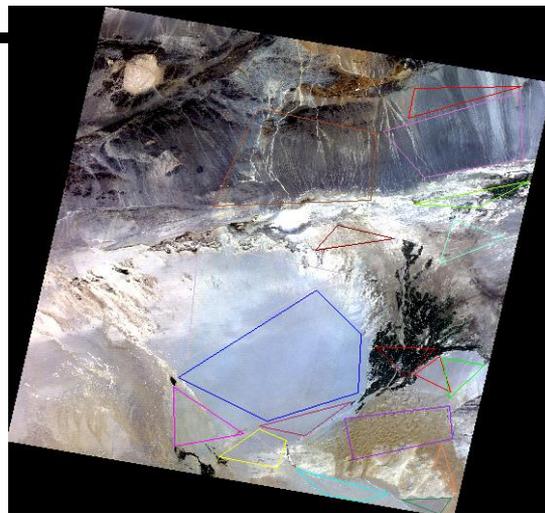
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- The HRCCD is the highest resolution sensor offering a GSD of 20 m at nadir
- HRCCD is a Pushbroom scanner
- Quantization: 8 bits
- Ground swath is 113 km with 26 days repeat cycle
- Steerable up to +/- 32° across track to obtain stereoscopic imagery
- Operates in five spectral bands - one pan & four VNIR
  - ◆ CCD has one focal plane assembly
  - ◆ The signal acquisition system operates in two channels
    - Channel 1 has Bands 2, 3, 4
    - Channel 2 has Bands 1, 3, 5
    - Four possible gain settings are 0.59, 1.0, 1.69, and 2.86

# L5 TM and CBERS-2 CCD Image Pairs

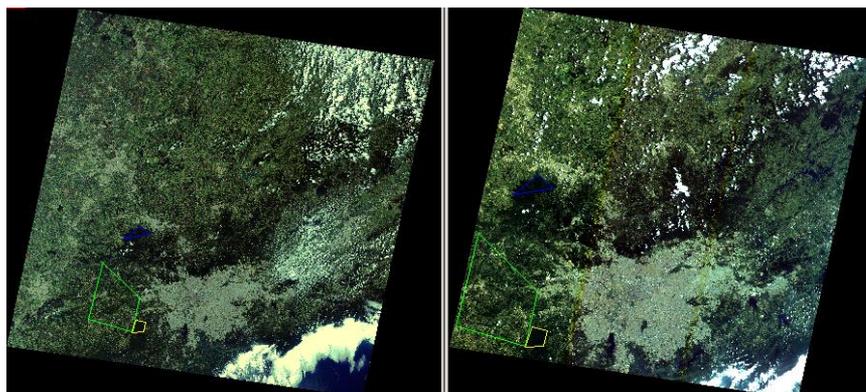


L5 TM WRS Path = 137 Row = 032  
Nadir looking



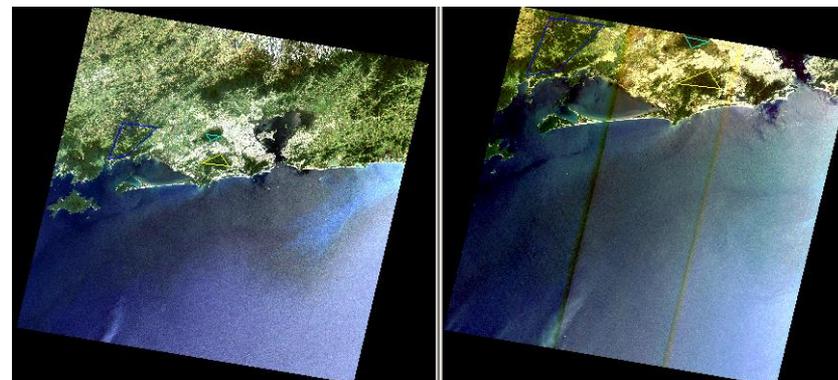
CBERS-2 CCD Path = 23 Row = 55 side-  
looking (off-nadir-look-angle=-6.0333)

Gobi (Dunhuang) desert test site  
Data acquired on  
Aug. 25, 2004 (20 min apart)



L5 TM WRS Path = 219 Row = 076  
Nadir looking Acquisition Date: Dec. 29, 2004

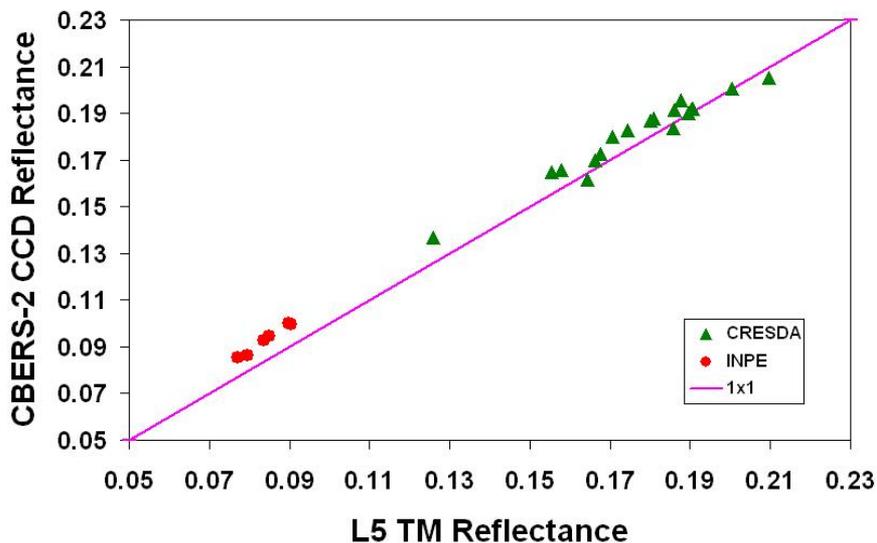
CBERS-2 CCD Path = 154 Row = 126  
Acquisition Date: Dec. 30, 2004



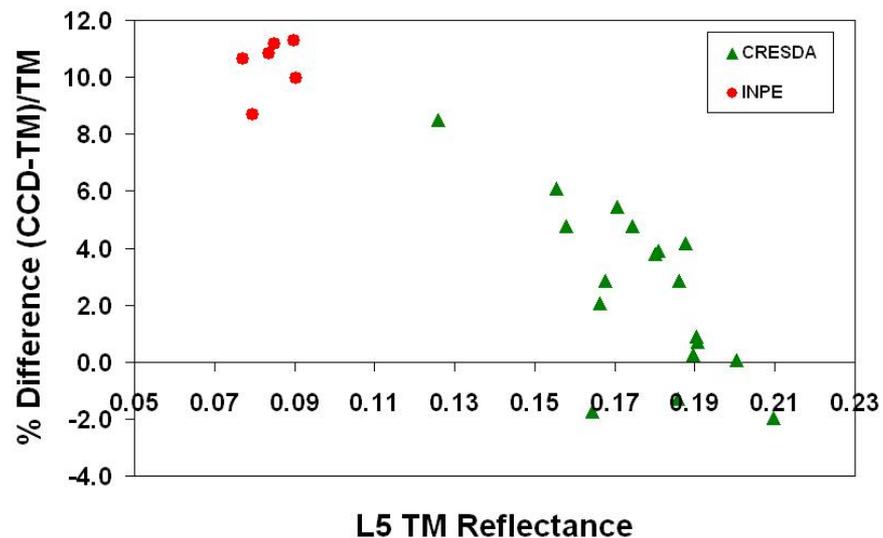
L5 TM WRS Path = 217 Row = 076  
Nadir looking Acquisition Date: Nov. 16, 2005

