Evaluation and Comparison of the IRS-P6 AWiFS and the Landsat Sensors

NASA LCLUC Science Team Meeting

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Gyanesh Chander, SGT at USGS EROS

Dennis L. Helder, SDSU

Gregory L. Stensaas, USGS EROS

Thomas R. Loveland, USGS EROS

Brian L. Markham, NASA GSFC

James R. Irons, NASA GSFC

U.S. Department of the Interior

U.S. Geological Survey

Landsat Data Gap!

- The EO community is facing a probable gap in Landsat data continuity before LDCM data arrive in Dec 2012

- A data gap will interrupt a 38+ yr time series of land observations

- Landsat data are used extensively by a broad & diverse users
  - Landsat 5 limited lifetime/coverage
  - Degraded Landsat 7 operations
  - Either or both satellites could fail at any time: both beyond design life

- Urgently need strategy to reduce the impact of a Landsat data gap
  - Landsat Program Management must determine utility of alternate data sources to lessen the impact of the gap & feasibility of acquiring data from those sources in the event of a gap

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Primary Objectives

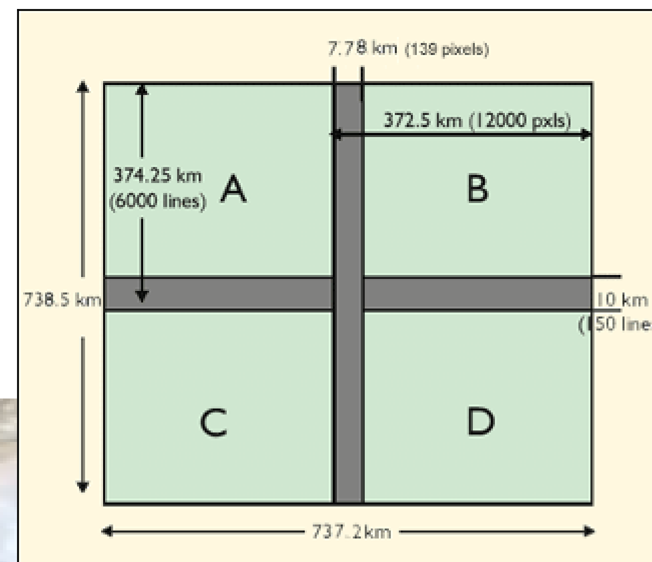
- **Cross-calibration**
  - Worldwide Test Site Catalog
  - Coincident Imaging Tool
  - Cross-calibration Results
  - Long Term Stability Monitoring
- **Sensitivity Studies**
  - Geometric Registration
  - Spectral Profiles
  - Spatial Resolution
  - Radiometric Resolution
  - BRDF & Atmospheric Effects (SSC)
- **Application Evaluation**
  - Multi-Resolution Land Characteristics Consortium (MRLC)
  - Monitoring Trends in Burn Severity (MTBS)
  - LANDFIRE

AWiFS Sensor Overview

Platform	Landsat 5	Landsat 7	Terra	IRS-P6
Sensor	TM	ETM+	MODIS	AWiFS
Number of bands	7	8	36	4
Spatial resolution	30 m, 120 m	15 m, 30 m, 60 m	250 m, 500 m, 1 km	56 m (nadir), 70 m (edge)
Swath	183 km	183 km	2330 km	740 km
Spectral coverage	0.4~12.5 µm	0.4~12.5 µm	0.4~14 µm	0.52~1.7 µm
Pixel quantization	8 bit	8 bit	12 bit	10 bit
Launch date	1-Mar-84	15-Apr-99	18-Dec-99	17-Oct-03
Orbit type	Sun synchronous	Sun synchronous	Sun synchronous	Sun synchronous
Equatorial Crossing Time	10:00 AM	10:00 AM	10:30 AM	10:30 AM
Altitude	705 km	705 km	705 km	817 km

AWiFS VITAL FACTS:

- **Instrument: Pushbroom**
- **Bands (4): 0.52-0.59, 0.62-0.68, 0.77-0.86, 1.55-1.70 µm**
- **Spatial Resolution: 56 m (near nadir), 70 m (near edge)**
- **Radiometric Resolution: 10 bit**
- **Swath: 740 km**
- **Repeat Time: 5 days**
- **Design Life: 5 years**



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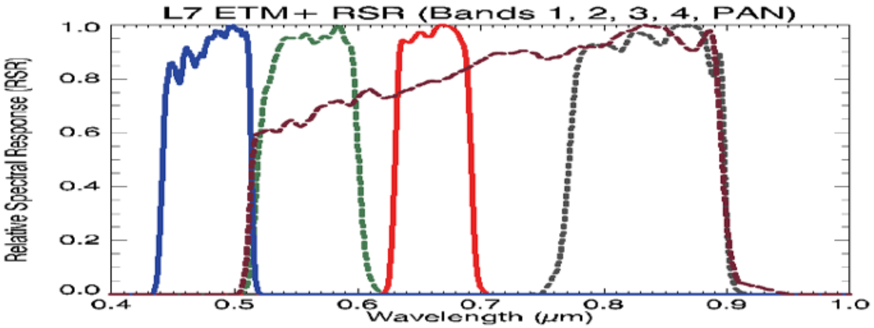
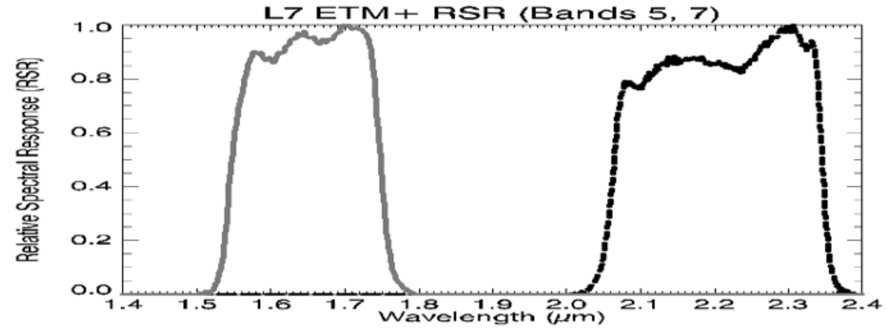
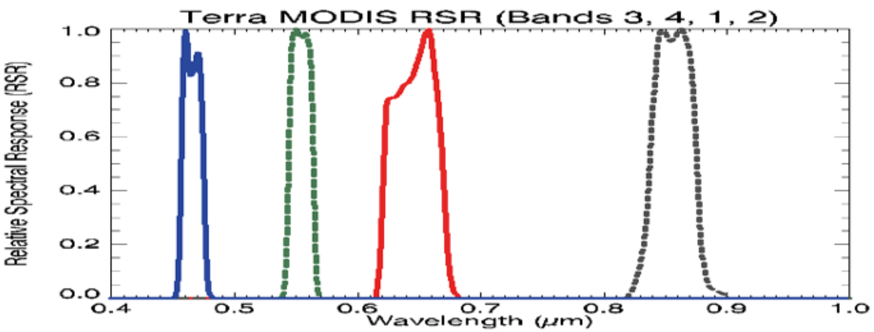
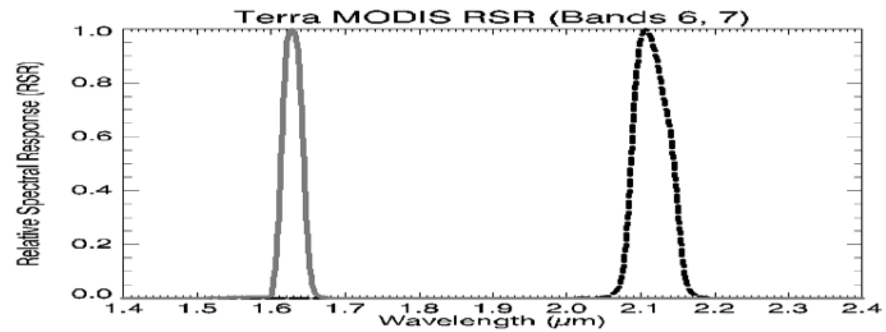
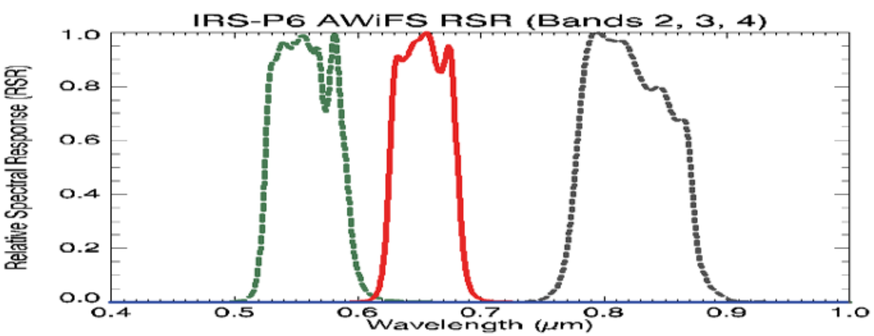
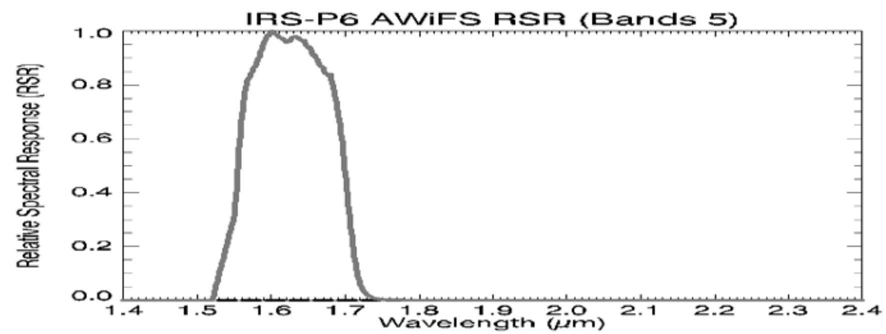


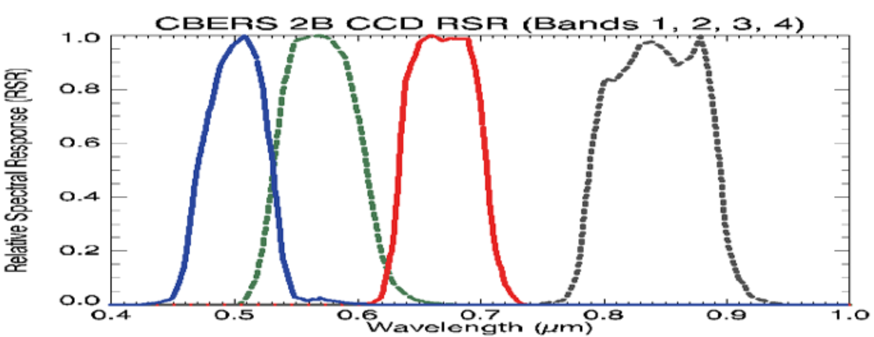












Relative Spectral Response (RSR)

Cross-Calibration Methodology

- Co-incident image pairs from the two sensors were compared

- The cross-cal was performed using image statistics from large common areas observed by the two sensors
  - Define Regions of Interest over identical homogenous regions
    - All ROIs have about 400 x 400 Landsat pixels (160000 points) and 214 x 214 AWiFS pixels (45796 points)
    - Bright and dark regions were selected to obtain a maximum coverage over each sensor's dynamic range
    - All the saturated pixels and SLC-off pixels were discarded
  - Calculated the mean and standard deviation of the ROIs
  - Converted the satellite DN to TOA reflectance

- Performed a linear fit between the satellites to calculate the cross-cal gain and bias

Conversion to at-sensor spectral radiance (Q_{cal}-to- L_λ) & reflectance

- **IRS-P6 AWiFS sensor**

$$L_\lambda = \left(\frac{LMAX_\lambda - LMIN_\lambda}{Q_{cal\max} - Q_{cal\min}}\right)(Q_{cal} - Q_{cal\min}) + LMIN_\lambda$$

$$L_\lambda = \left(\frac{LMAX_\lambda}{Q_{cal\max}}\right)(Q_{cal})$$

$$Q_{cal<8>} = Q_{cal<10>}\left(\frac{255}{1023}\right)$$

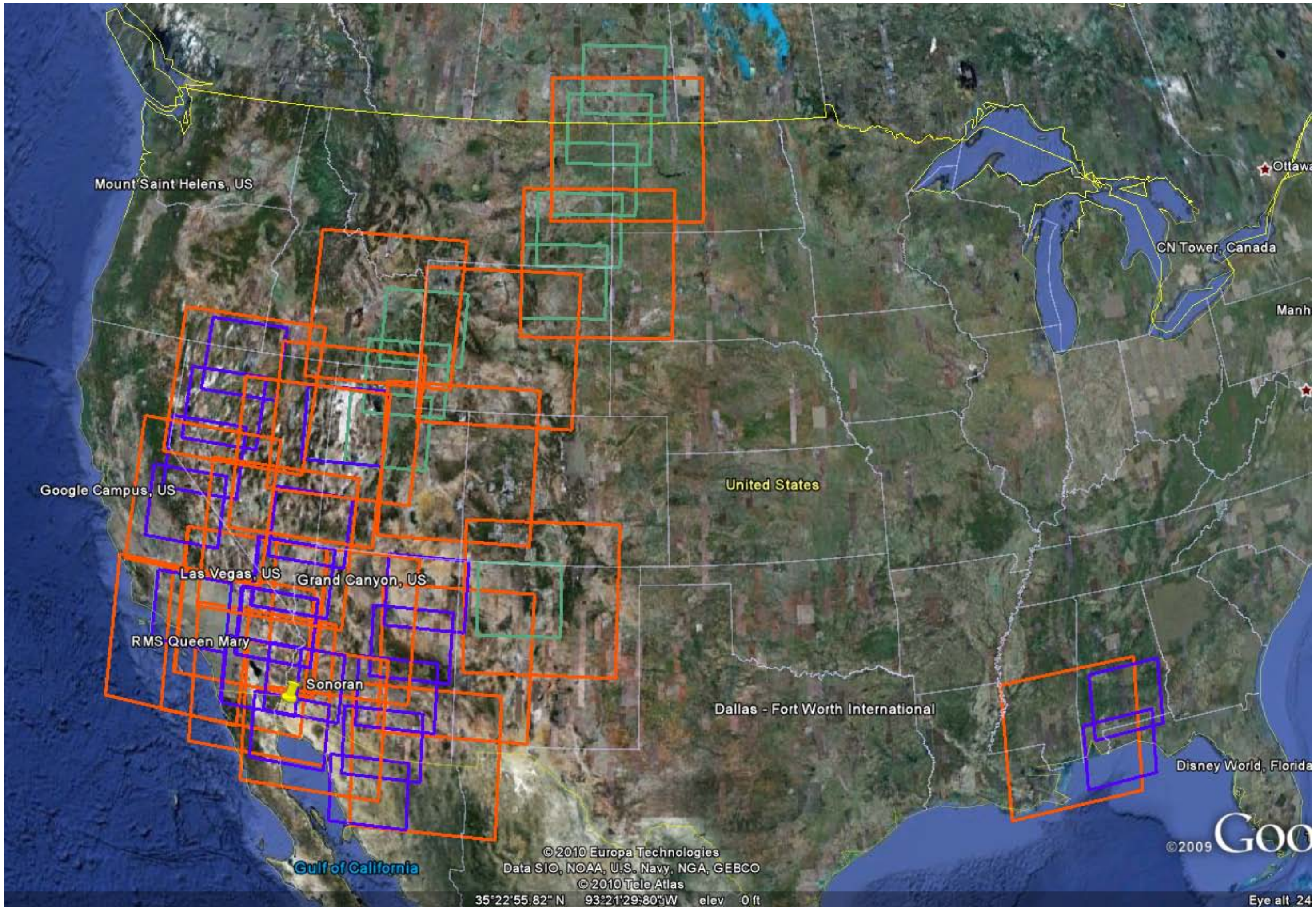
  - Q_{calmax} is 1023 for 10-bit AWiFS
  - Q_{calmax} is 255 for 8-bit AWiFS products (USDA)

- **AWiFS-B camera (B&D quadrant scenes):**
  - 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**
  - Same numbers for AWiFS-A camera (A&C quadrant scenes)

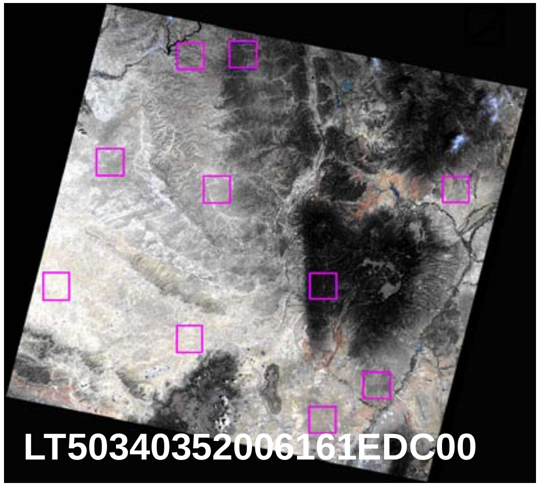
IRS-P6 AWiFS $ESUN_\lambda$ [Units: W/m^2 µm]						
Band	**CHKUR**	**Thuillier**	**SIRS**	**WRC**	**Kurucz**	**Neckel**
2	1852	1820	1845	1850	1826	1854.7
3	1605	1579	1545	1606	1589	1556.4
4	1114	1105	1055	1118	1073	1082.4
5	235.6	240.6	242.9	241.1	236.0	239.84

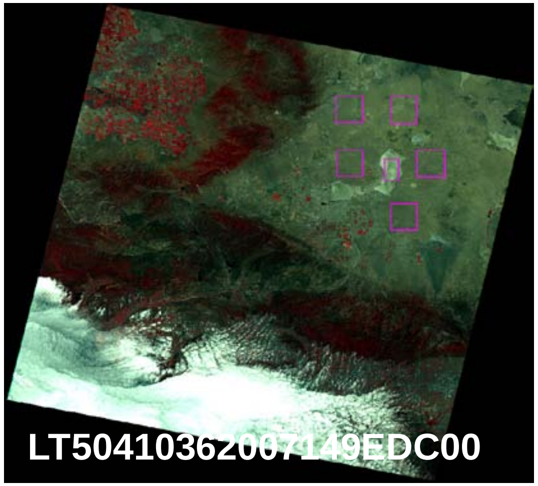
$$\rho_\lambda = \frac{\pi \cdot L_\lambda \cdot d^2}{ESUN_\lambda \cdot \cos\theta_s}$$

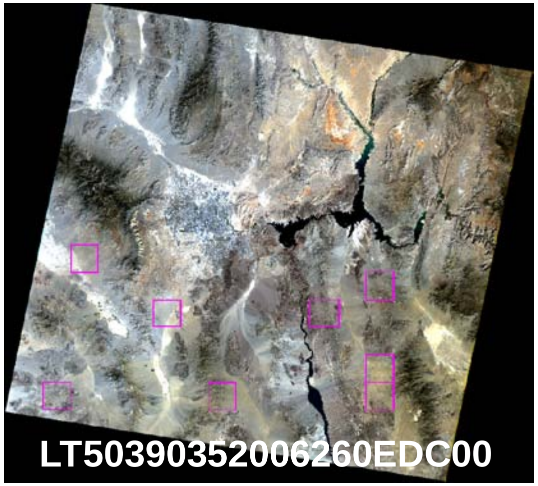
L5 TM, L7 ETM+ & P6 AWiFS Image Pairs

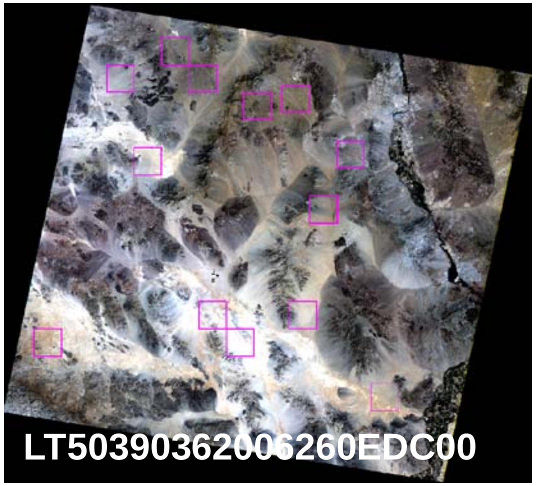


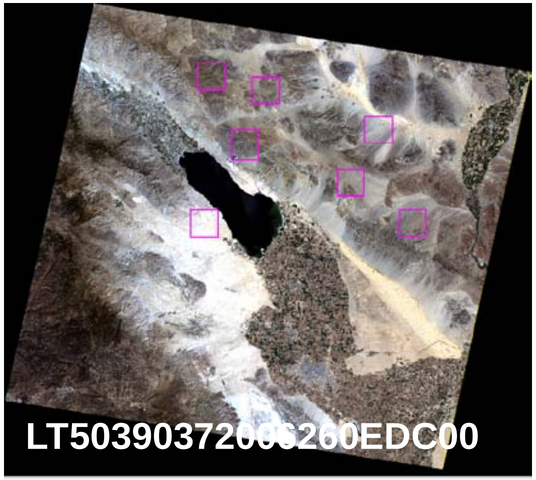
L5 TM and AWiFS-BD Quads (ROI)

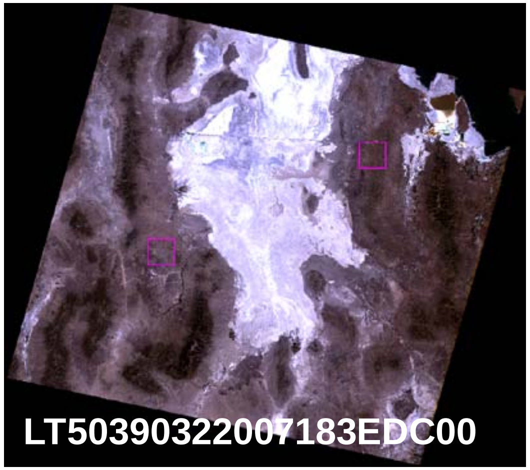




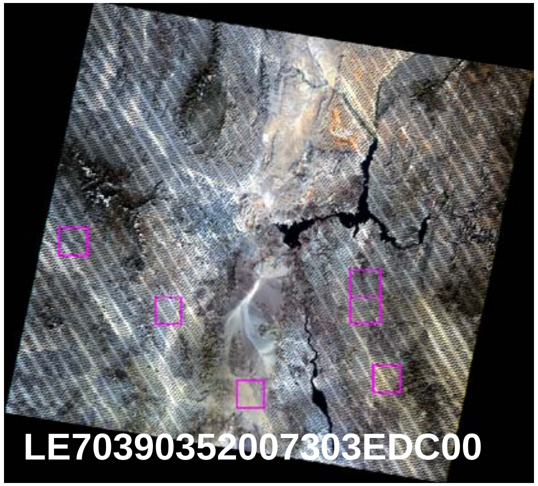


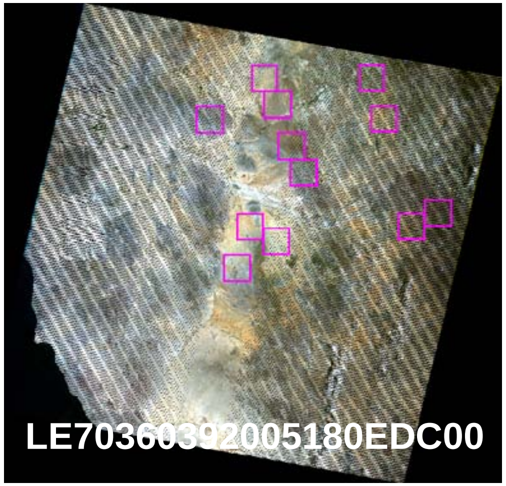


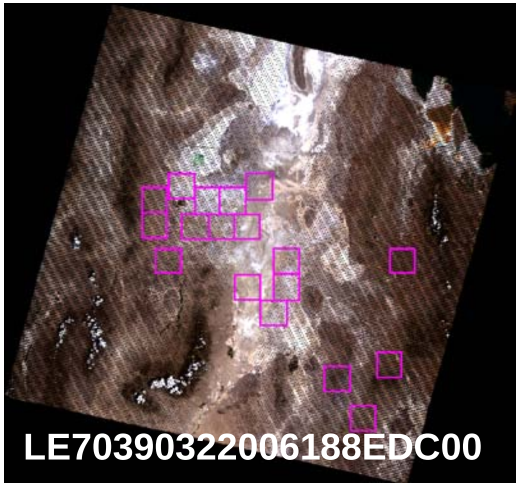


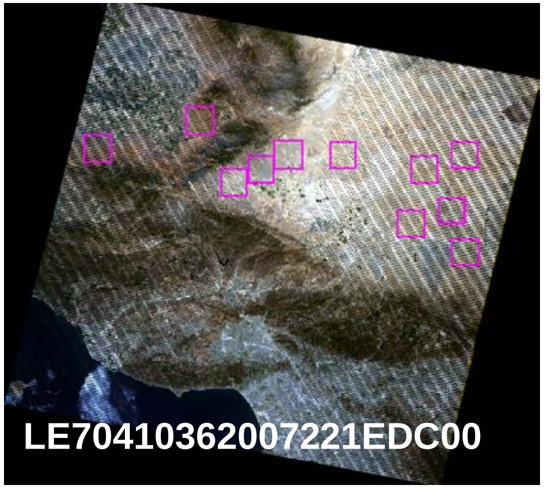


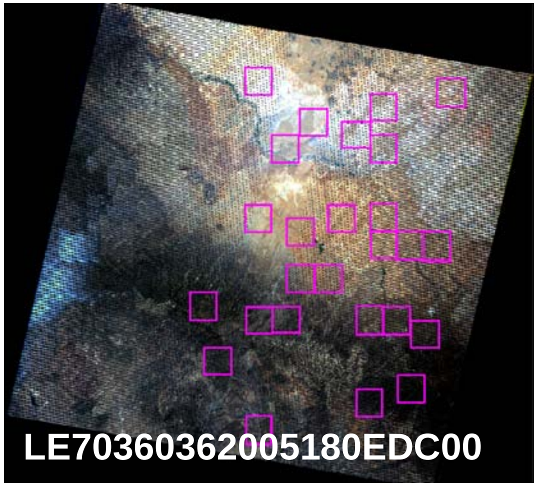
L7 ETM+ and AWiFS-BD Quads (ROI)

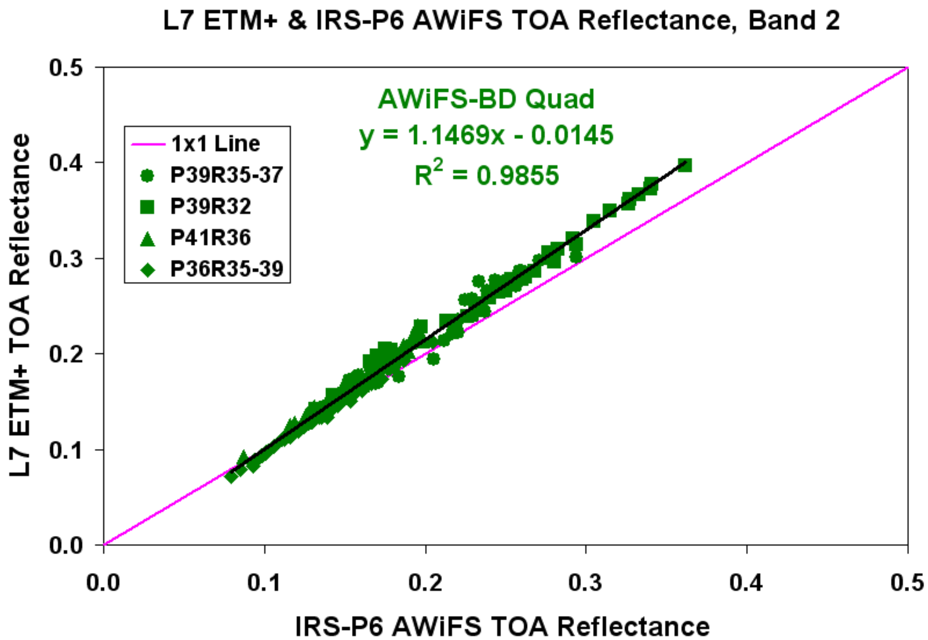


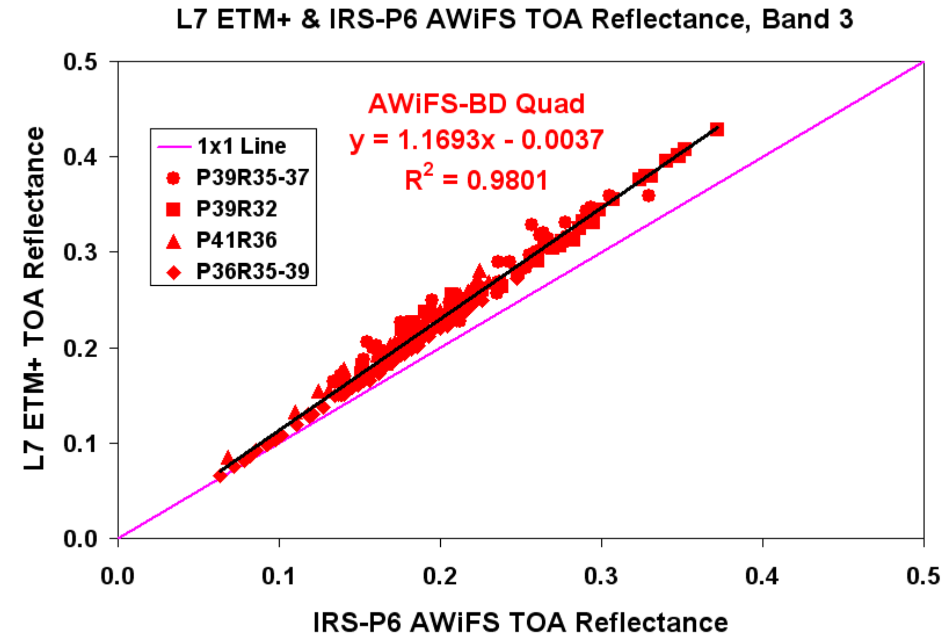


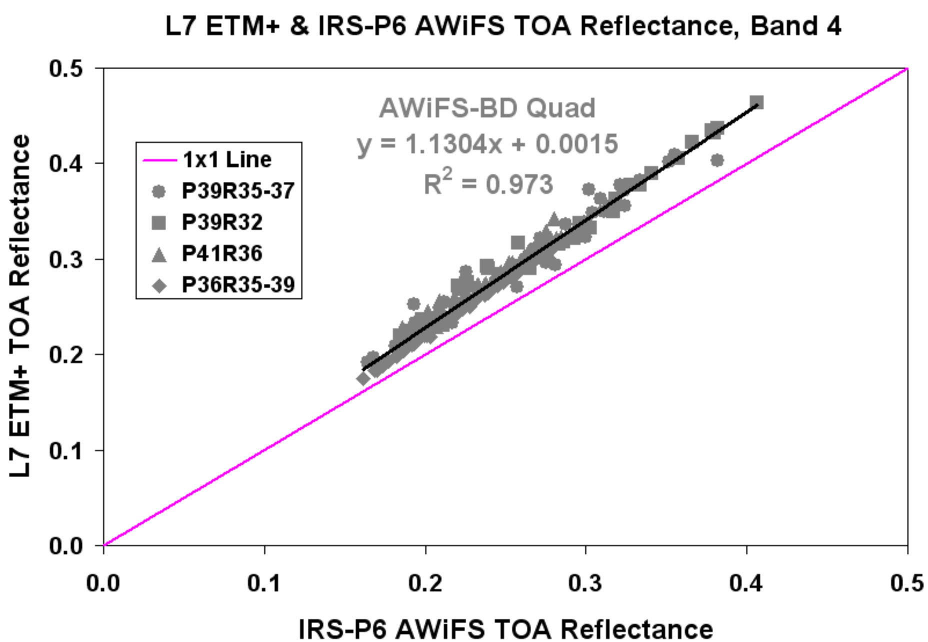


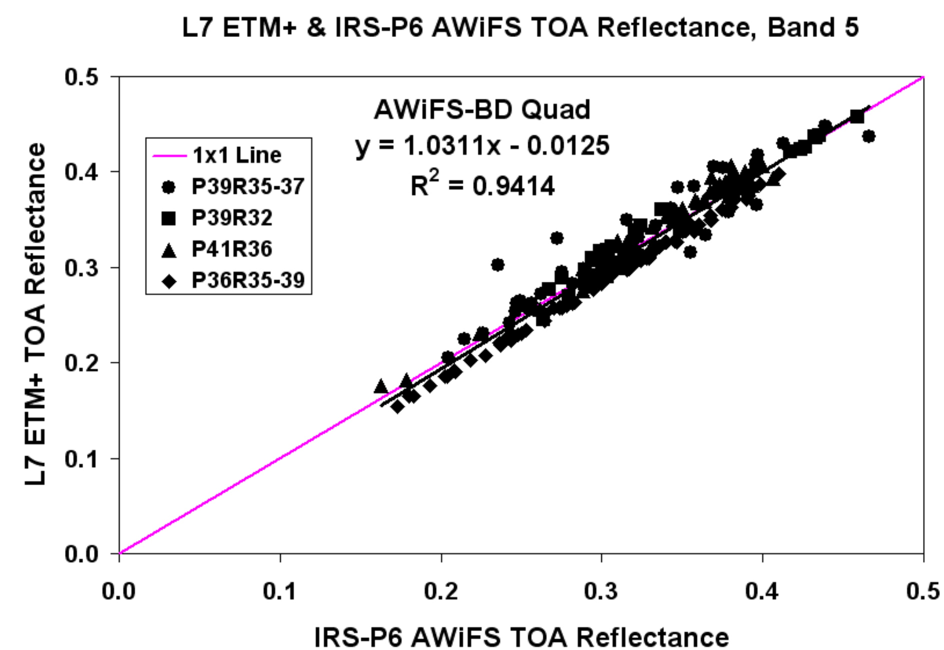


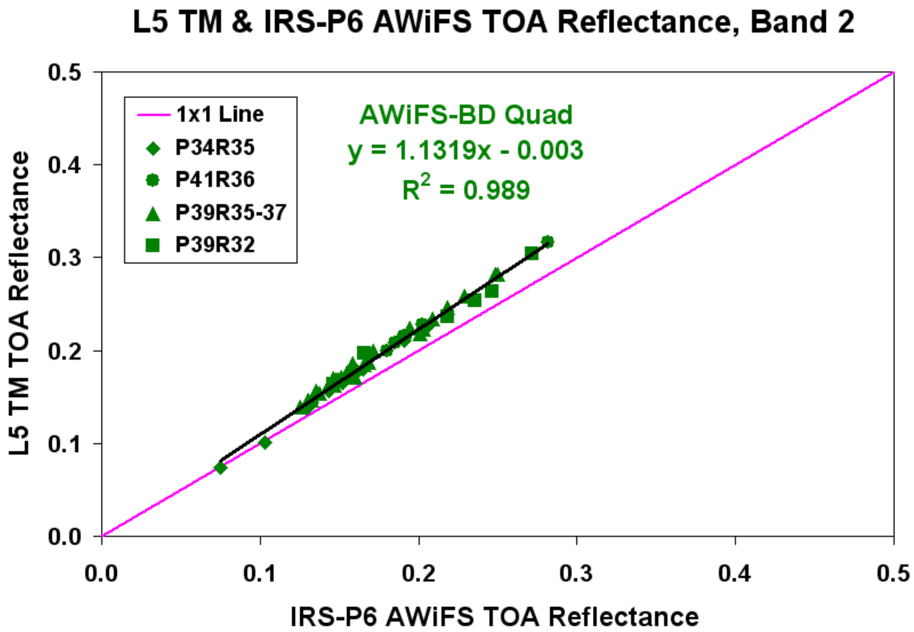


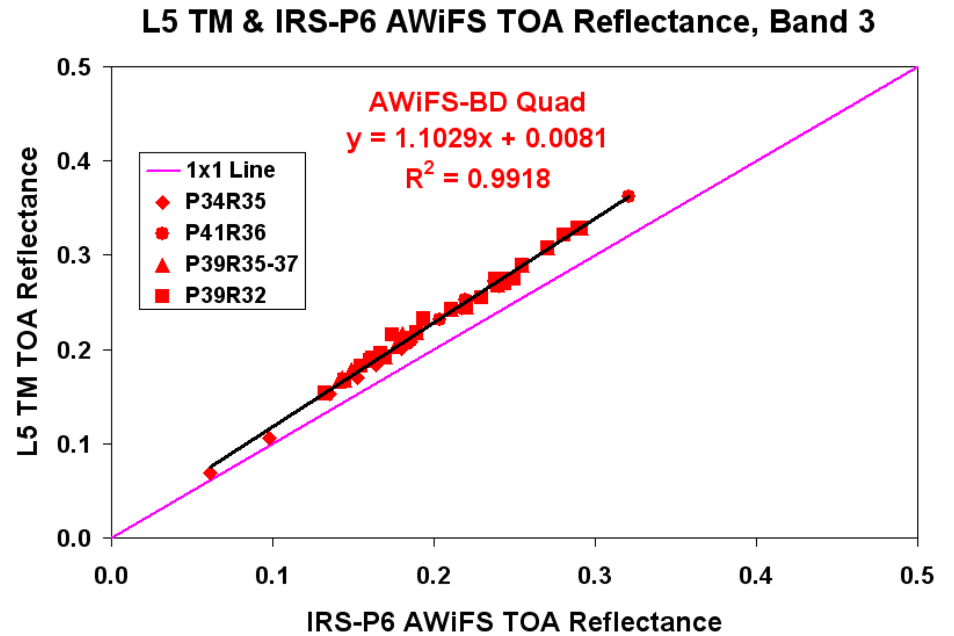

L7 ETM+ & IRS-P6 AWiFS TOA Reflectance, Band 2
AWiFS-BD Quad
y = 1.1469x - 0.0145
R^2 = 0.9855
1x1 Line
P39R35-37
P39R32
P41R36
P36R35-39
L7 ETM+ TOA Reflectance
IRS-P6 AWiFS TOA Reflectance
0.0
0.1
0.2
0.3
0.4
0.5