CBERS-2 CCD Path = 151 Row = 126  
Acquisition Date: Nov. 16, 2005

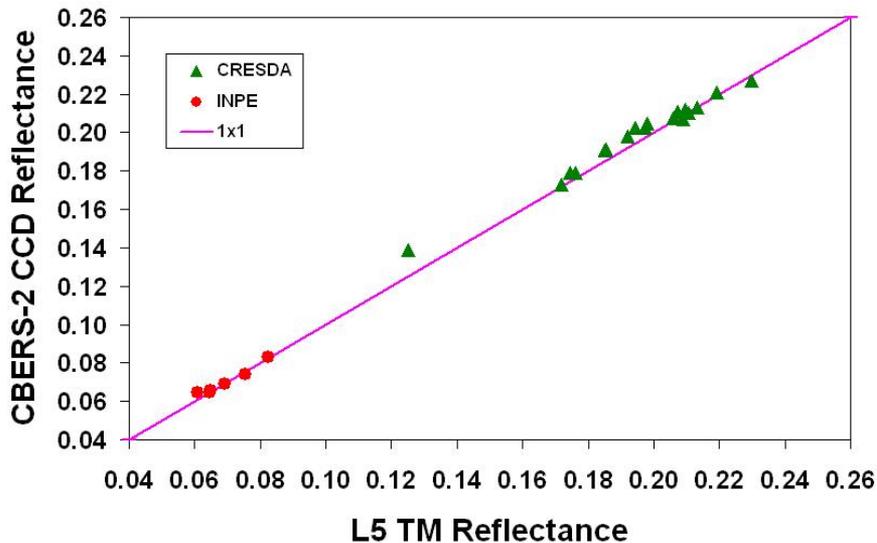
Reflectance obtained from L5 TM and CBERS-2 CCD (Band 1)



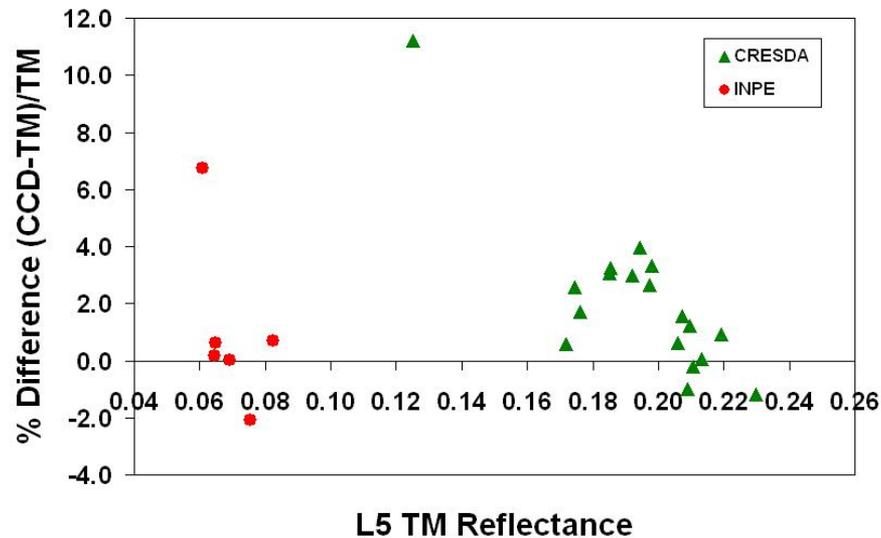
CBERS-2 CCD % difference relative to L5 TM (Band 1)



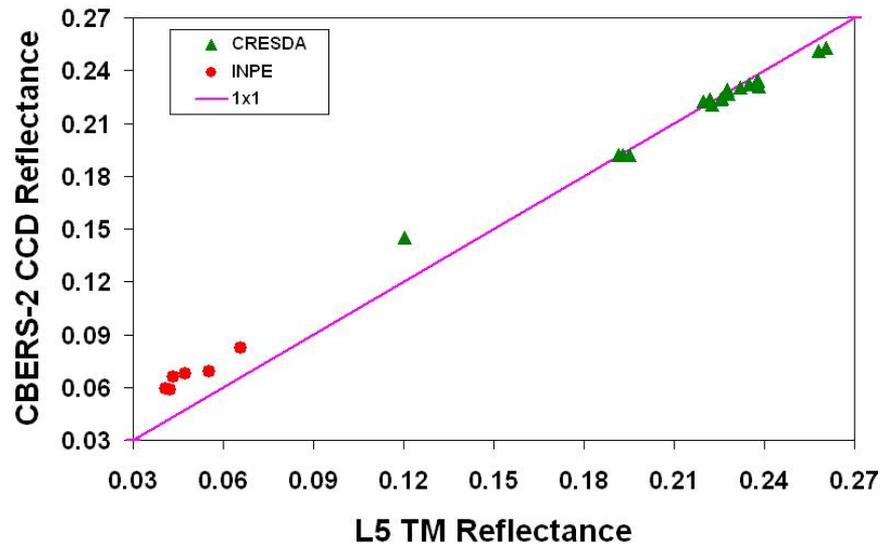
Reflectance obtained from L5 TM and CBERS-2 CCD (Band 2)



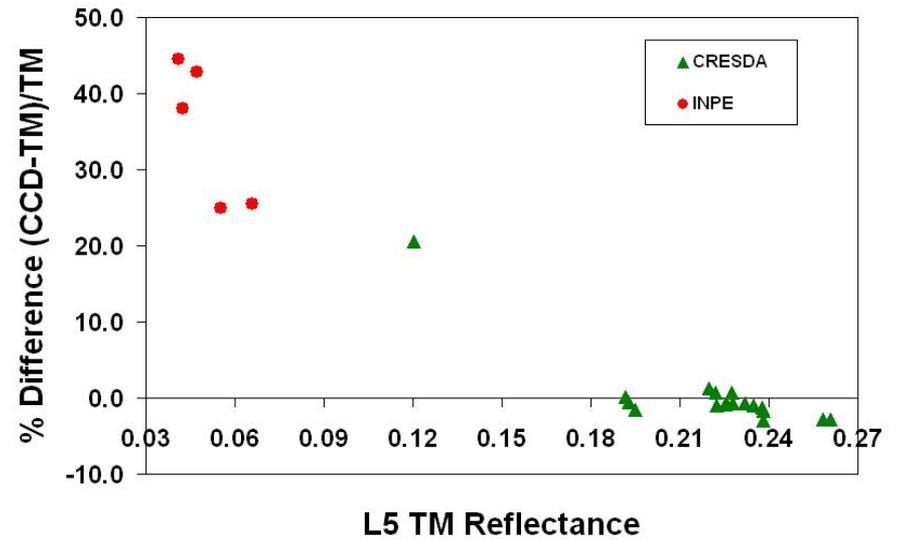
CBERS-2 CCD % difference relative to L5 TM (Band 2)



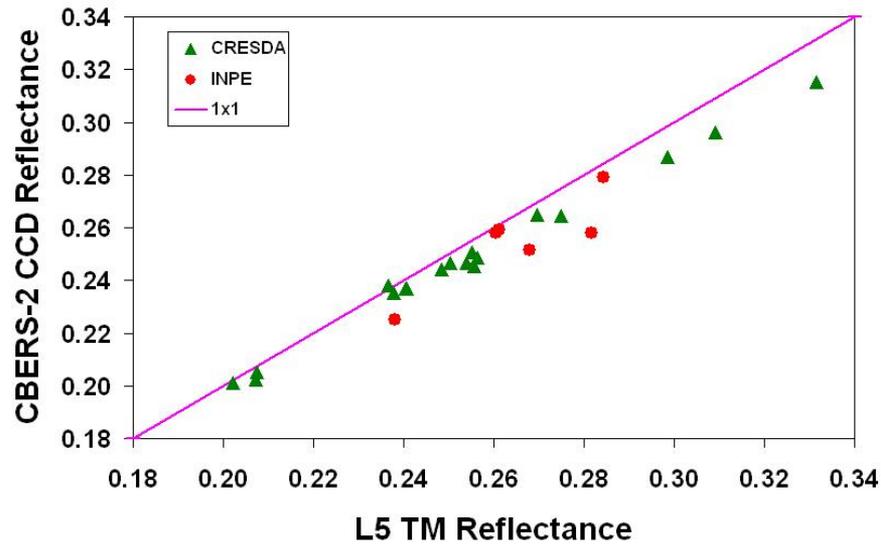
Reflectance obtained from L5 TM and CBERS-2 CCD (Band 3)