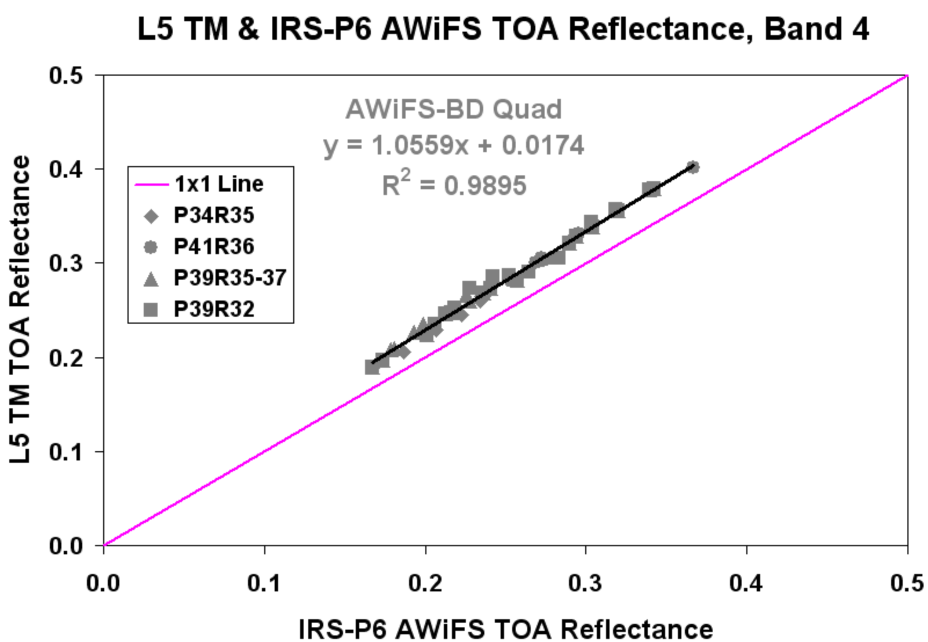

L7 ETM+ & IRS-P6 AWiFS TOA Reflectance, Band 3
AWiFS-BD Quad
y = 1.1693x - 0.0037
R^2 = 0.9801
1x1 Line
P39R35-37
P39R32
P41R36
P36R35-39
L7 ETM+ TOA Reflectance
IRS-P6 AWiFS TOA Reflectance
0.0
0.1
0.2
0.3
0.4
0.5

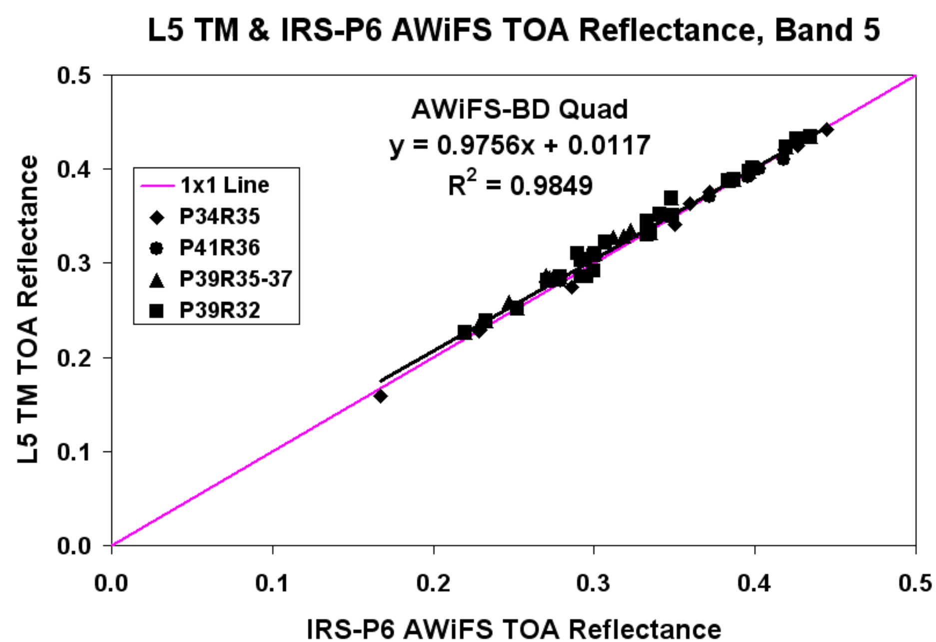

L7 ETM+ & IRS-P6 AWiFS TOA Reflectance, Band 4
AWiFS-BD Quad
y = 1.1304x + 0.0015
R^2 = 0.973
1x1 Line
P39R35-37
P39R32
P41R36
P36R35-39
L7 ETM+ TOA Reflectance
IRS-P6 AWiFS TOA Reflectance
0.0
0.1
0.2
0.3
0.4
0.5


L7 ETM+ & IRS-P6 AWiFS TOA Reflectance, Band 5
AWiFS-BD Quad
y = 1.0311x - 0.0125
R^2 = 0.9414
1x1 Line
P39R35-37
P39R32
P41R36
P36R35-39
L7 ETM+ TOA Reflectance
IRS-P6 AWiFS TOA Reflectance
0.0
0.1
0.2
0.3
0.4
0.5

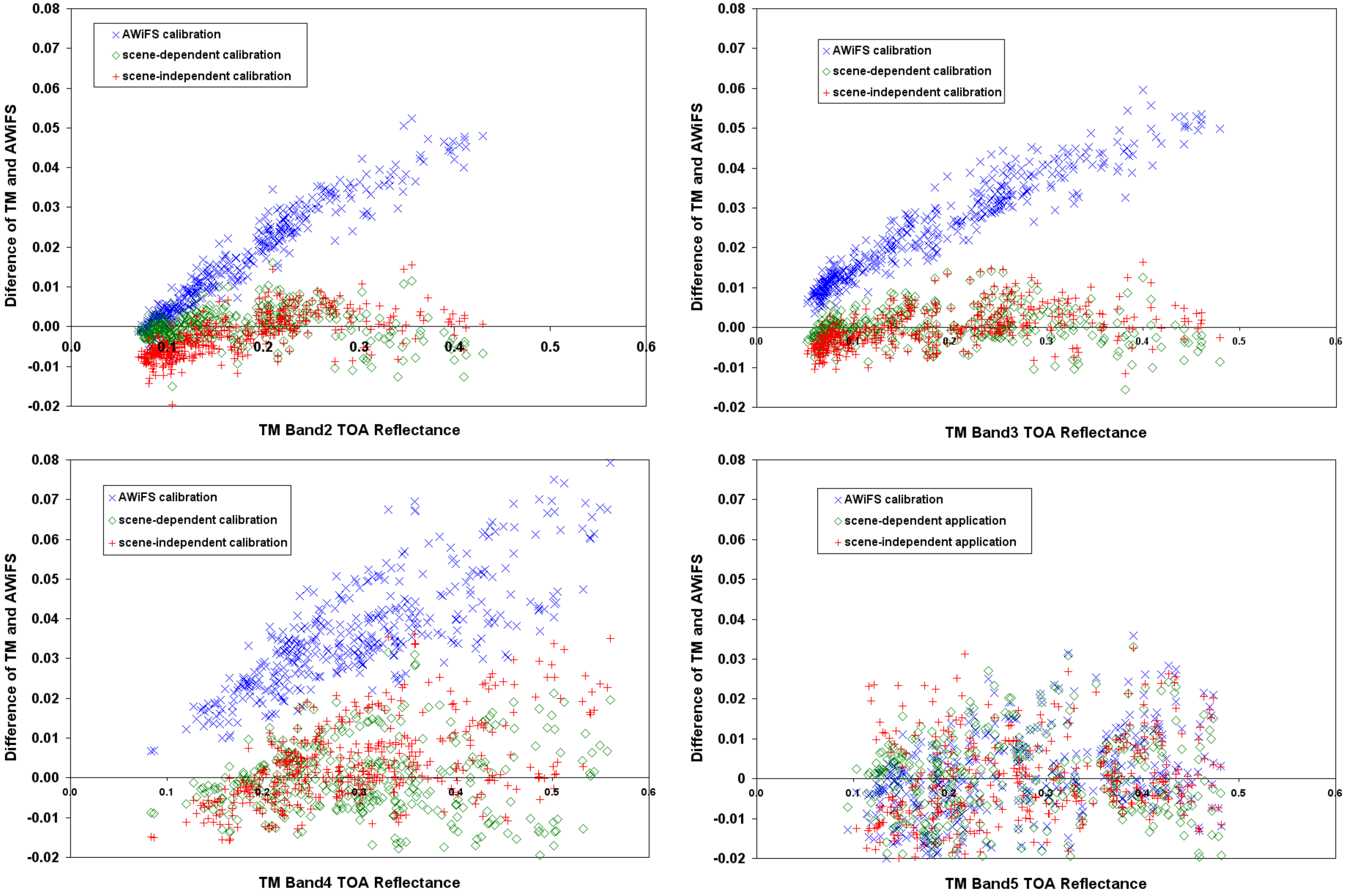

L5 TM & IRS-P6 AWiFS TOA Reflectance, Band 2
AWiFS-BD Quad
y = 1.1319x - 0.003
R^2 = 0.989
1x1 Line
P34R35
P41R36
P39R35-37
P39R32
L5 TM TOA Reflectance
IRS-P6 AWiFS TOA Reflectance
0.0
0.1
0.2
0.3
0.4
0.5


L5 TM & IRS-P6 AWiFS TOA Reflectance, Band 3
AWiFS-BD Quad
y = 1.1029x + 0.0081
R^2 = 0.9918
1x1 Line
P34R35
P41R36
P39R35-37
P39R32
L5 TM TOA Reflectance
IRS-P6 AWiFS TOA Reflectance
0.0
0.1
0.2
0.3
0.4
0.5

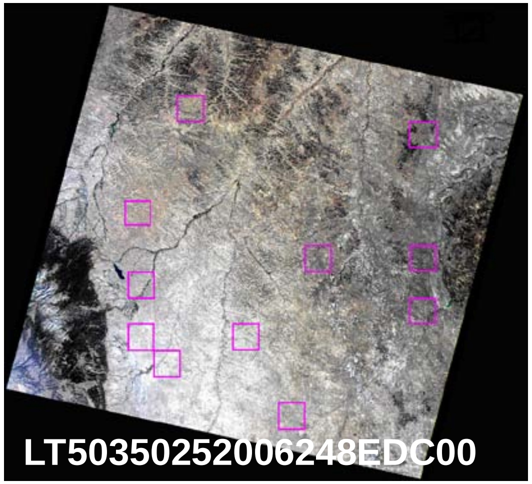

L5 TM & IRS-P6 AWiFS TOA Reflectance, Band 4
AWiFS-BD Quad
y = 1.0559x + 0.0174
R^2 = 0.9895
1x1 Line
P34R35
P41R36
P39R35-37
P39R32
L5 TM TOA Reflectance
IRS-P6 AWiFS TOA Reflectance
0.0
0.1
0.2
0.3
0.4
0.5

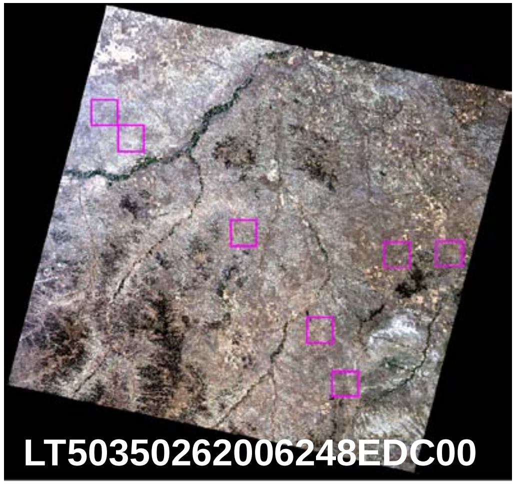

L5 TM & IRS-P6 AWiFS TOA Reflectance, Band 5
AWiFS-BD Quad
y = 0.9756x + 0.0117
R^2 = 0.9849
1x1 Line
P34R35
P41R36
P39R35-37
P39R32
L5 TM TOA Reflectance
IRS-P6 AWiFS TOA Reflectance
0.0
0.1
0.2
0.3
0.4
0.5

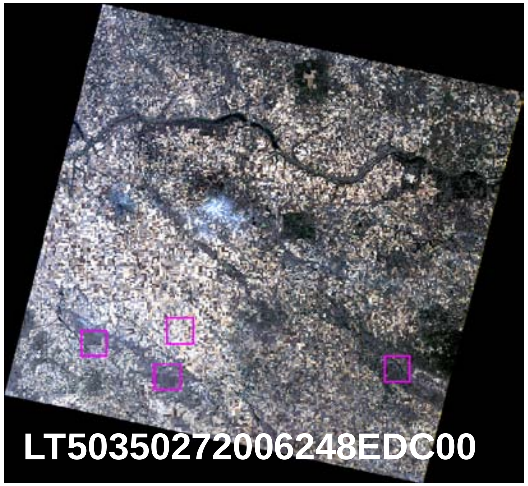
Reflectance comparison of ~500 polygons

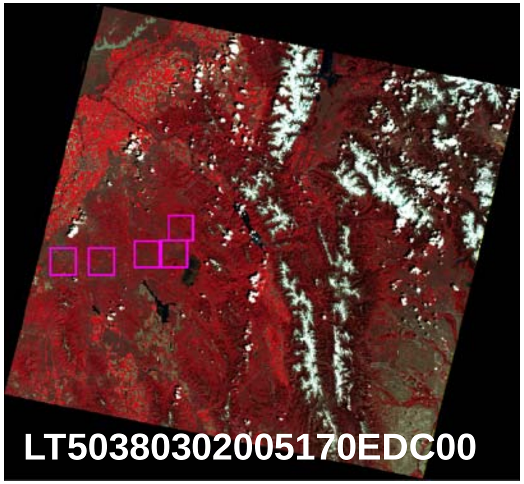


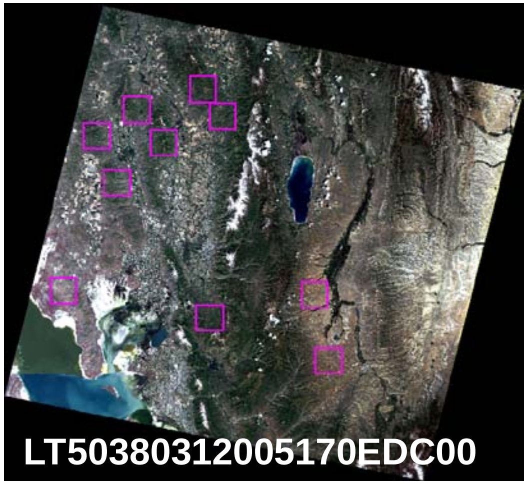
L5 TM and AWiFS-AC Quads (ROI)