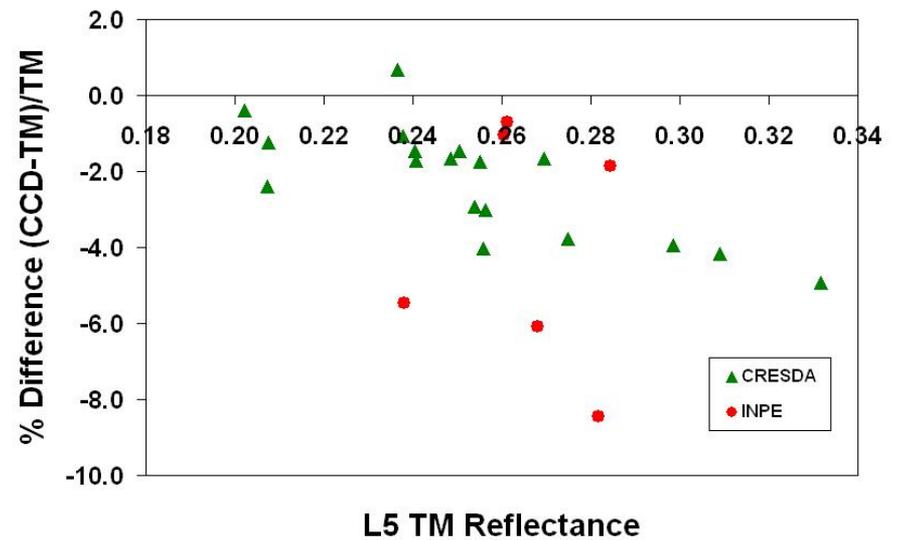
CBERS-2 CCD % difference relative to L5 TM (Band 3)



Reflectance obtained from L5 TM and CBERS-2 CCD (Band 4)



CBERS-2 CCD % difference relative to L5 TM (Band 4)



# Bridging the gap: cross-calibration with other sensors

## ■ Issues

### ■ Temporal Resolution

- Can the sensor provide Landsat-like coverage of the Earth?
- Primarily an operational issue as opposed to a calibration issue

### ■ Spatial Resolution

- Is the footprint similar—FOV, GIFOV, MTF, Nadir looking
- Can appropriately aggregate pixels; not a showstopper

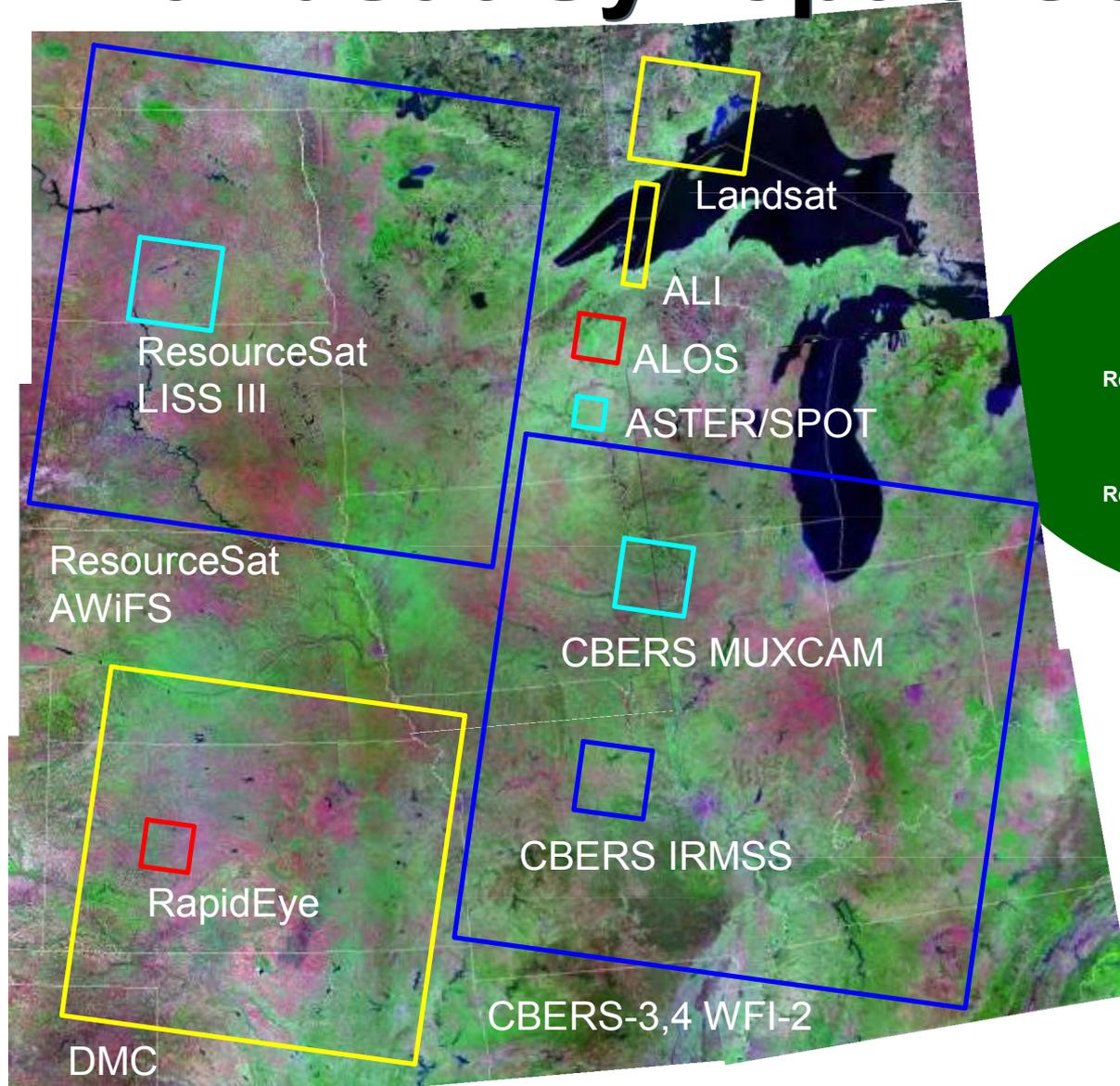
### ■ Radiometric Resolution

- Similar dynamic range
- Many sensors are 10-12 bit, can be advantageous

### ■ Spectral Resolution

- Similar spectral bands—number and location?
- Similar spectral bandpasses?
- Most difficult issue to deal with...

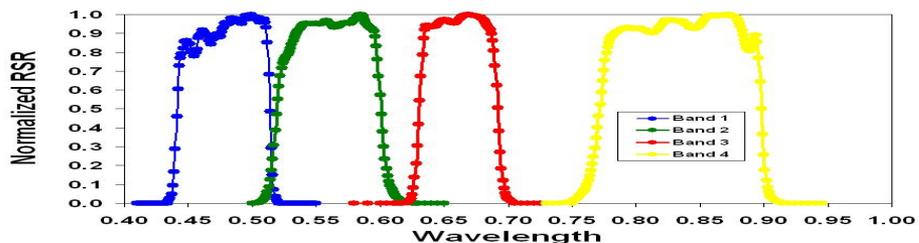
# Landsat Synoptic Coverage



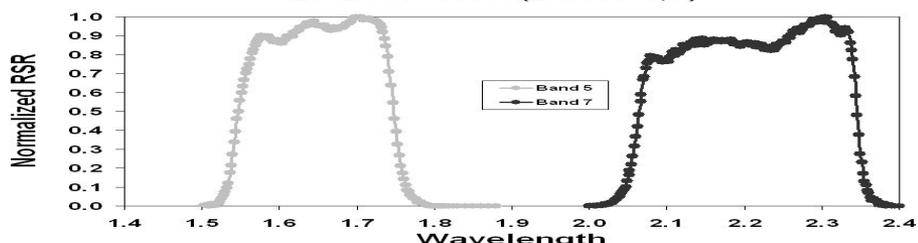
Satellite	Sensor	Ground Sample Distance (m)
RapidEye	REIS	6.5
ALOS	AVNIR	10
CBERS-3,4	MUXCAM	20
SPOT 5	HRG	10/20
Terra	ASTER	15/30/90
ResourceSat-1	LISS III+	23.5
Landsat 7	ETM+	15/30/60
EO-1	ALI	30
DMC	MSDMC	32
ResourceSat-1	AWiFS*	56
CBERS-3,4	WFI-2	73
CBERS-3,4	IRMSS	40/80

Note: For purposes of scene size comparison only. Locations do not represent actual orbital paths or operational acquisitions.