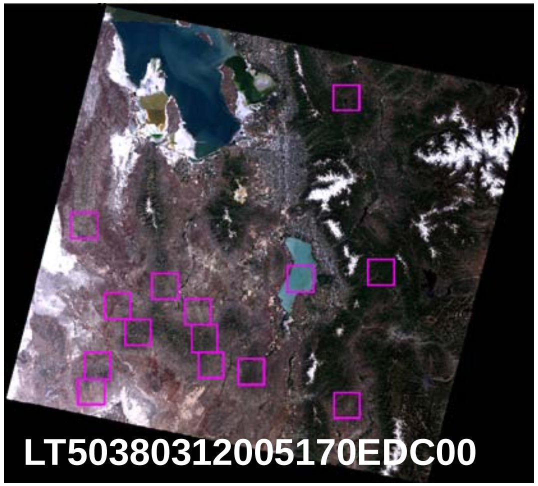


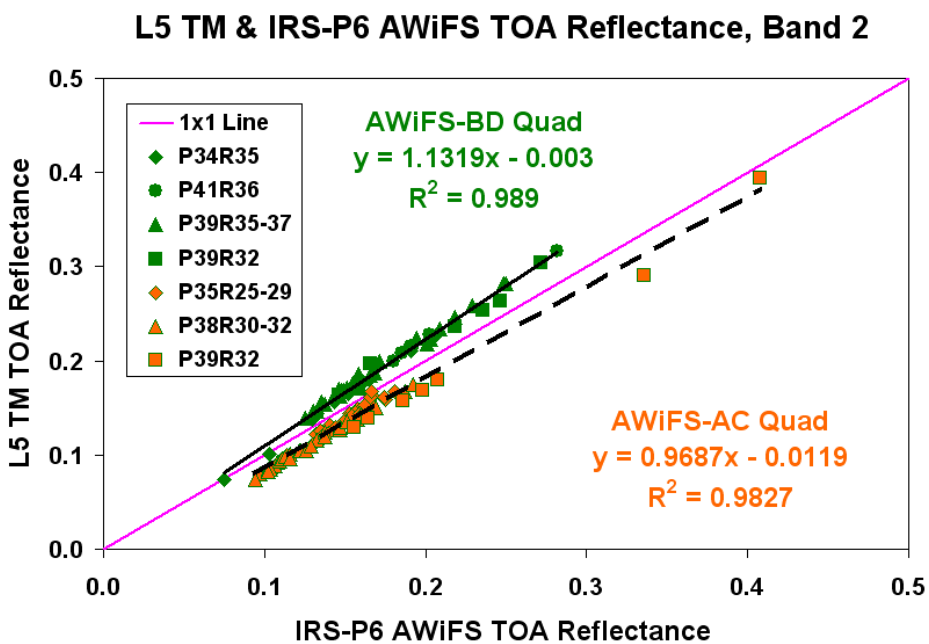


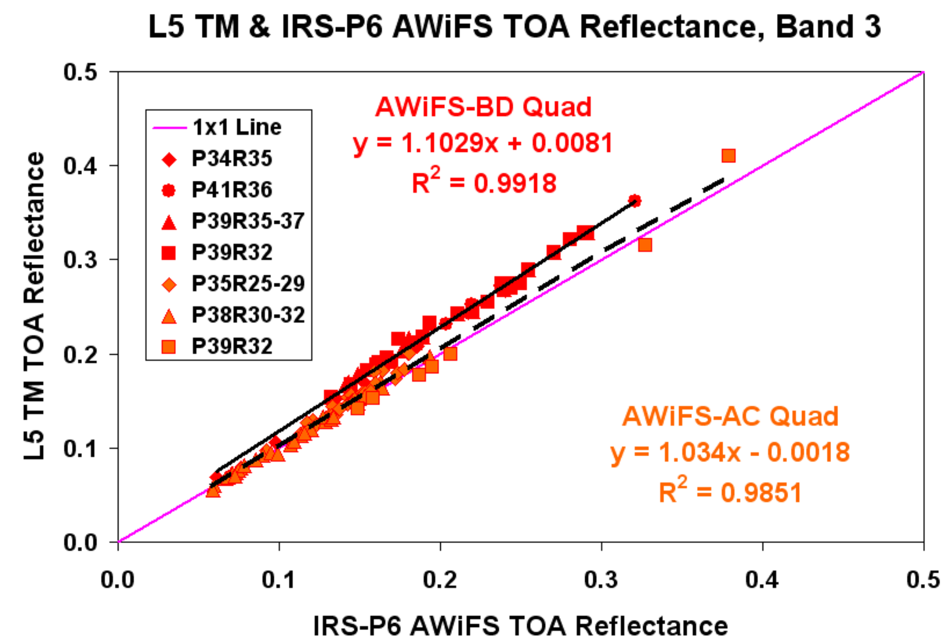


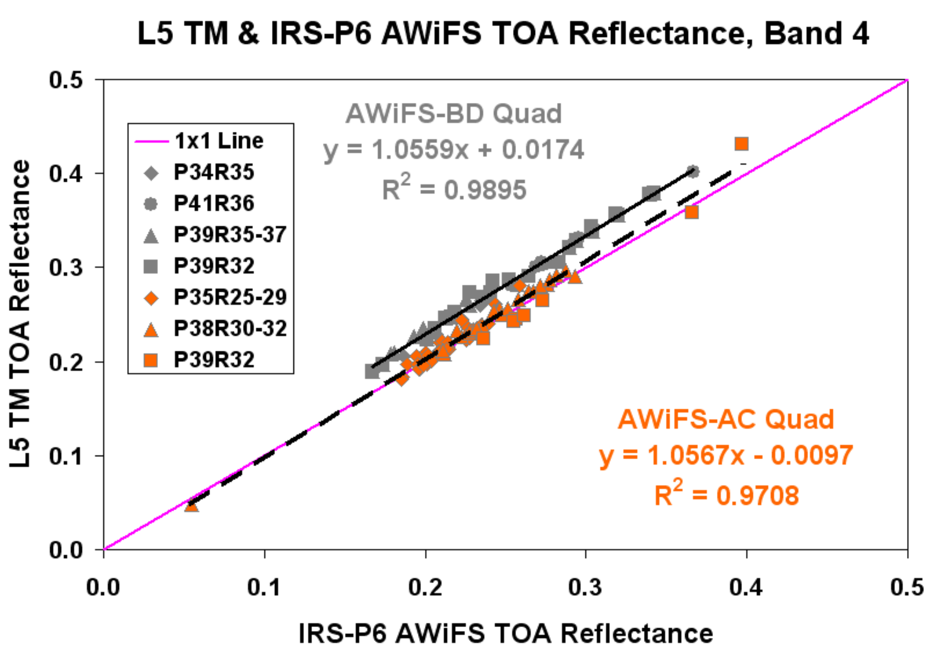


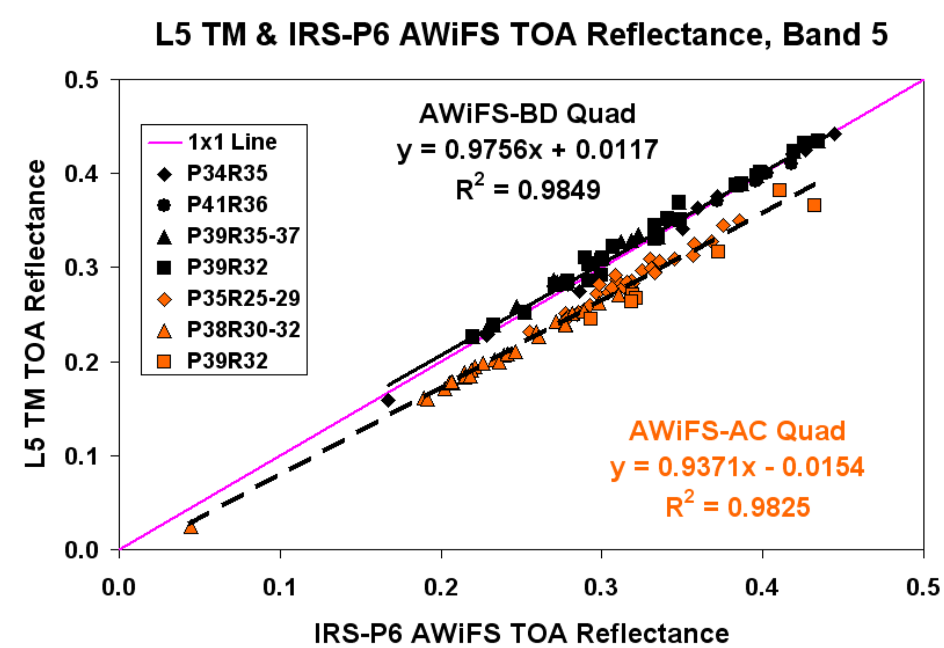





L5 TM & IRS-P6 AWiFS TOA Reflectance, Band 2
L5 TM TOA Reflectance
IRS-P6 AWiFS TOA Reflectance
1x1 Line
P34R35
P41R36
P39R35-37
P39R32
P35R25-29
P38R30-32
P39R32
AWiFS-BD Quad
y = 1.1319x - 0.003
R2 = 0.989
AWiFS-AC Quad
y = 0.9687x - 0.0119
R2 = 0.9827

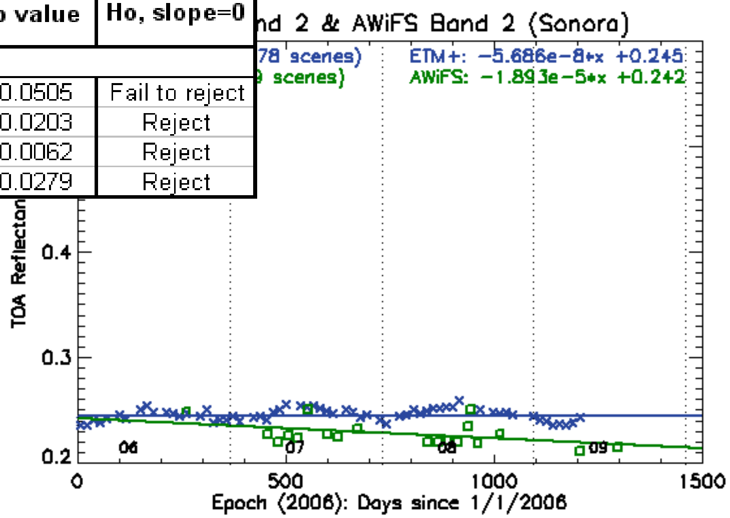

L5 TM & IRS-P6 AWiFS TOA Reflectance, Band 3
L5 TM TOA Reflectance
IRS-P6 AWiFS TOA Reflectance
1x1 Line
P34R35
P41R36
P39R35-37
P39R32
P35R25-29
P38R30-32
P39R32
AWiFS-BD Quad
y = 1.1029x + 0.0081
R2 = 0.9918
AWiFS-AC Quad
y = 1.034x - 0.0018
R2 = 0.9851

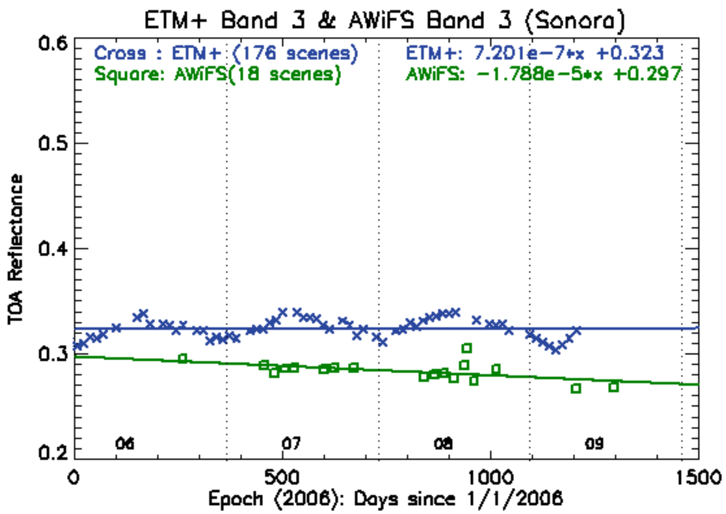

L5 TM & IRS-P6 AWiFS TOA Reflectance, Band 4
L5 TM TOA Reflectance
IRS-P6 AWiFS TOA Reflectance
1x1 Line
P34R35
P41R36
P39R35-37
P39R32
P35R25-29
P38R30-32
P39R32
AWiFS-BD Quad
y = 1.0559x + 0.0174
R2 = 0.9895
AWiFS-AC Quad
y = 1.0567x - 0.0097
R2 = 0.9708

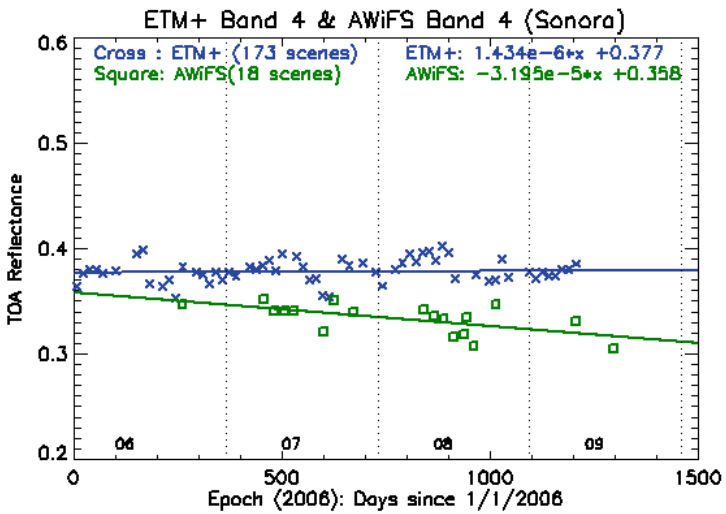

L5 TM & IRS-P6 AWiFS TOA Reflectance, Band 5
L5 TM TOA Reflectance
IRS-P6 AWiFS TOA Reflectance
1x1 Line
P34R35
P41R36
P39R35-37
P39R32
P35R25-29
P38R30-32
P39R32
AWiFS-BD Quad
y = 0.9756x + 0.0117
R2 = 0.9849
AWiFS-AC Quad
y = 0.9371x - 0.0154
R2 = 0.9825

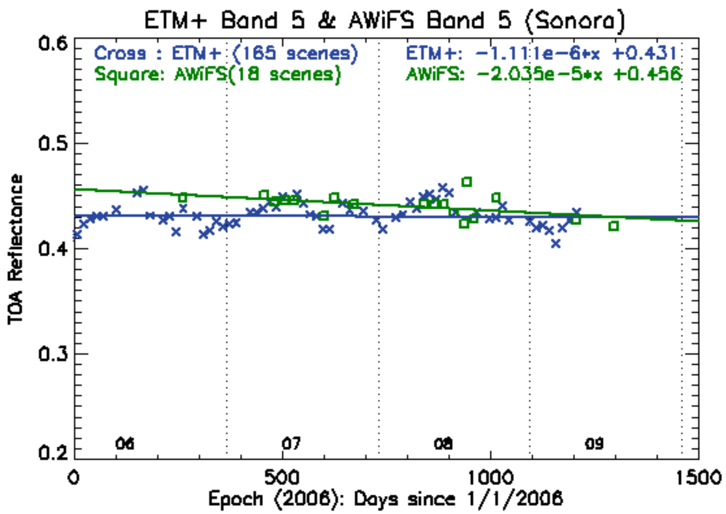
Long-term TOA Reflectance Trending (Sonoran & Railroad Valley Test Sites)

AWiFS				
Band	**Slope**	**t-value**	**p value**	**Ho, slope=0**
Sonora				
2	-1.900E-05	-2.1	0.0505	Fail to reject
3	-1.788E-05	-2.58	0.0203	Reject
4	-3.200E-05	-3.15	0.0062	Reject
5	-2.035E-05	-2.42	0.0279	Reject



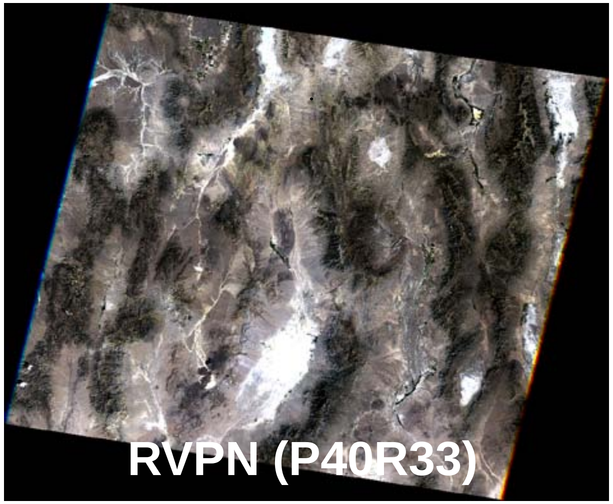


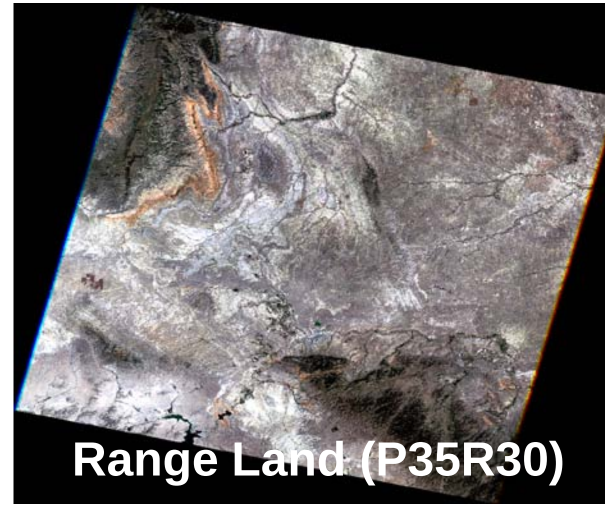


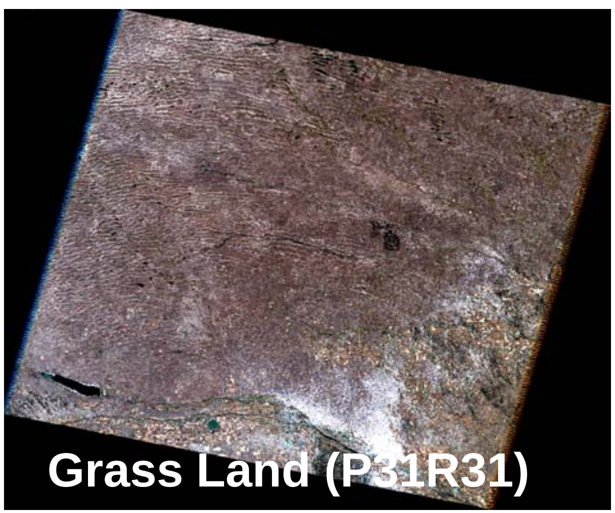


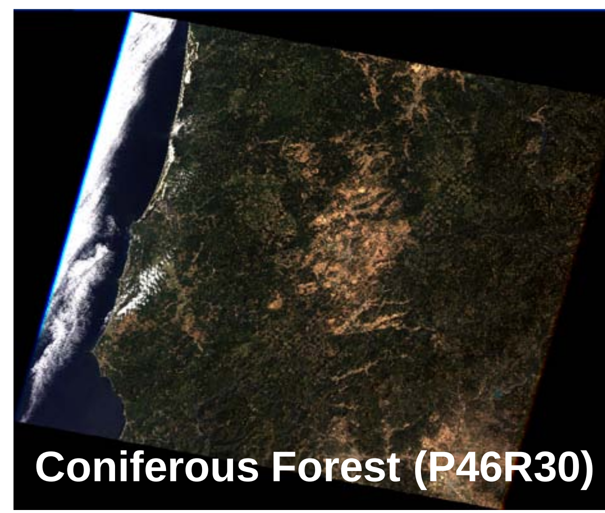
USGS

Sensitivity Studies (Test Scenes)



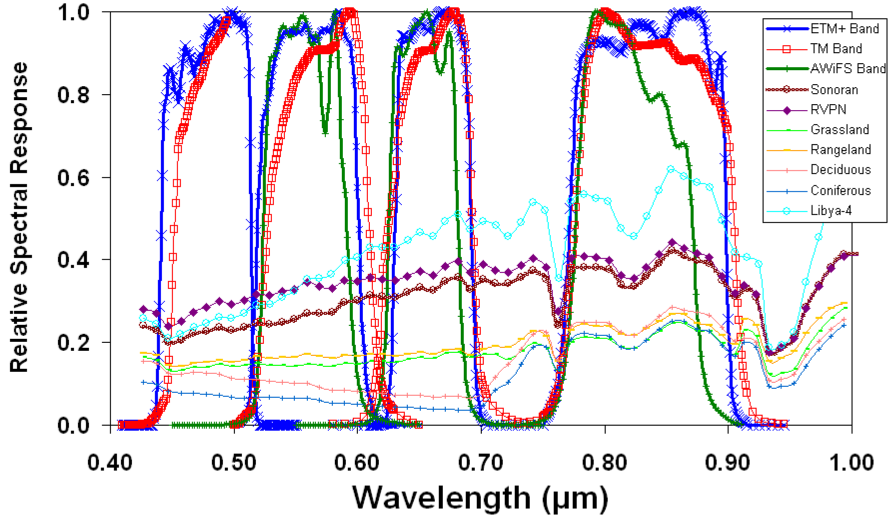




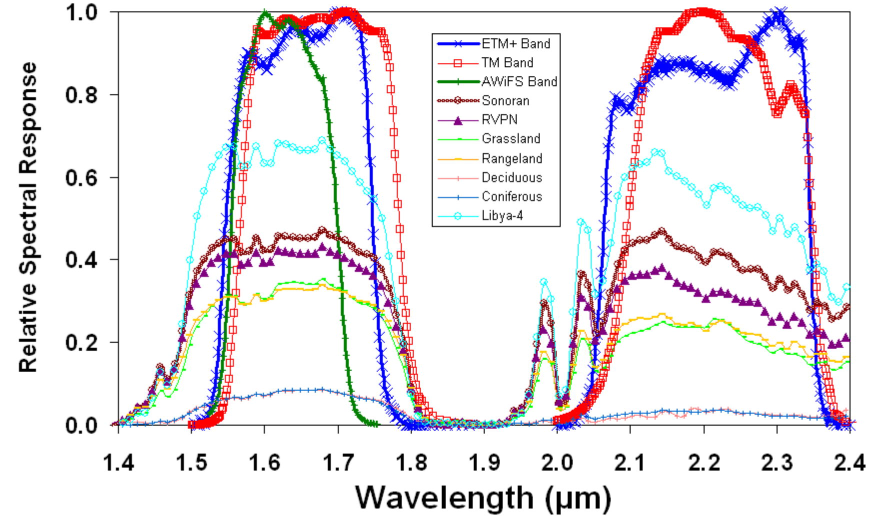


Spectral Differences Uncertainty

AWiFS, TM & ETM+ RSR (Bands 1, 2, 3, 4) along with typical TOA Reflectance



AWiFS, TM & ETM+ RSR (Band 5,7) along with typical TOA Reflectance



- SBAF were derived using hyperspectral EO-1 Hyperion measurements
- To understand the impact of the sensor spectral response differences on TOA reflectance measurements, the following equations were used

$$\overline{\rho_\lambda} = \frac{\int \rho_\lambda \, RSR_\lambda \, d\lambda}{\int RSR_\lambda \, d\lambda} \qquad SBAF = \frac{\rho_{ETM+}}{\rho_{AWiFS}} = \frac{\left(\int \rho_\lambda \, RSR_{\lambda(ETM+)} d\lambda\right) / \left(\int RSR_{\lambda(ETM+)} d\lambda\right)}{\left(\int \rho_\lambda \, RSR_{\lambda(AWiFS)} d\lambda\right) / \left(\int RSR_{\lambda(AWiFS)} d\lambda\right)} \qquad \rho^*_{ETM+} = \frac{\rho_{ETM+}}{SBAF}$$

Spectral Differences Uncertainty

Expected % differences because of the differences in spectral responses							
Bands	Libya 4	Sonora	RVPN	Grassland	Rangeland	Deciduous	Conferous
Path/Row	P181R40	P38R38	P40R33	P31R31	P35R30	P14/R31	P46/R30
Date	Avg	Avg	Avg	3/19/2004	4/12/2005	4/29/2004	9/22/2002
(SBAF-1)x100 for the ETM+ and AWIFS							
2	1.50	1.58	0.41	0.36	0.22	-1.27	-1.62
3	1.45	1.02	0.86	1.27	0.53	-1.45	-2.62
4	0.26	-0.44	-0.67	0.97	-0.03	1.18	0.68
5	-2.87	-1.45	-1.86	-1.79	-0.91	-2.43	-3.54