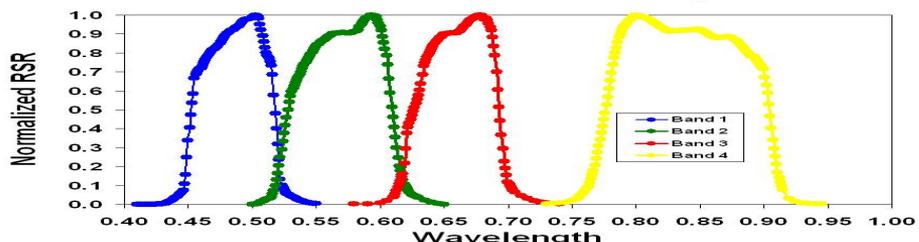
L7 ETM+ RSR (Bands 1,2,3,4)



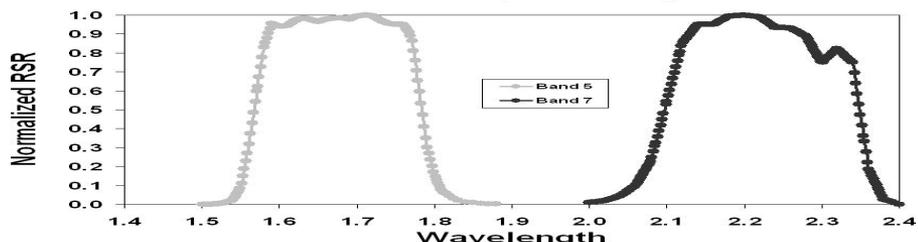
L7 ETM+ RSR (Bands 5,7)



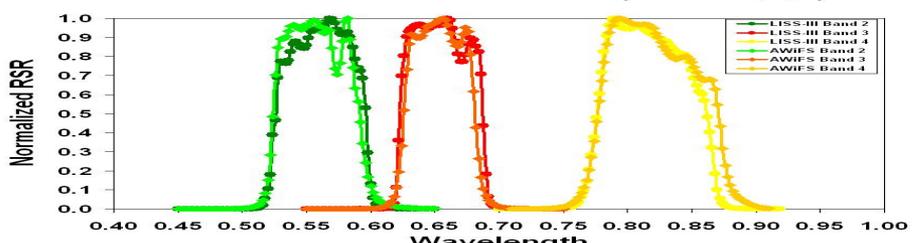
L5 TM RSR (Bands 1,2,3,4)



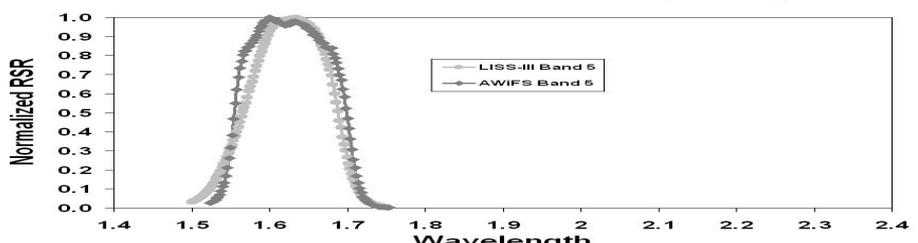
L5 TM RSR (Bands 5,7)



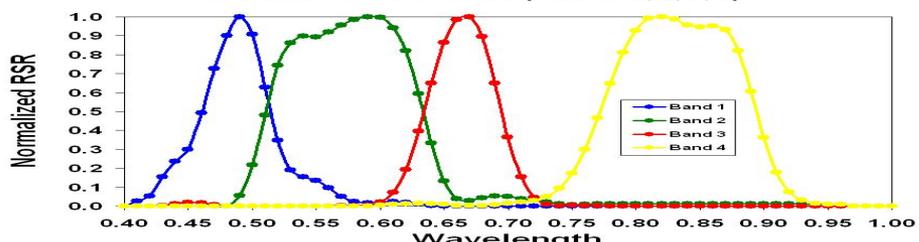
P6 AWiFS and P6 LISS-III RSR (Bands 2,3,4)



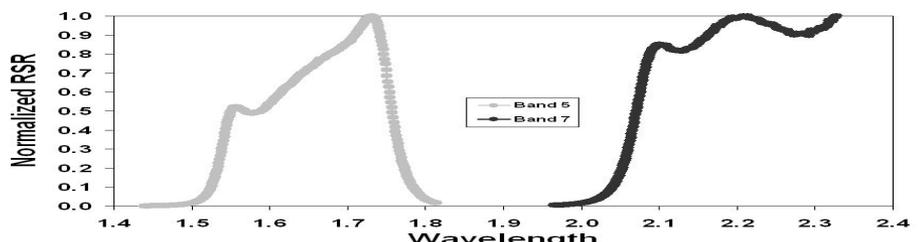
P6 AWiFS and P6 LISS-III RSR (Band 5)



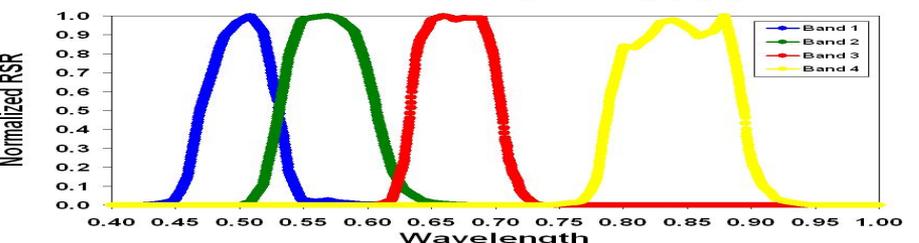
CBERS-2 CCD RSR (Band-1,2,3,4)



CBERS-2 IRMSS RSR (Band-5,7)



CBERS-2B CCD RSR (Band-1,2,3,4)



Normalized Relative Spectral Responses (RSR)

# Bridging the gap: cross-calibration with other sensors

## ■ Actions

- Develop and implement a cross-calibration plan for Landsat (ETM+ and L5 TM) with bridge sensors
  - Identify appropriate bridge sensors
  - Perform detailed cross-calibration using simultaneous collects, vicarious calibration campaigns, and pseudo-invariant sites
  - Begin trending of bridge sensors
- *Clearly, these activities need to begin now!*

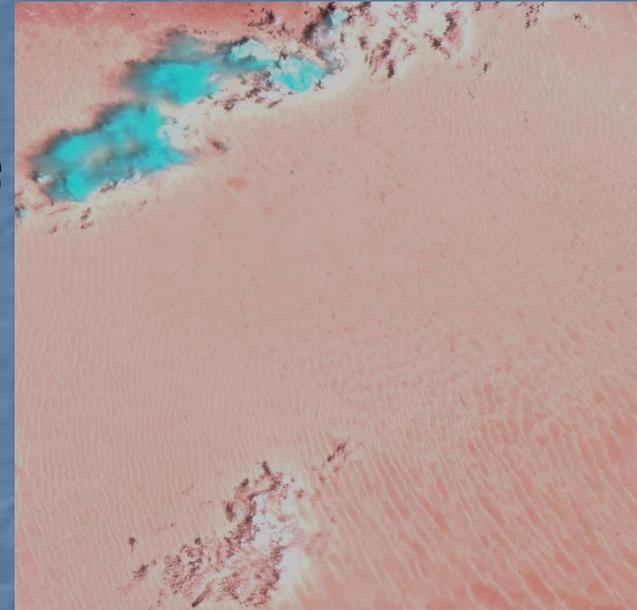
# Bridging the gap: use of pseudo-invariant sites

## ■ Overview of Concept

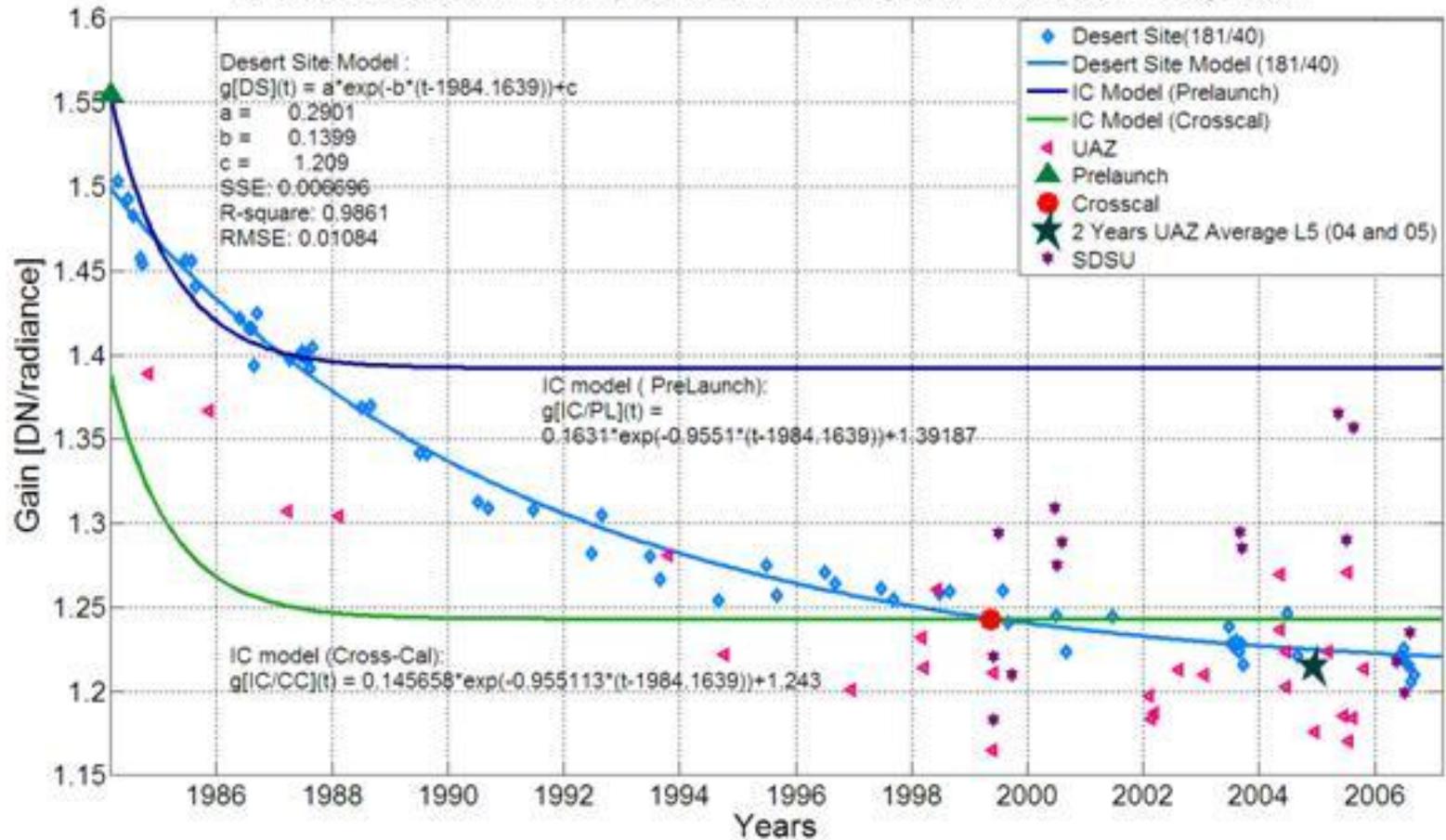
- Many locations on the Earth exhibit 'constant' surface reflectance and BRDF over short and long periods of time
- Locations are homogeneous both spatially and temporally
- Atmospheric effects are minimal, fairly constant, and can be accounted for in a 'reasonably simple' manner
- Current sites are primarily located in deserts
- Pseudo-invariant sites can be used much the same as a standard reflectance panel for monitoring trends in instrument response

# Landsat 5 Radiometric Gain Update Using Multiple Calibration Sources

- Desert Sites used in L5 calibration update
  - Saharan location: Path 181 Row 40
    - Also known as Libya 4
    - Our favorite site in the whole world!
  - Collaboration with CNES
  - Processing steps:
    - Center 3000 x 3000 pixels used
    - Level 0R data
    - Check for saturated pixels (Band 5)
    - Sun angle  $> 48.5^\circ$
    - Earth-sun distance correction
    - Solar Zenith Angle correction
    - Outgassing correction for cold focal bands



Desert Site L5 Gain Model, IC L5 Gain Model, UAZ and SDSU Data, Band1



# Need for a Global, Integrated Network of Calibration Sites

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- **User communities increasingly rely on information products from multiple satellite sensors**
- **Better calibration can result from more post launch calibration, involving standardized measurement protocols, instrumentation, and processing**
- **Field measurements remain resource-intensive activities**
- **Less expensive complementary approaches can provide more frequent calibration updates and enable the monitoring of sensor performance trends, even without surface measurements**
- **Future global monitoring systems, using increasingly complex constellations of satellites with multiple sensors, such as the Global Earth Observation System of Systems (GEOSS), will amplify the need for this initiative to address global societal benefits**

# Well-Established Site Selection Criteria

---

- High spatial uniformity over a large area (within 3 %)
- Surface reflectance greater than 0.3
- Flat spectral reflectance
- Temporally invariant surface properties (within 2 %)
- Horizontal surface with nearly lambertian reflectance
- At high altitude, far from ocean, urban, and industrial areas
- In arid regions with low probability of cloud cover

# Prime Candidate Earth Target Types

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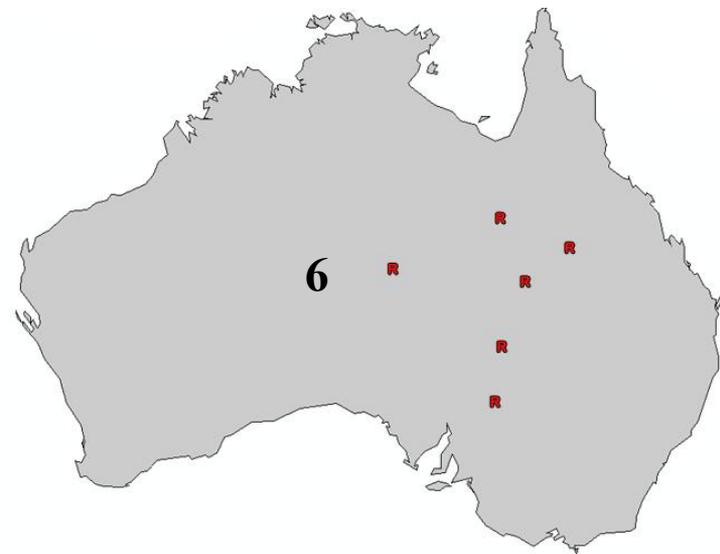
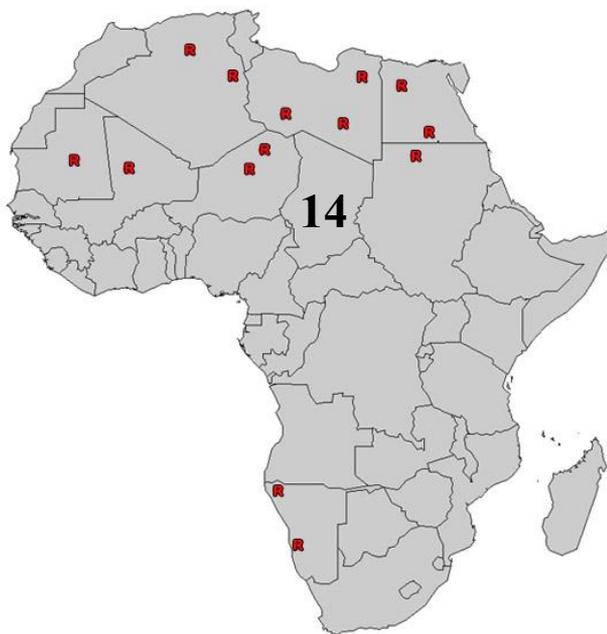
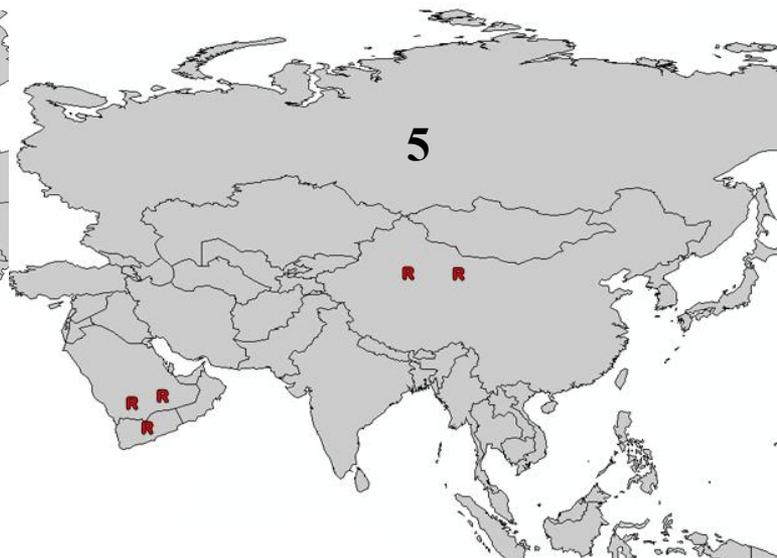
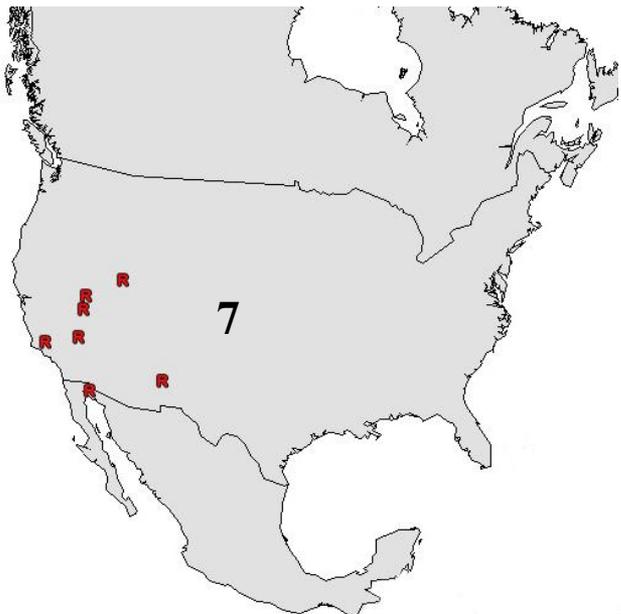
- **Including only playa (dry lakebed), salt flat, and desert sand sites**
- Snow fields are excluded primarily because high surface reflectances are more sensitive to variations in atmospheric particle size distribution and because they are usually located at latitudes characterized by low solar zenith angles
- Vegetation targets are excluded because they are subject to phenological changes as well as strong reflectance anisotropy effects
- Water targets are excluded because low surface reflectances are more sensitive to atmospheric path radiance and because of sun glint
- Other target types (uniform cloud cover, atmospheric scattering, ocean glint) are excluded because more specialized analysis is required, not in keeping with operational use of benchmark test sites