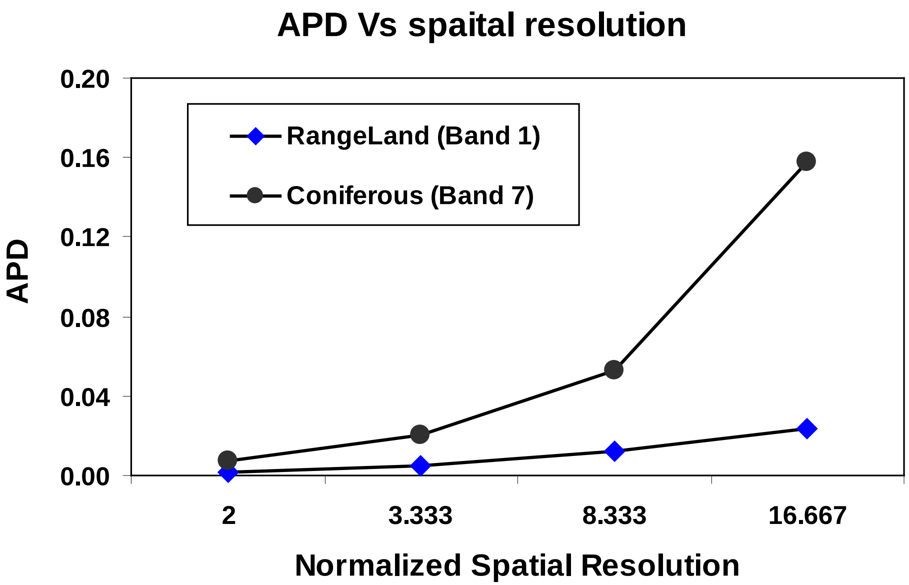
- The simulated percent difference in TOA reflectance that is expected ONLY due the differences in spectral responses between the AWiFS and ETM+ sensors for different land cover types is typically within ~3%

USGS

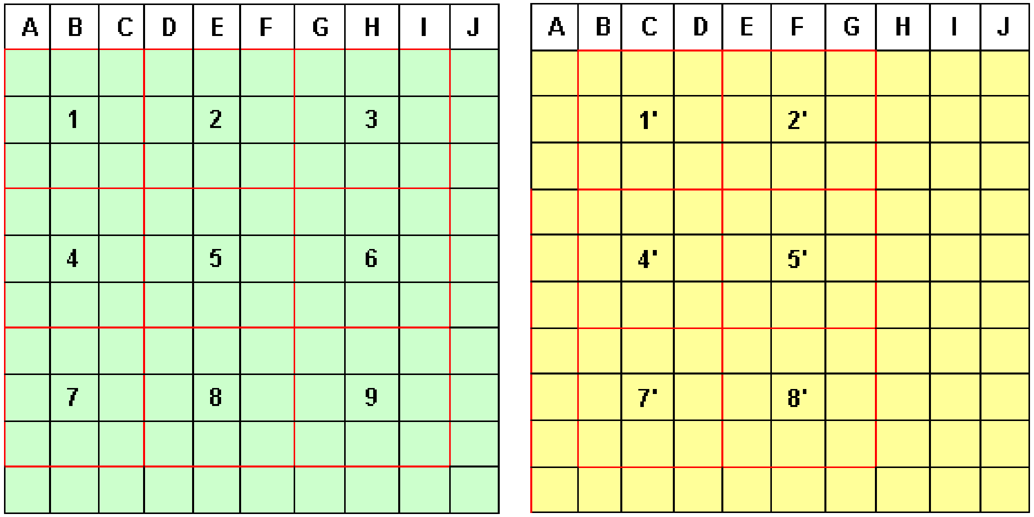
Spatial Resolution Uncertainty

- To check the sensitivity of the ROIs due to differing spatial resolution, the 30 m TM data was resampled (cubic convolution) to 60 m, 100 m, 250 m, and 500 m spatial resolution
- For spatial analysis, the ROI in original image was always chosen to be 50X50 pixels
- Mean and Maximum APD were calculated for each band

APD versus differing spatial resolution				
Resolution	ROI Pixels	X-axis	RangeLand Band-1	Coniferous Band-7
30 m to 30 m	50 x 50	1		
30 m to 60 m	25 x 25	2	0.002	0.008
30 m to 100 m	15 x 15	3.333	0.004	0.020
30 m to 250 m	6 x 6	8.333	0.012	0.053
30 m to 500 m	3 x 3	16.667	0.024	0.158



Mis-registration Uncertainty



Absolute % difference (APD) for each ROI (r) and scene (s)

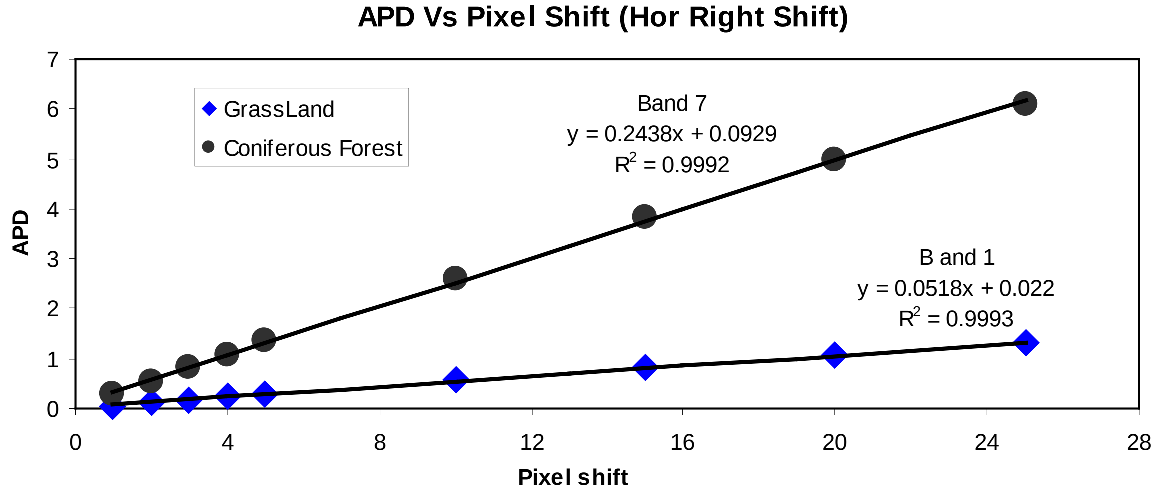
$$APD_{sr} = \left(\frac{\left| \mu_{sr} - \mu_{sr'} \right|}{\mu_{sr}} * 100 \right)$$

$$APD_s = mean(APD_{sr})$$

$$APD = mean(APD_s)$$

To check the sensitivity of the regions to image geometry, a moving window technique was used

The selected ROI (100x100 pixels) were shifted by few pixels (1, 2, 3, 4, 5, 10, 15, 20, 25) in horizontally right/left and vertically up/down



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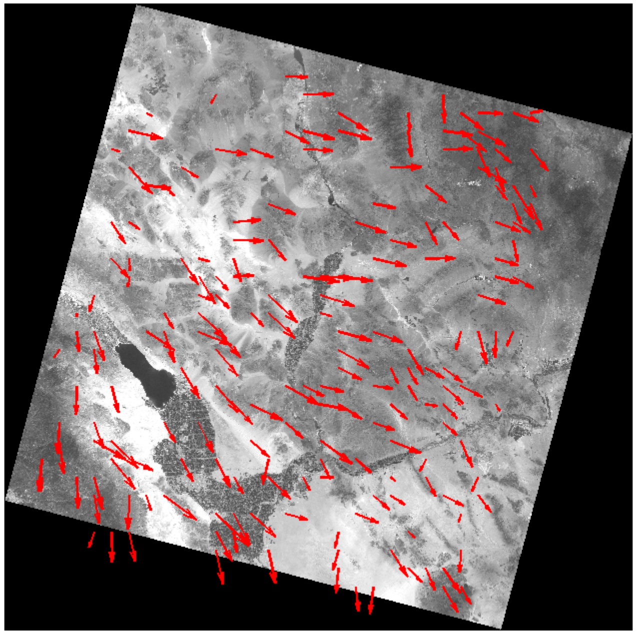
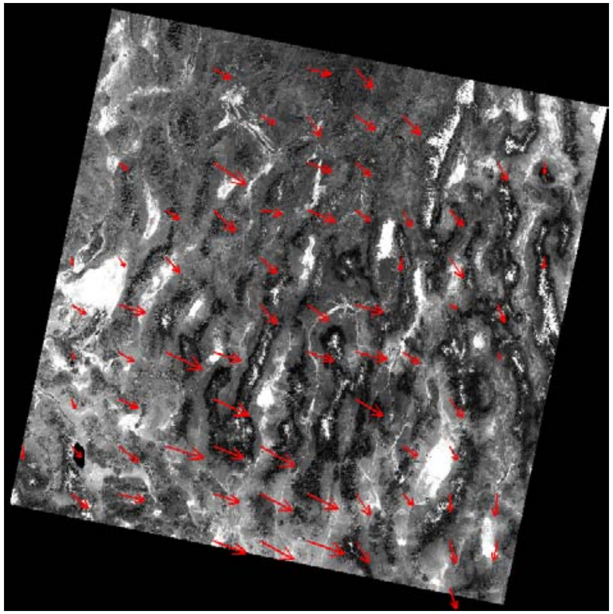
Vector scale: 1:2800

Image-to-Image (I2I) Assessment (Sonoran & Railroad Valley Test Sites)



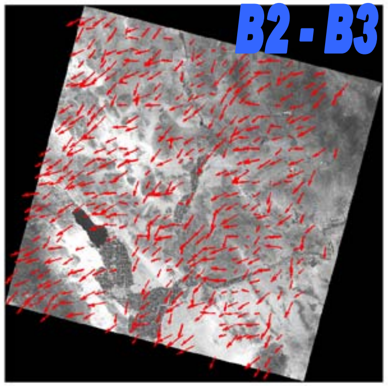
252_045_D_20090420

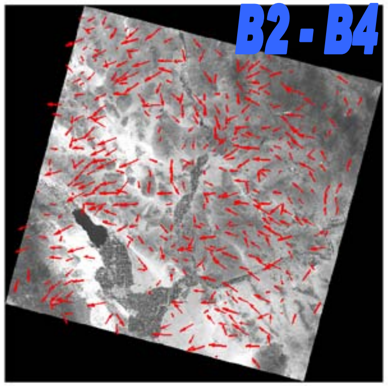


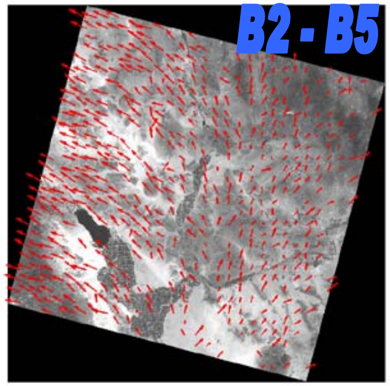
248_040_D_20081014

- The I2I characterization was performed to compare the accuracy of AWiFS against the GLS2000 dataset as a reference image
  - A total of 33 AWiFS images over Railroad Valley, and 22 images over Sonoran were used
  - The AWiFS images were typically registered to within one pixel to the GLS2000 dataset

AWiFS (B2B) – Sonoran
Vector scale: 1 : 2800

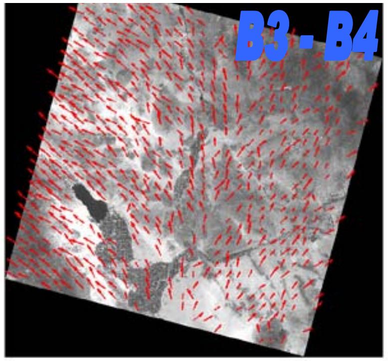


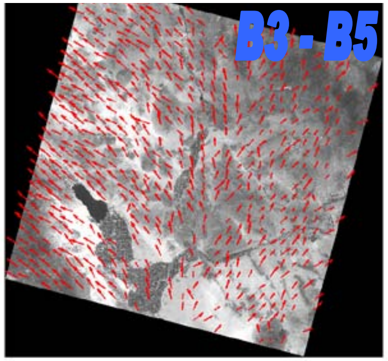


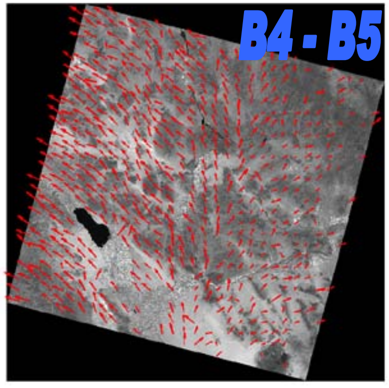


The MS bands are registered to sub-pixel accuracy

The results show that alignment between bands 2, 3 and 4 is very good, while the alignment errors with band 5 are higher







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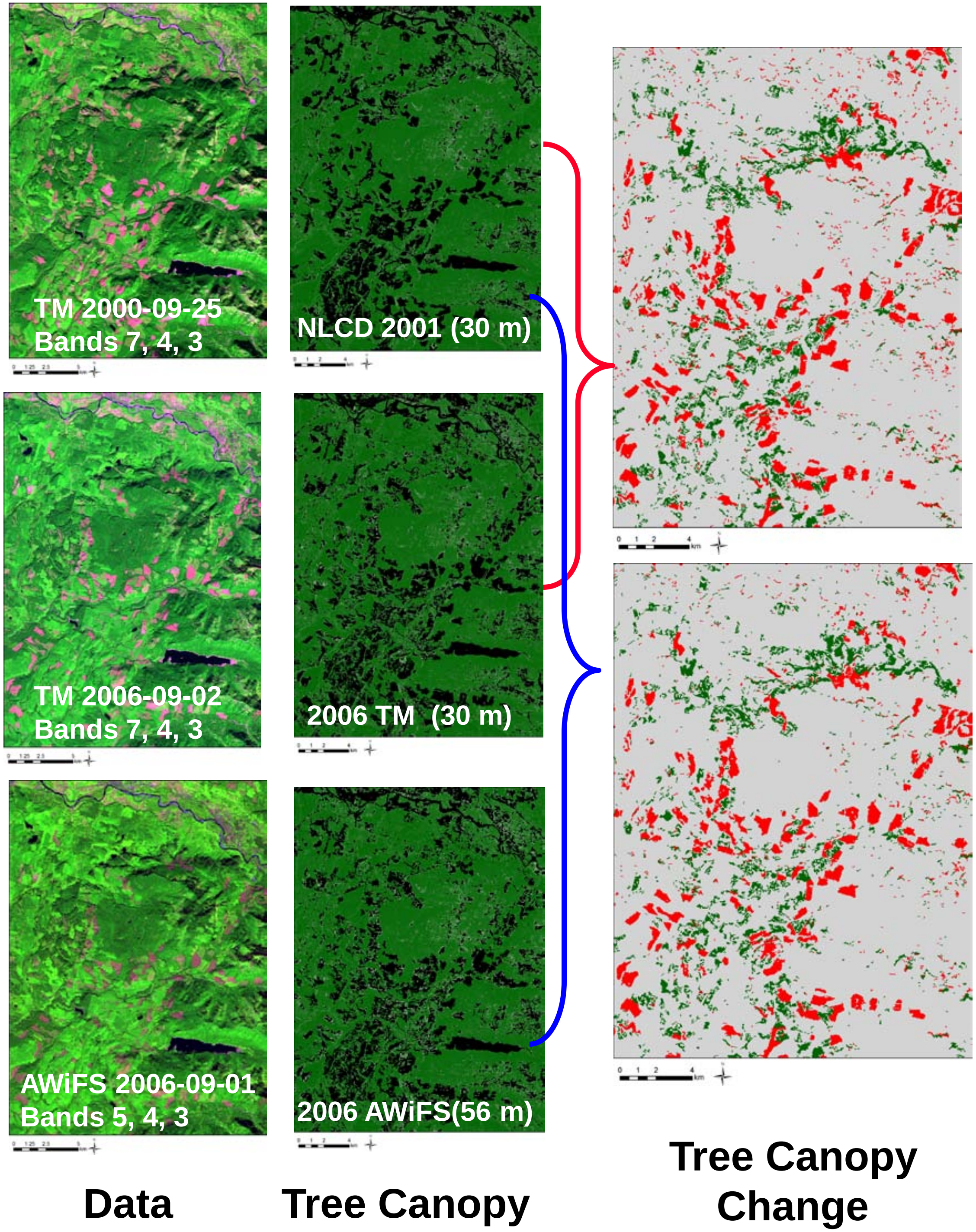
NLCD Tree Canopy Change Assessment

Seattle (Mostly Forest)



Decrease

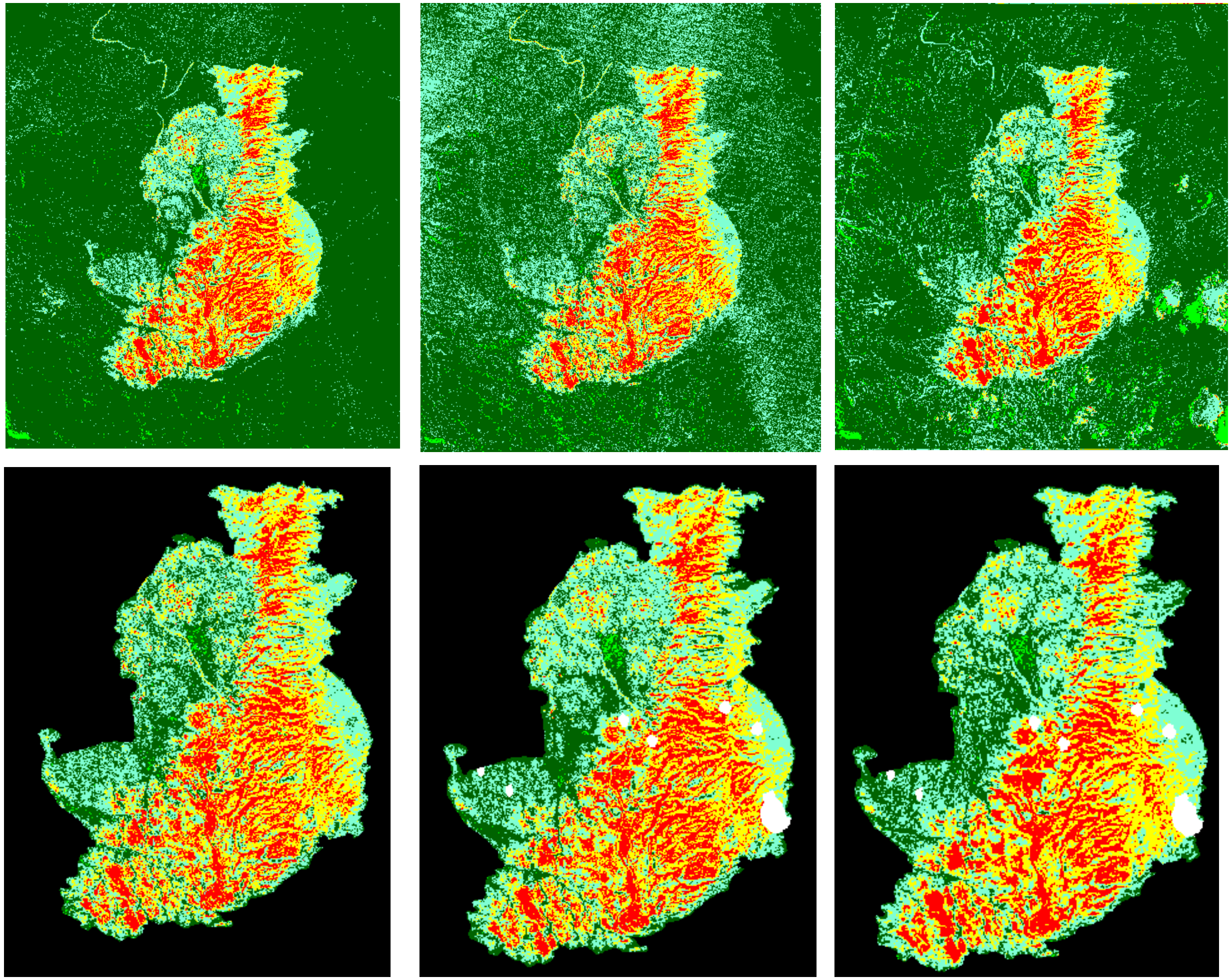
Increase

Change comparison for Tree Canopy derived from Landsat and AWiFS Images

Change Agreement	
Seattle	
Decrease area	Increase area
56 m	
87.40%	84%

MTBS dNBR Burn Severity Maps:

Arizona, Warm Fire [July 06, 2006]



Official TM dNBR **TM B5 dNBR** **AWiFS dNBR**

Class Severity		Pixel Counts	Class 1	Class 2	Class 3	Class 4	Total	% agreement
Unburned to low		Class 1	9713	4301	59	1	14223	68.3
Low		Class 2	4224	17114	3098	40	24479	69.9
Moderate		Class 3	14	3318	15478	2781	21591	71.7
High		Class 4	0	16	2815	11535	14366	79.6

Arizona Warm Fire (July 06, 2006) Mostly Ponderosa pine with a Pinyon Juniper/ Shrub mixture at lower elevations on the east

Pre AWiFS June 5, 2006
Post AWiFS June 4, 2007
Pre L5 TM May 30, 2006
Post L5 TM June 18, 2007

Visually the maps look similar

In the TM B5 map, the confusion between the unburned and low severity class outside the perimeter is because of using B5 which is not as sensitive as B7

In the AWiFS map, the confusion is reduced because of the coarser spatial resolution of 56 m that may cause a smoothing effect

Table shows a comparison of "official TM" versus "AWiFS" dNBR

Science Utility Evaluation Summary

- Indicates that AWiFS data is potentially a usable alternative to Landsat during the mission gap
  - The higher radiometric resolution (10 bits), larger swath area coverage (740 km), and a frequent repeat cycle (five days) will be **an advantage for science applications**, allowing for the increased likelihood of cloud-free acquisitions and reduction in the processing and handling of a lower number of images
  - The lack of an AWiFS equivalent to the Landsat spectral Bands 1& 7 can have **an adverse impact on a few assessments**, likely resulting in reduced but acceptable derived-product accuracy and sensitivity
  - The coarser spatial resolution of AWiFS could negatively impact the **ability to discriminate fine-scale landscape features**, especially those related to urban development (It is possible, however, that the disadvantage of lower spatial resolution could be offset by the more frequent repeat coverage of AWiFS)
  - Lack of **thermal band** will have an obvious negative impact on applications depending on the use of thermal (e.g. Water management)

Future Work

- Investigate differences between AWiFS quad AC/BD
- Get additional data to track the long term stability of the AWiFS sensor
- Characterize the uncertainties due to spectral mismatches, spatial, radiometric, BRDF, and atmospheric impacts
- Quantify the science utility and investigate the impact of cross-cal coefficients on LCLUC applications
- Finalize the AWiFS evaluation from the CEOS Tuz Golu and Dome-C campaigns
- ResoureSat-2 characterization

Contributors

- The slides in this presentation include contributions from a number of individuals in various organizations
  - USDA/FAS (Tetrault)
  - SDSU (Helder, Shrestha, Mishra)
  - USGS/EROS (Stensaas, Howard, McKinley, Homer, Yang, Xian, Vogelmann, Chen, Tolk, Sampath)
  - NASA/MCST (Xiong, Angal, Choi)
  - Others!
- This work was supported by Dr. Gutman through the NASA LCLUC Grant NNH08AI30I

USGS

Catalog of Worldwide Test Sites for Sensor Characterization

http://calval.cr.usgs.gov/sites_catalog_map.php

Gyanesh Chander, GEO Task: DA-09-01a_2 Lead

SGT Inc., contractor to the U.S. Geological Survey (USGS) Earth Resources Observation and Science (EROS) Center, Sioux Falls, SD. Work performed under USGS contract 08HQCN0005.

Scope of Test Sites

- Test sites are central to any future Quality Assurance/Quality Control (QA/QC) strategy
- Test sites provide a convenient means of obtaining information to verify sensor performance
- Test sites are the only practical means of deriving knowledge of biases between sensors
- Test sites allow, at some level, a means of bridging anticipated data gaps caused by lack of measurement continuity, due to lack of co-existent in-flight sensors

Characteristics of Sensors which can Benefit from Test Sites

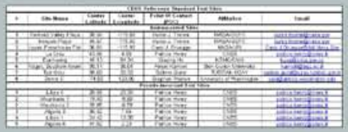
- Gain
- Stability
- Modulation Transfer Function (MTF)
- Uniformity
- Stray light
- Polarization
- Spectral
- Signal-to-Noise Ratio (SNR)
- Geolocation
- Camera model
- Band-to-band
- Internal Geometry

Well-Established Site Selection Criteria for Radiometry Test Sites

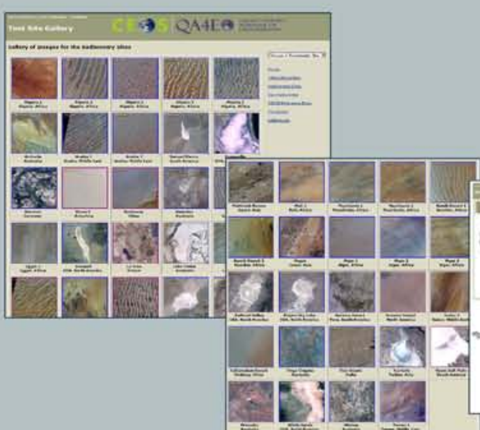
- High spatial uniformity over a large area (within 3%)
- Surface reflectance [0, 1] greater than 0.3
- Flat spectral reflectance
- Temporally invariant surface properties (within 2%)
- Horizontal surface with nearly lambertian reflectance
- At high altitude, far from ocean, urban, and industrial areas
- In arid regions with low probability of cloud cover

CEOS Reference Standard Test Sites

- The instrumented sites are primarily used for field campaigns to obtain radiometric gain. These sites can serve as a focus for international efforts, facilitating traceability and cross-comparison to evaluate biases of in-flight sensors in a harmonized manner
- The pseudo-invariant desert sites have high reflectance with low aerosol loading and practically no vegetation. Consequently, these sites can be used to evaluate the long-term stability of a sensor and facilitate cross-comparison of multiple sensors



Online Test Site Catalog



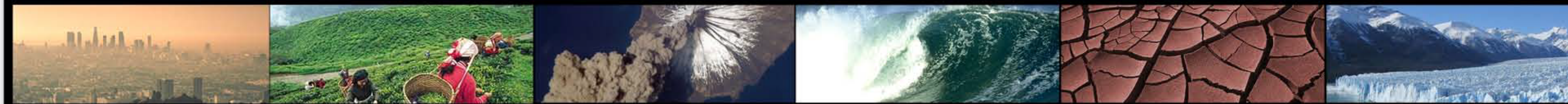
Summary

- The test site catalog provides a comprehensive list of prime candidate terrestrial targets for consideration as benchmark sites for the postlaunch calibration of space-based optical sensors
- The online test site catalog provides easy public Web site access to this vital information for the global community
- The incompleteness of available information on even these prime test sites is an indication that much more coordination and documentation are still needed to facilitate the wider use of calibration test sites in remote sensing

Proposed Future Plans

- Gather complete site characterization data & define core measurements (eg. Instruments)
- Create an operational network of land sites ("Landnet") & develop online data access infrastructure
- Encourage agencies to acquire, archive, and provide data over the CEOS sites
- Integrate the catalog into the CEOS Cal/Val portal
- Establish traceability chain for primary site data
- Develop "best practice" guidance on site characterization and its use

COVE (CEOS Visualization Environment)



CEOS Committee on Earth Observation Satellites

TEAM:

SEO Sponsors:
Brian D. Killough, Ph.D.
CEOS Systems Engineering Office (SEO)
Email: Brian.D.Killough@nasa.gov
Phone: 757-864-7047

SEO Team Member:
Shelley K. Stover
Science Systems & Applications Inc.
Email: Shelley.K.Stover@nasa.gov
Phone: 757-593-4962

WGCV Customer:
Gyanesh Chander
SGT, Inc., Contractor to the USGS EROS
Email: gchander@usgs.gov
Phone: 605-594-2554

AMA, Inc. Developer:
Sanjay Gowda, Ph.D.
AMA, Inc.
Email: gowda@ama-inc.com
Phone: 757-865-0944

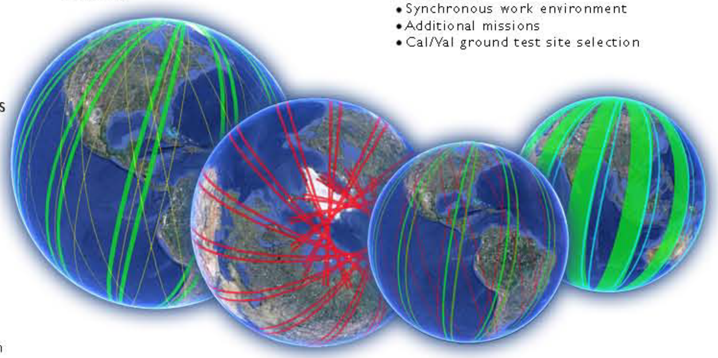
OVERVIEW:

The CEOS Visualization Environment (COVE) tool is a browser-based system that leverages Google-Earth to display satellite sensor coverage areas and for the identification of coincident scene locations. The NASA CEOS Systems Engineering Office (SEO) worked with the Committee on Earth Observing Satellites (CEOS) Working Group on Calibration and Validation to develop the COVE tool.

CEOS is currently operating and planning hundreds of Earth observation satellites. Standard Calibration and Validation (Cal/Val) exercises to compare near-simultaneous surface observations and to identify corresponding image pairs are time-consuming and labor-intensive. COVE is comprised of a suite of tools developed to make such tasks easier.

FEATURES:

Key features and capabilities include user-defined evaluation periods (start and end dates) and regions of interest (rectangular areas). COVE allows predefined geographical locations or a point search (specific lat/long) capability.



Users can select two or more CEOS missions from a database including Satellite Tool Kit (STK) generated orbit information and perform rapid calculations to identify coincident scenes where the groundtracks of the CEOS mission instrument fields-of-view overlap. Calculated results are displayed on a customized Google Earth web interface to view location and time information along with optional output to Excel table format.

COVE is fully collaborative and allows multiple users to observe the same data at once. It supports bookmarking particular views and datasets to be easily reloaded in the future.

FUTURE WORK:

COVE is developed on a flexible framework that allows it to remain easily extensible. Future work under consideration includes:

- Output data validation and verification testing
- Planning for specific WGCV campaigns
- Earth maps
- Synchronous work environment
- Additional missions
- Cal/Val ground test site selection

MISSIONS & INSTRUMENTS

COVE currently includes the following missions and instruments:

Mission: ALOS
Instrument: AVNIR-2

Mission: CBERS-2
Instrument: HRCCD

Mission: Envisat
Instrument:SCIAMACHY
MIPAS
MERIS

Mission: GOSAT
Instrument: TANSO-FTS

Mission: IRS-P6
Instrument: LISS-II
AWIFS

Mission: Landsat-7
Instrument: ETM+

Mission: Sentinel-2
Instrument: Multispectral Imager

Mission: SPOT-5
Instrument: HRG

Mission: TERRA
Instrument: MODIS

Mission: THEOS
Instrument: MS

and more to come!

Notional Architecture

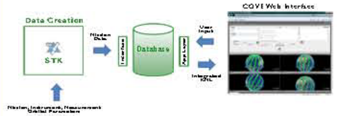


IMAGE A - Orbital parameters are added to a database from which COVE processes the data and displays the results to the user.

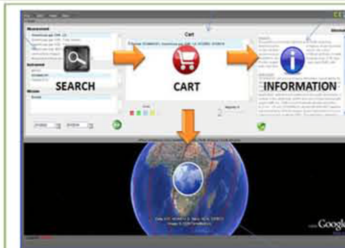


IMAGE B - The COVE User Interface is divided into 4 sections: Dynamic search menus, cart for selected missions, context-specific information panel, and Google Earth Viewport.

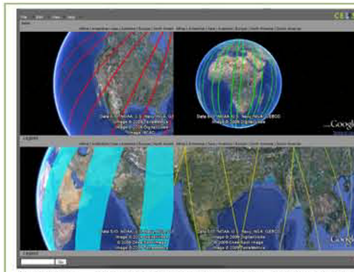


IMAGE C - Multiple viewports display different views of the Earth at once, and can also be synced to a single viewport for easy navigation.

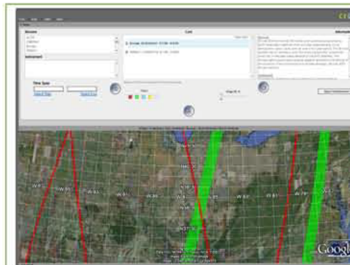


IMAGE D - Brightly colored lines represent satellite sensor coverage areas. Overlapping scans can be easily identified.

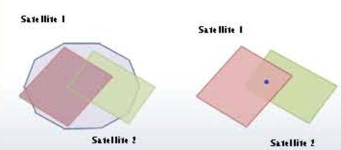


IMAGE E - Areas of interest can be specified as a single point or as a region bound by multiple points. All coincidences over the area are identified.

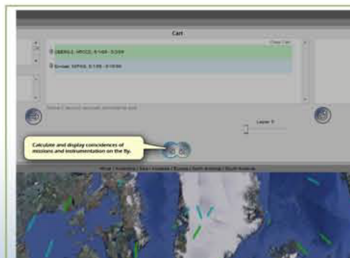


IMAGE F - Coincidence calculations for multiple missions and instrumentation are performed quickly at the push of a button. Detailed results are displayed on the surface of the Earth and can be exported in Excel or WRS format.

Future ResourceSat Sensors

- **ResourceSat-2**
  - Launch currently scheduled for Q3 2010
  - Virtually identical to Resourcesat-1 (with miniaturization)
  - Improved solar array and power handling system
  - Radiometric resolution of LISS-III/IV will be improved from 7 bits to 10 bits
  - AWiFS will have improved multi-linear gains
  - OBSSR will be increased in size (2 each at 200 GB)
  - Resourcesat-2 has a 7-10 year design life
- **ResourceSat-3**
  - Increased resolution and more spectral bands to existing sensors
  - AWiFS (A & B) improved to 25 m resolution, 600 km swath
  - LISS-III will remain at 23.5 m resolution with 2 additional bands
  - Thermal at 70 m resolution under consideration
  - LISS-IV will remain at 5.8 m resolution, but swath will be increased
  - Possible addition of new sensors with 25 km swath:
    - LISS-V (PAN) at 2.5 m resolution
    - Hyperspectral at 25 m resolution (~200 Bands)

Backup Slides

IRS-P6 Data Through INPE

- Since 09/15/2009, INPE is receiving and processing ResourceSat-1 imagery
  - LISS-3 (23 m) and AWiFS (56 m)
  - LISS-4 (5 m) is not included

- The images cover South America region in the range of INPE's reception antenna in Cuiaba, MT

- Images are costless distributed in the catalog http://www.dgi.inpe.br/CDSR/

AWiFS Product Options (GeoEye)

	Standard Products	Value Added Products
1	Path/Row Based	Ortho Products
2	Shift Along Track	
3	Quadrant Products	
4	Georeferenced Products	

Level	Type of Correction Applied
Level 0	No correction (not available for sale)
Level 1	Radiometric Correction only
Level 2 (Standard)	Radiometric and Geometric Correction
Level 3	Precision Correction (using GCPs)

Resampling Options	Map Projections	Earth Ellipsoids	Data Formats
Cubic Convolution	Polyconic	Clark 1866	LGSOWG Superstructure Format
Nearest Neighbor	Lambert Conformal Conical	Int'l 1909	Fast Format
Bilinear	Universal Transverse Mercator	GRS 1980	GeoTIFF (Gray Scale)
16 Point Sinc	Space Oblique Mercator	Everest	GeoTIFF (RGB)
Kaiser -16		WGS 84	HDF
4 Point Sinc		Bessel	
		Krassovsky	

- Space Imaging (now GeoEye) was granted a license to receive & distribute AWiFS imagery from their ground station in Oklahoma (Jan. 2005)
- Effective 1 January 2009, EOTec became the exclusive distributors for Resourcesat Data in North America (GeoEye is key partner)

34

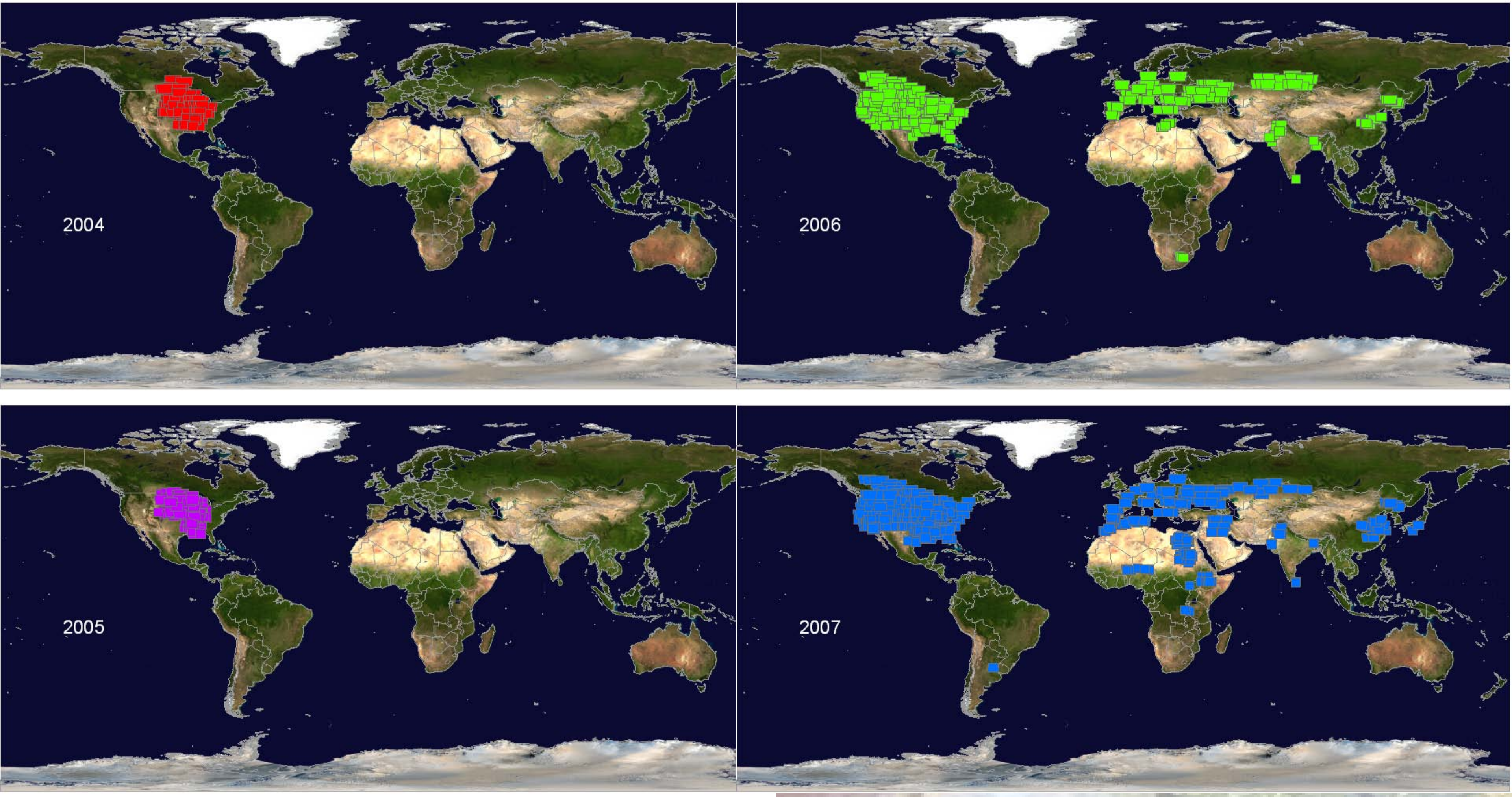
USDA Satellite Imagery Archive

The USDA AWiFS imagery product was standardized using the following parameters

1. Item: AWiFS orthorectified quad. L1T (terrain-corrected)
2. Identification: path, row, quad, date
3. Projection: Lambert Conformal Conic
4. Resampling: Cubic convolution
5. Datum: WGS84
6. Orientation: North up
7. Format: 4-bands, unstacked geoTIFF
8. Bit depth: 8-bits (**10 bits for data processed after 4/1/2008**)
9. Media: CDROM
10. License for redistribution: Tier 2 (Federal/Civilian agencies)