# Initial List of 36 Test Sites for Consideration

---

- Algeria 3
- Algeria 5
- Amburla
- Arabia 1
- Arabia 2
- Barreal Blanco
- Bonneville Salt Flats
- Dunhuang
- Dunrobin
- Egypt 1
- Egypt 2
- Ivanpah Playa
- La Crau
- Lake Frome
- Libya 1
- Libya 2
- Libya 4
- Lunar Lake Playa
- Mali 1
- Mauritania 1
- Namib Desert 1
- Namib Desert 2
- Niger 1
- Niger 2
- Railroad Valley Playa
- Rogers Dry Lake
- Sechura Desert
- Sonoran Desert
- Sudan 1
- Taklamakan Desert
- Tinga Tingana
- Uyuni Salt Flats
- Warrabin
- White Sands
- Winton
- Yemen Desert 1

# Distribution of the 36 Radiometric Sites





## The USGS Remote Sensing Technologies Project

Home About Us Aerial Satellite Instrumentation Collaborations Resources Contact Us

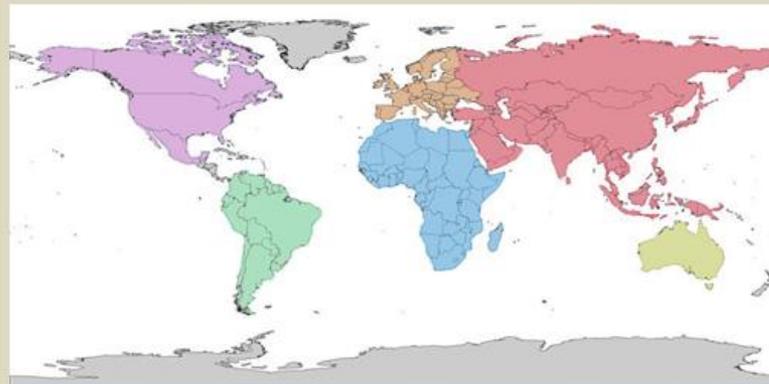
Remote Sensing Technologies - Satellite

### Test Site Catalog

#### Catalog of World-wide Test Sites for Sensor Characterization

In an era when the number of Earth-observing satellites is rapidly growing and measurements from these sensors are used to answer increasingly urgent global issues, it is imperative that scientists and decision-makers rely on the accuracy of Earth-observing data products. The characterization and calibration of these sensors are vital to achieve an integrated Global Earth Observation System of Systems (GEOSS) for coordinated and sustained observations of Earth. The U.S. Geological Survey (USGS), as a supporting member of Committee on Earth Observation Satellites (CEOS) and GEOSS, worked with partners around the world to establish an online Catalog of prime candidate world-wide test sites for the post-launch characterization and calibration of space-based optical imaging sensors. The online Catalog provides easy public web site access to this vital information for the global community. Through greater access to and understanding of these vital test sites and their use, the validity and utility of information gained from Earth remote sensing will continue to improve.

Contact Information: Gyanesh Chander [gchander@usgs.gov](mailto:gchander@usgs.gov) or Gregory L. Stensaas [stensaas@usgs.gov](mailto:stensaas@usgs.gov)



Choose A Radiometric St

Choose A Geometr St

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[Geometry Sites](#)

[Acronyms](#)

[References](#)

# Bridging the gap: use of pseudo-invariant sites

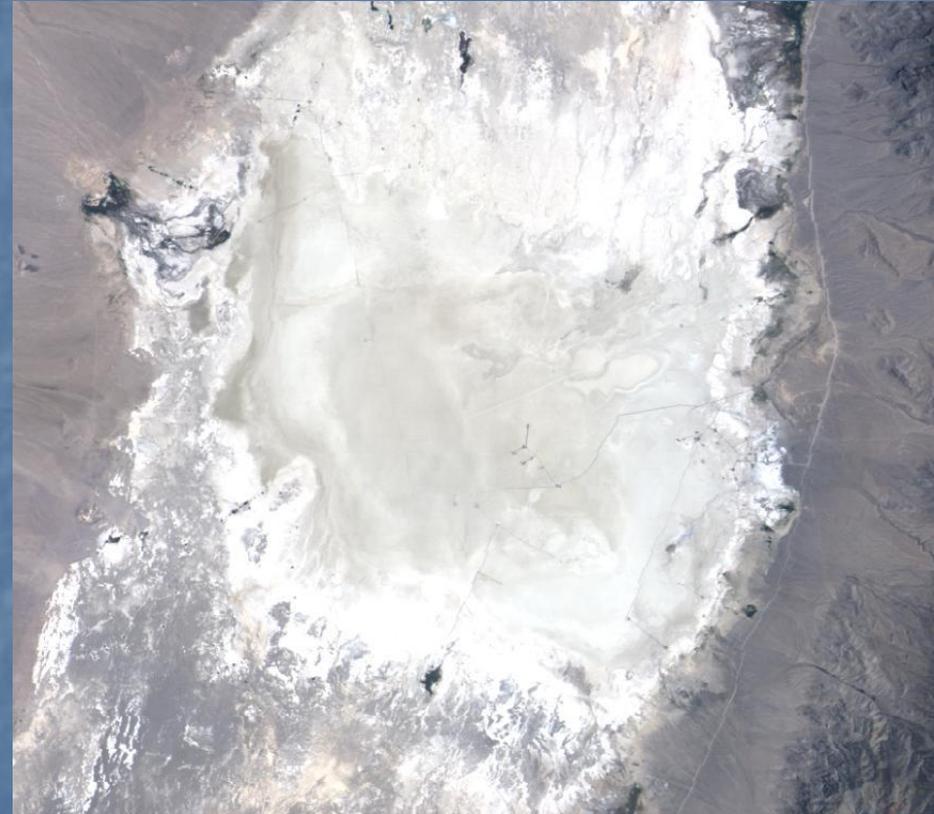
- Relationship to vicarious calibration
  - Vicarious calibration fundamentally provides additional data points for sensor calibration
  - Additionally, use of pseudo-invariant sites is greatly enhanced through use of in-situ information
    - This information is typically not available due to the nature of most pseudo-invariant sites
  - Suggests use of smaller, more accessible, sites that are also used for vicarious calibration
    - Railroad Valley (RRV) playa is a good example
    - Initial results show usefulness of this method at RRV

# Example of Vicarious Calibration: University of Arizona L5 TM Gain Estimates

Date	Site	Band 1	Band 2	Band 3	Band 4	Band 5	Band 7
13-May-04	RRV	1.237	0.644	0.916	1.102	7.930	14.980
23-Jun-04	Ivanpah	1.224	0.651	0.908	1.095	7.922	14.863
16-Dec-04	Ivanpah	1.176	0.639	0.906	1.096	8.180	14.435
17-Jun-05	RRV	1.185	0.642	0.915	1.113	8.073	15.185
12-Jul-05	Ivanpah	1.271	0.638	0.911	1.106	7.965	14.905
19-Jul-05	RRV	1.171	0.634	0.902	1.094	7.906	14.876
13-Aug-05	Ivanpah	1.184	0.622	0.885	1.076	7.712	14.074
23-Oct-05	RRV	1.213	0.655	0.927	1.104	8.081	14.718
Average		1.208	0.641	0.909	1.098	7.971	14.755
Std. Dev.		0.035	0.010	0.012	0.011	0.142	0.349
%Std. Dev.		2.90	1.59	1.35	1.01	1.78	2.36