AWiFS Data Holding in USDA

- 2004 to 2010 data available in the USDA Archive Explorer v.3.1 (**6,314** AWiFS scenes)
- 2004 to 2007 data available in EE (**2,922** scenes)



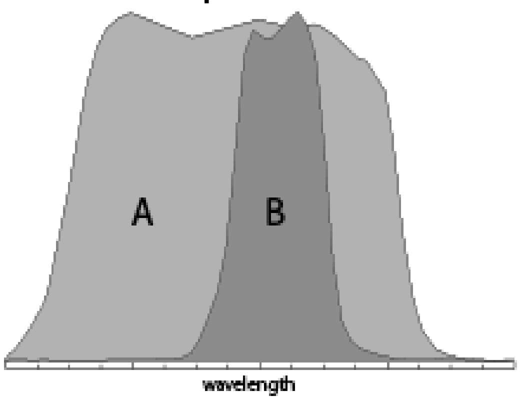
Conversion to TOA Reflectance

- When comparing images from different sensors, there are three advantages to using TOA reflectance instead of at-sensor spectral radiance
  - First, it **removes** the cosine effect of different **solar zenith angles** due to the time difference between data acquisitions
  - Second, TOA reflectance **compensates** for different values of the **exoatmospheric solar irradiance** arising from spectral band differences
  - Third, the TOA reflectance **corrects** for the variation in the **Earth-Sun distance** between different data acquisition dates. These variations can be significant geographically and temporally

USGS

Figure of Merit (alpha)

- The Figure of Merit ("alpha") is defined as the intersecting areas of two spectral response functions divided by the union of the two areas
  - alpha = 1.0 indicates complete spectral agreement between two bands
  - alpha = 0.0 indicates complete disagreement



$$\alpha = \frac{A \cap B}{A \cup B}$$

Figure of Merit (alpha)			
P6 AWiFS FOM comparison			
Bands	**ETM+**	**TM**	**MODIS**
2	0.806	0.671	0.302
3	0.746	0.719	0.692
4	0.686	0.706	0.304
5	0.694	0.551	0.211

where *A* & *B* represent the areas under the RSR curves

- The figure of merit approach is plagued by the lack of spectral scene content information, but at least provides a non-unity factor
  - For a spectrally flat scene, the RSR differences will not matter
- The figure of merit can be viewed more as a quantization of ‘potential’ differences in cross-cal between the sensors

USGS

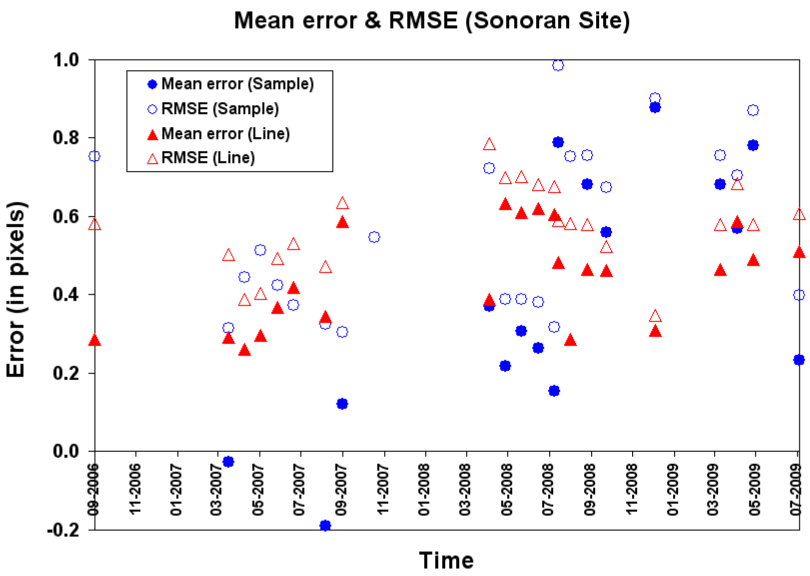
Geometric Assessment

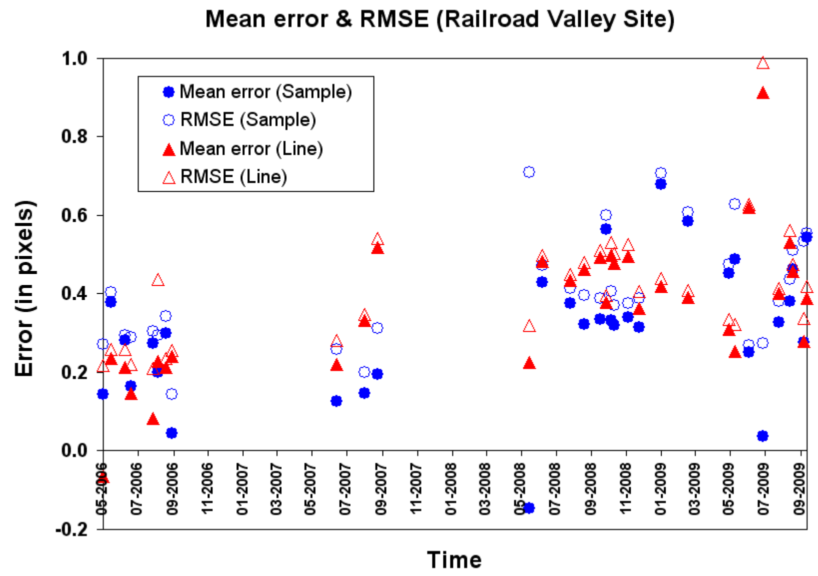
- Completed using the Image Assessment System (IAS) which was developed for Radiometric and Geometric Characterization and Calibration for the Landsat Program

- Image to Image (I2I) registration assessment tool
  - I2I is usually performed to compare the registration between two images
  - One image is selected as reference and another as the search image
  - Image chips are selected from reference image and are correlated with search image
  - The co-registration results provide an insight to the relative accuracy of the search image with respect to the reference image
  - When the correlated points are plotted in the image, it also helps to detect any systematic bias in the image

- Band to Band (B2B) registration assessment tool
  - B2B is performed to ensure that the proper band alignment parameters are provided
  - It is typically done by registering each band against every other band

Image-to-Image (I2I) Assessment (Sonoran & Railroad Valley Test Sites)

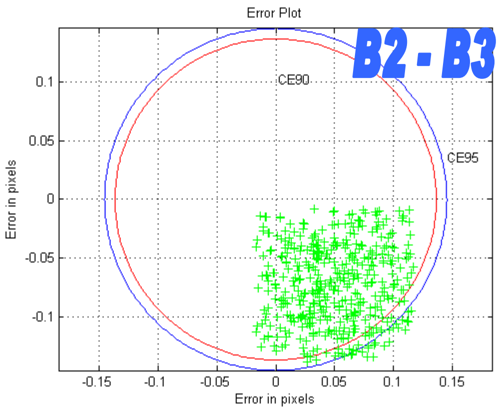


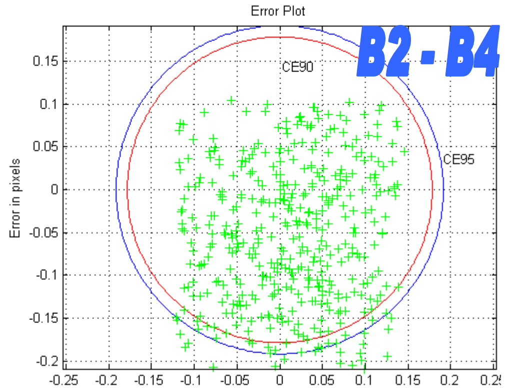


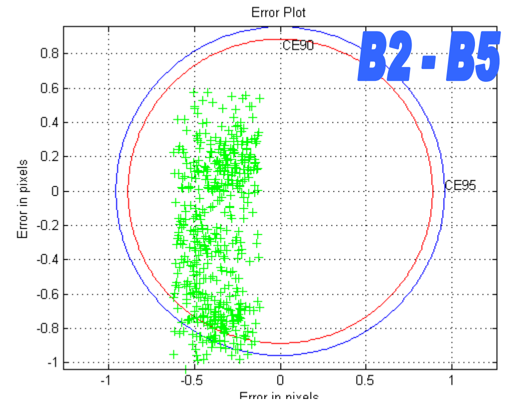
	Pixels		Meters	
Sonoran	Line	Sample	Line	Sample
Mean	0.48	0.18	26.69	10.25
Standard Deviation	0.34	0.38	18.82	21.00
RMSE	0.60	0.56	33.65	31.63

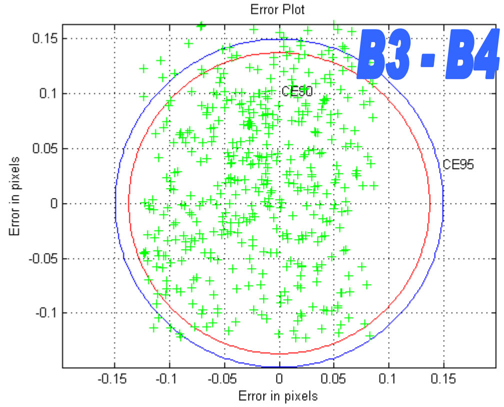
	Pixels		Meters	
RVPN	Line	Sample	Line	Sample
Mean	0.36	0.30	20.15	16.92
Standard Deviation	0.15	0.22	8.48	12.56
RMSE	0.41	0.40	22.87	22.33

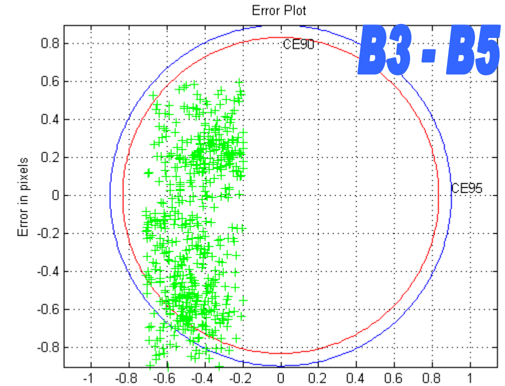
AWiFS (B2B) – Sonoran

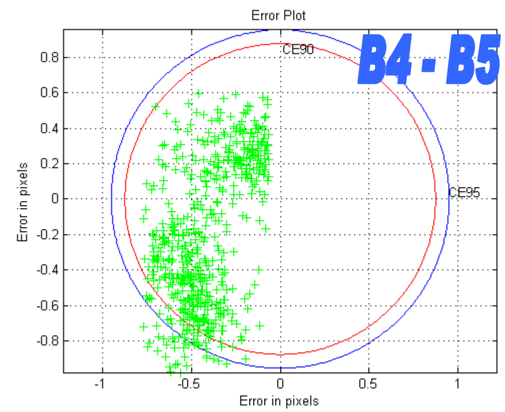






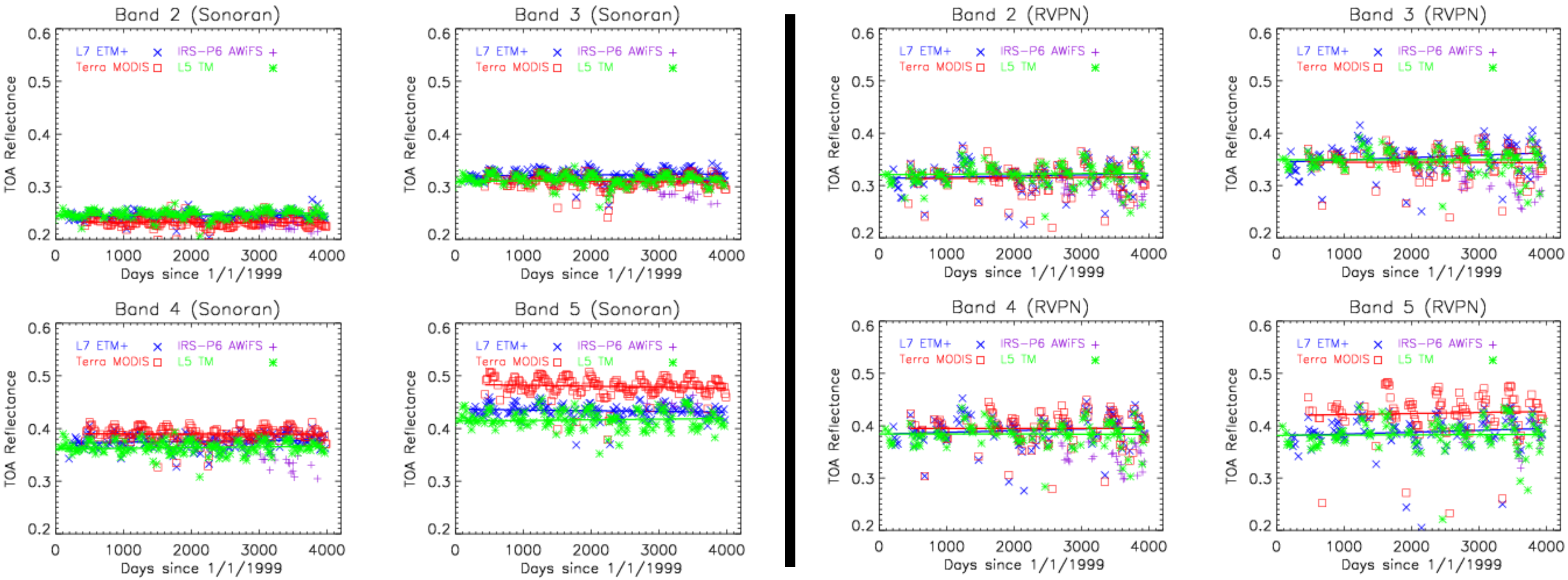






The circular error plot, with the red circle showing CE90 and the blue circle showing CE95

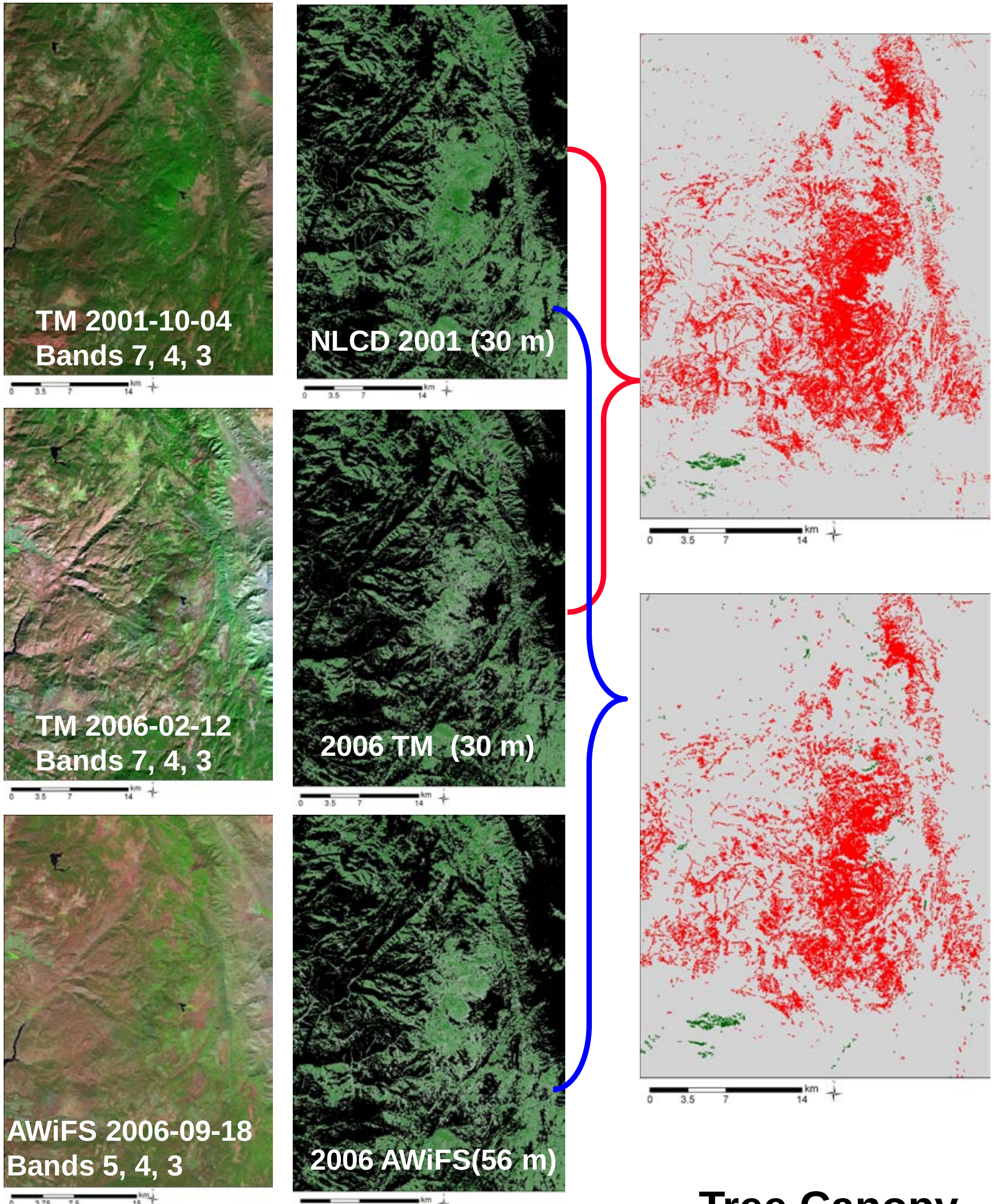
Long-term TOA Reflectance Trending (Sonoran & Railroad Valley Test Sites)



- Linear equations are fitted to the long-term TOA reflectance trends
  - Slope values are very small: prove the long term stability of sensors
  - There are constant offsets: caused by a combination of the spectral signature of the ground target, atmospheric composition and the RSR characteristics
- The annual oscillation were caused by BRDF effect

NLCD Tree Canopy Change Assessment

San Diego (Forest, Grassland, Shrubland, etc.)