# Use of Small Pseudo-Invariant Sites

- Railroad Valley (RRV), NV Information
  - 38.504° N 115.692° W
  - Path/Row: 40/33
  - Elevation 1.3 km ASL
  - Univ. of AZ vicarious calibration site
- Current L5-TM absolute gain model (LUT07) was developed through analysis of large African pseudo-invariant desert sites.
- Many satellite imaging sensors have a limited archive of large desert sites available for analysis



Railroad Valley – June 24, 1996

# Experimental Procedure- TMIAS Processing

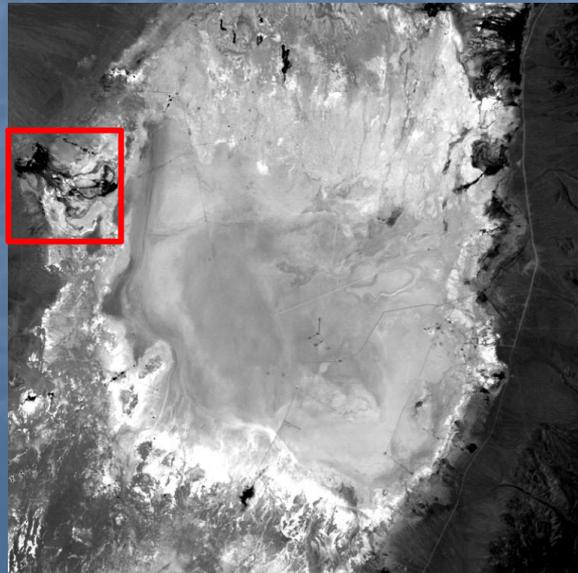
- 31 scenes obtained from TMIAS 8.0.0 (22) and 8.0.1 (9)
  - ME/SCS corrected
  - Bias Subtracted
  - Relative gain corrected
  - Not converted to radiance
- All scenes used in study were summer scenes (June-Sept.)
- No scenes after switch to bumper mode due to correlation difficulties

Acquisition Dates	
8/13/1985	7/18/1993
6/13/1986	6/19/1994
6/29/1986	7/5/1994
7/31/1986	6/22/1995
7/2/1987	7/24/1995
7/20/1988	6/24/1996
9/6/1988	7/13/1997
7/23/1989	7/29/1997
8/24/1989	7/16/1998
6/8/1990	8/1/1998
8/27/1990	6/1/1999
6/11/1991	7/3/1999
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7/31/1992	6/22/2001
8/16/1992	7/24/2001
7/2/1993	

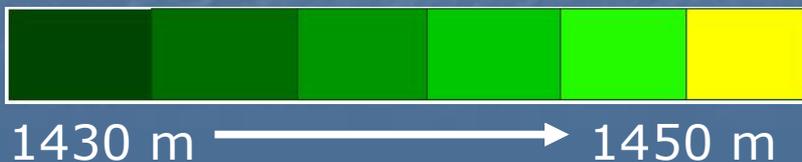
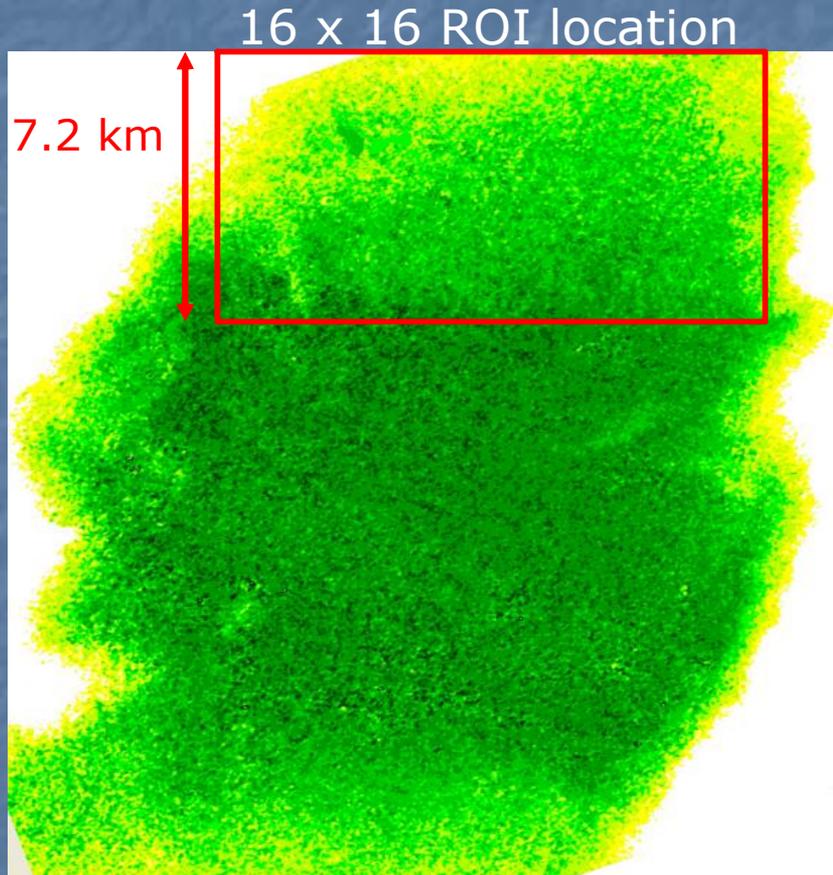
# Experimental Procedure-

## Local Processing – Corrections/Correlation

- Standard Earth-Sun Distance Correction
- Standard Sun Elevation Angle Correction
- Correlation of each scene with reference
  - June 24, 1996 reference image
    - 800 x 800 pixel image of RRV



# Experimental Procedure- Local Processing – Regions of Interest



- DEM\* of RRV shows gradual elevation change of 15-20 m along northern 7.2 km of RRV.
- This gradual slope is desired for reducing the possibility of standing water.

\*Shuttle Radar Topography Mission (SRTM) data

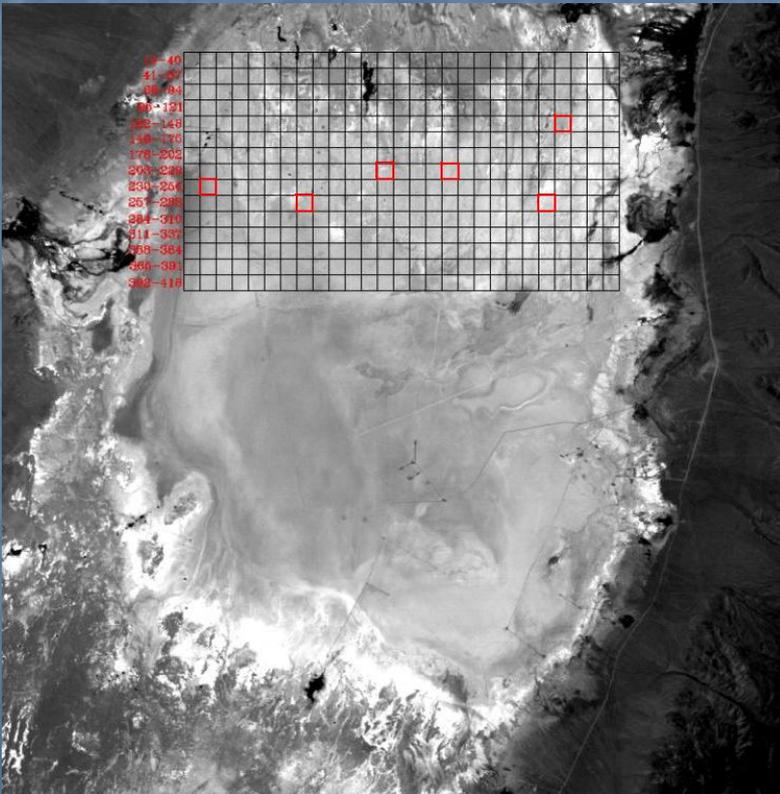
# Experimental Procedure-

## Local Processing – Regions of Interest

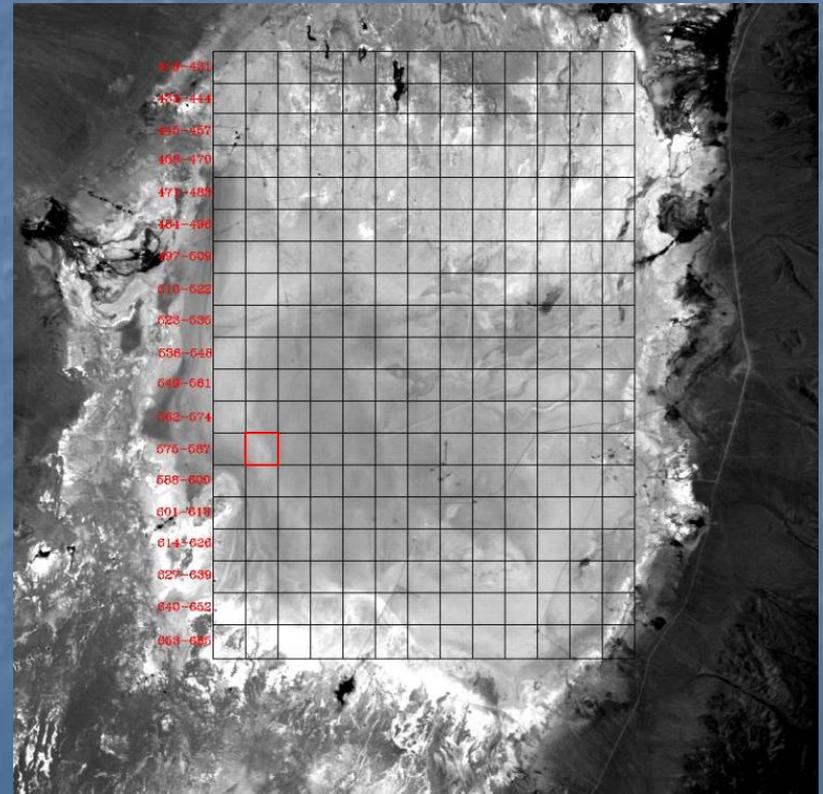
- As a first cut analysis, visual examination of the data was used to identify seven ROIs
  - The desired result of the study is a lifetime gain model that resembles LUT07.
  - The following seven regions most closely resembled this model.

# Experimental Procedure- Local Processing – Regions of Interest

- 1- 32 x 32 and 6- 16 x 16 pixel regions chosen for the absolute gain analysis

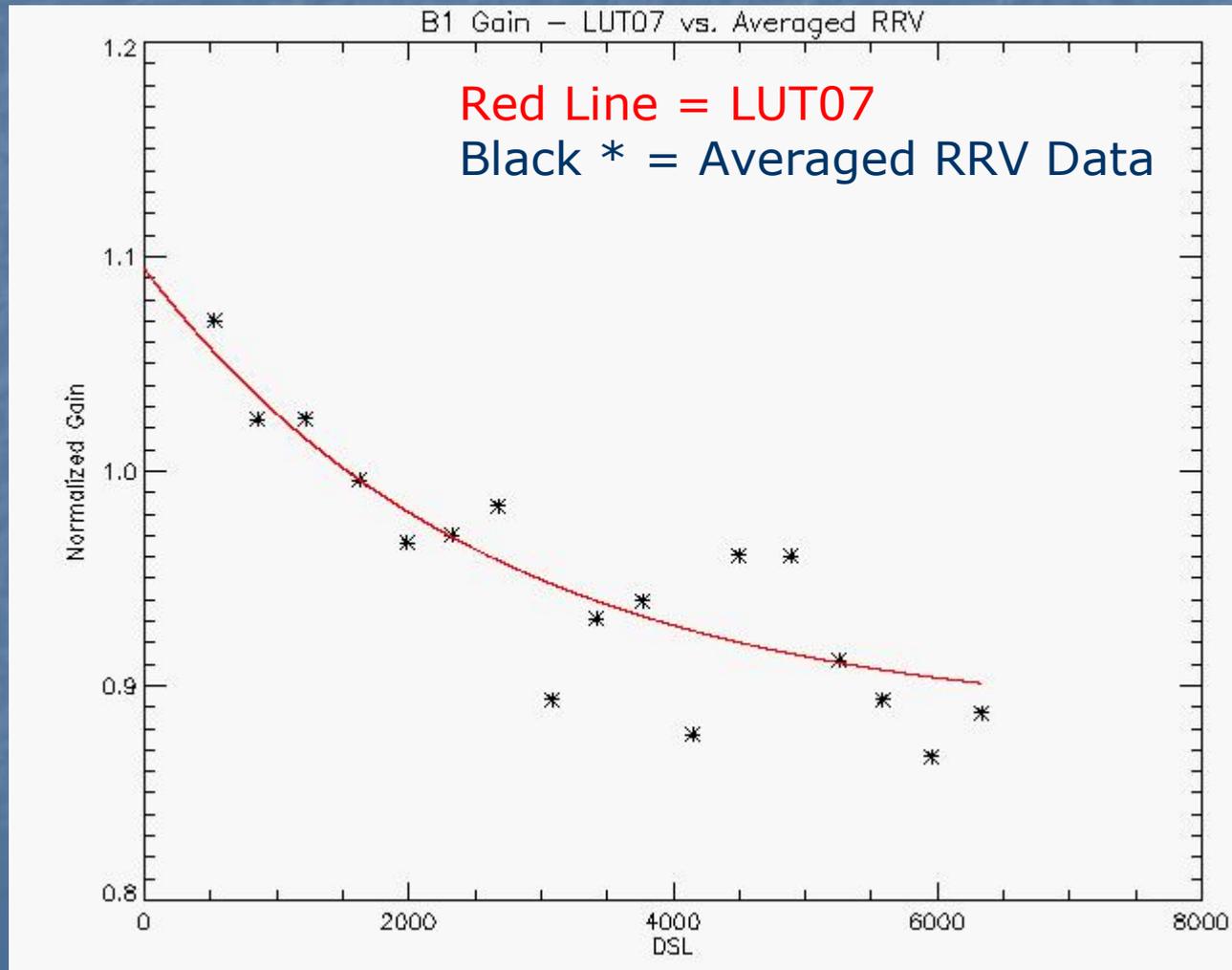


16 x 16 regions



32 x 32 regions

# Results and Analysis- L5TM - Band 1 - Normalized Gain



# Bridging the gap: use of pseudo-invariant sites

## ■ Issues

- Just how invariant are pseudo-invariant sites?
  - Spatially as well as temporally
- Approach is not suited for absolute calibration of sensors
  - But has shown excellent capabilities for long term trending of sensors
- Selection of preferred sites still in its initial stages
- Several effects remain to be addressed
  - BRDF, atmosphere, spectral stability, use of small sites

# Bridging the gap: use of pseudo-invariant sites

## ■ Actions

- Develop and implement a plan for use of pseudo-invariant sites as a calibration tool during the impending Landsat data gap
  - Determine appropriate sites
  - Begin stability assessment of the sites
    - Spatially, temporally, spectrally
    - ALI/Hyperion tasked for Sahara sites now
      - *>100 Libya 4 Hyperion scenes have been collected since 2004!*
    - In-situ measurements where possible
  - View each site with Landsat instruments at each opportunity
  - View each site with bridge sensors at each opportunity
  - Begin analysis of second order effects to improve trending accuracy
    - RIT and SDSU have begun initial investigations
- *Clearly, these activities need to begin now*

# Consistent Landsat Calibration: ETM+ to OLI

## ■ Summary

- In a *perfect* world, there will be no data gap. Comprehensive systems are in place or being designed that will ensure a consistent radiometric calibration of ETM+ through OLI
- In a *real* world, a data gap will likely occur
  - Initial work has been done suggesting mechanisms exist to bridge the gap
  - Cross-calibration with 'bridge sensors' can provide a limited capability to ensure consistent calibration and data collection of the Earth's surface
  - Use of pseudo-invariant sites for trending, along with vicarious calibration and bridge sensors can provide a second approach to bridging the gap
- It is imperative to take action now to mitigate the effects of a data gap
  - Develop and implement a cross-calibration plan for Landsat (ETM+ and L5 TM) with bridge sensors
  - Develop and implement a cross-calibration plan for Landsat (ETM+ and L5 TM) with pseudo-invariant sites
- A recommendation from the Landsat Science Team will help to insure that this happens!