Data | Tree Canopy | Tree Canopy Change

Decrease in tree canopy estimate is relatively easy to detect (spectral variation due to fire disturbance, clear-cut)

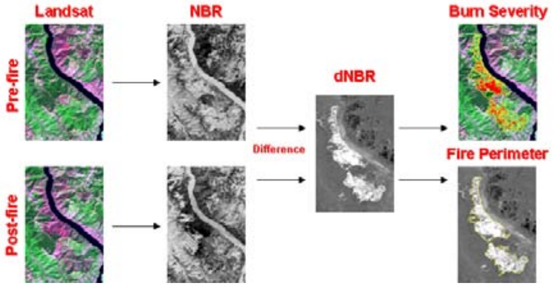
Increase is a gradual change. Increase in tree canopy estimate is harder to detect. (Spectral mixing makes it harder to detect re-growth)

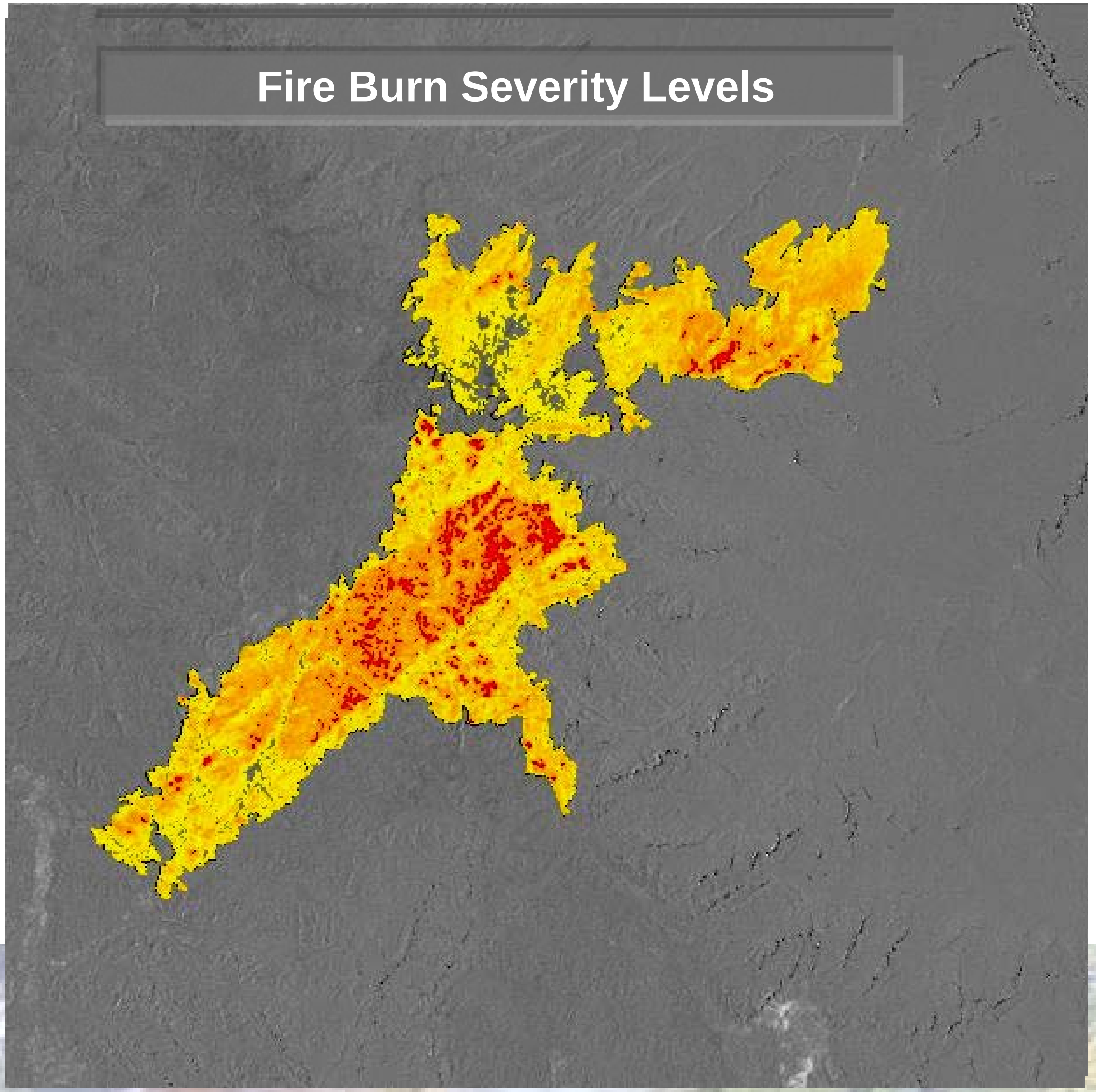
Change comparison for Tree Canopy derived from Landsat and AWiFS Images

Change Agreement	
San Diego	
Decrease area	Increase area
56 m	
82.10%	42%

Monitoring Trends in Burn Severity: MTBS

- Mapping the Location, Extent and Severity of Fires in the United States
- Burn severity products are based on the differenced Normalized Burn Ratio (dNBR) derived from Landsat TM & ETM+ data:
- Normalize Burn Ratio (NBR) = (B4 – B7) / (B4 + B7)
- dNBR = PreFire NBR – PostFire NBR
- Burn Severity is visually estimated from the dNBR



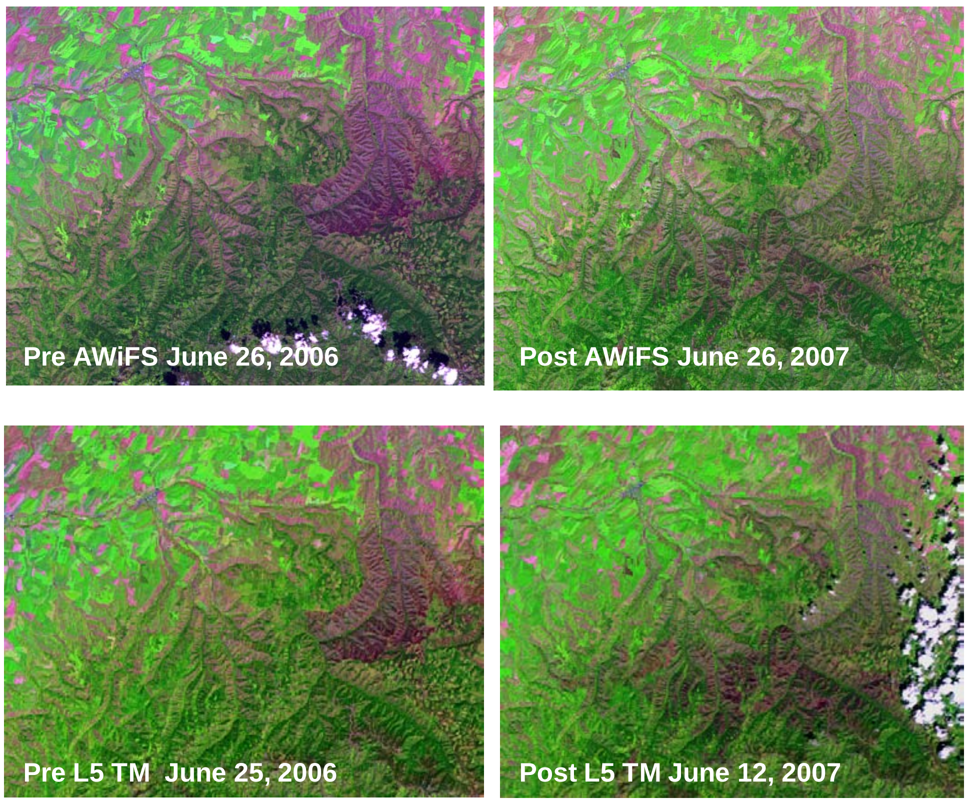


USGS

MTBS Burn Severity Maps Assessment
Data Sources

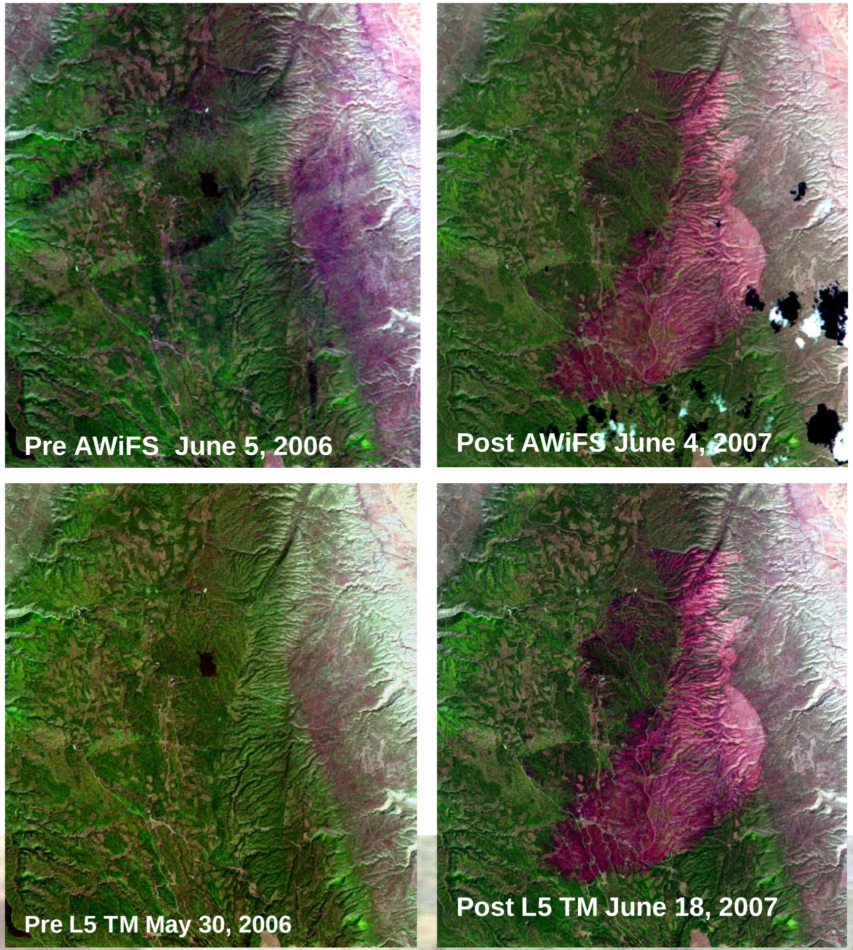
Pacific NW Columbia Complex Fire (Aug 21, 2006)

Primarily **evergreen forest** but also in surrounding agricultural lands and adjacent to a previous burn

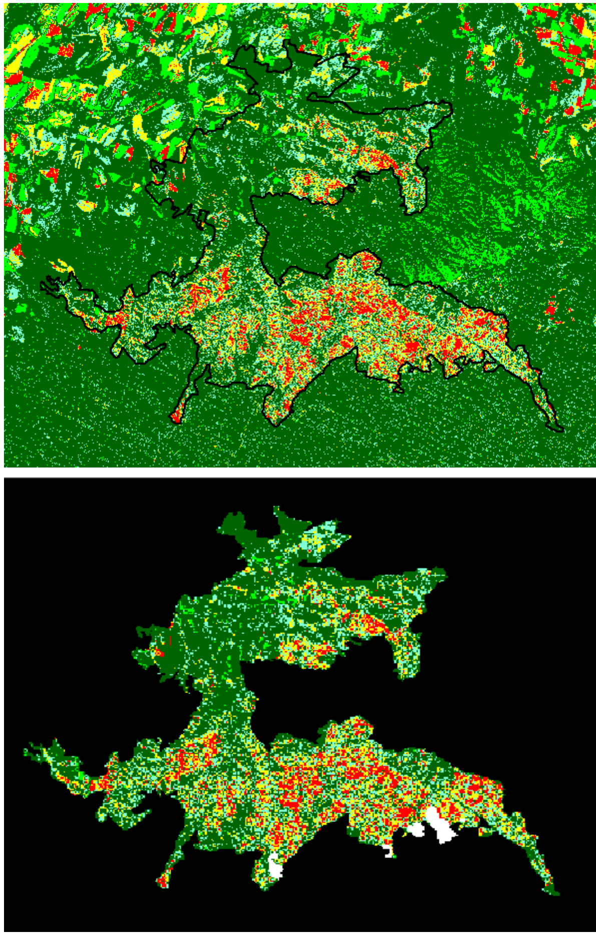


Arizona Warm Fire (July 06, 2006)

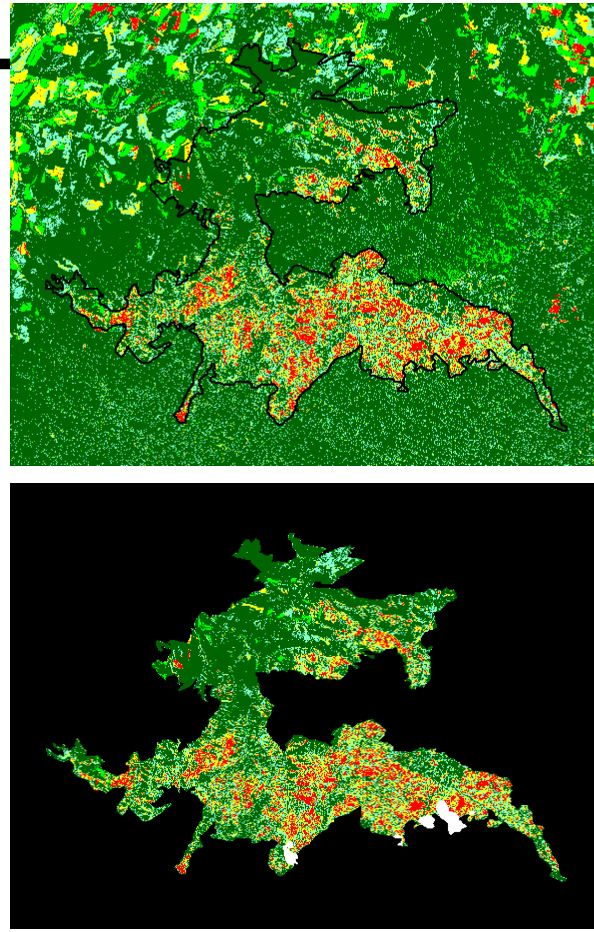
Mostly **Ponderosa pine** with a Pinyon Juniper/ Shrub mixture at lower elevations on the east



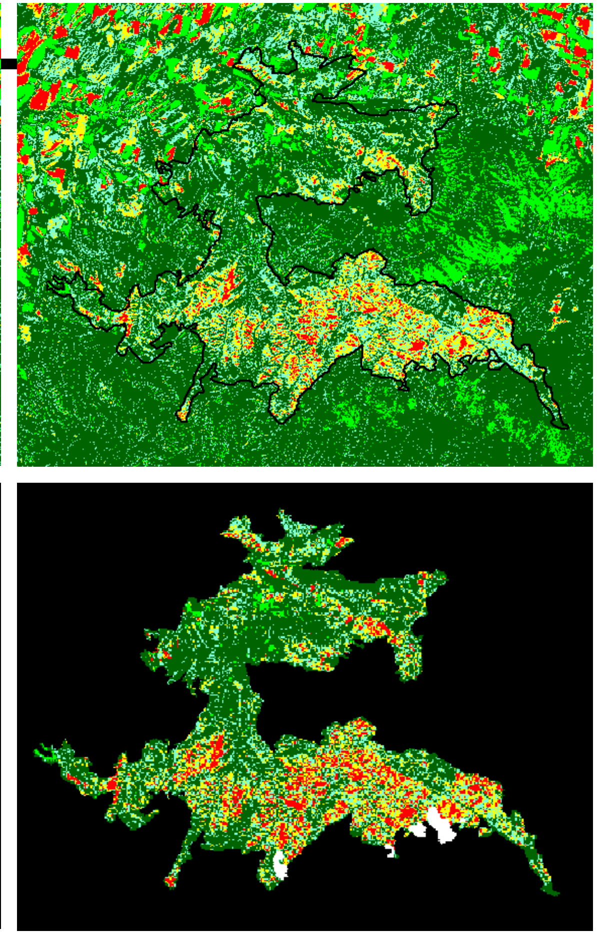
MTBS dNBR Burn Severity Maps:
Pacific NW Columbia Fire [Aug 21, 2006]



Official TM dNBR



TM B5 dNBR

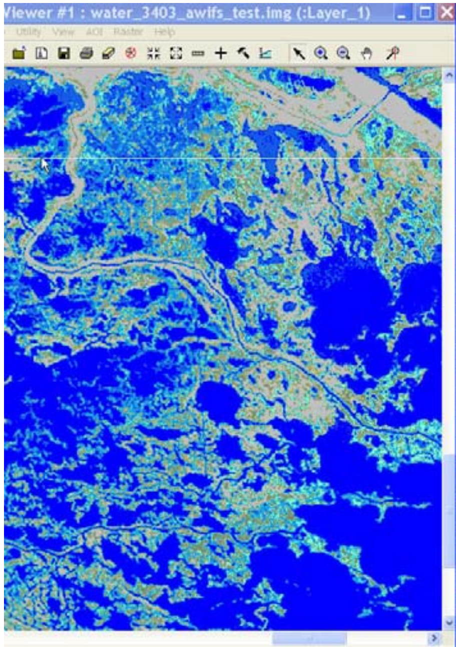


AWiFS dNBR

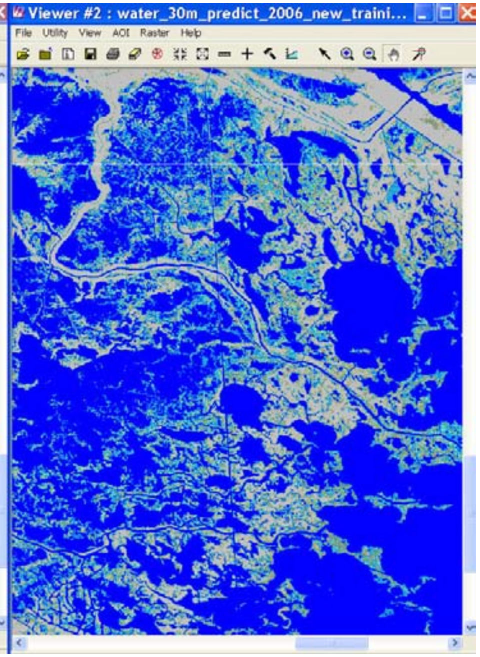
Class Severity		Pixel Counts	Class 1	Class 2	Class 3	Class 4	Total	% agreement
Unburned to low	(green)	Class 1	62997	12866	4102	802	81933	76.9
Low	(cyan)	Class 2	13733	9795	5837	958	30472	32.14
Moderate	(yellow)	Class 3	3919	6437	9287	3598	23277	39.9
High	(red)	Class 4	293	1046	4093	10299	15733	65.46

NLCD Wetland Mapping and Monitoring

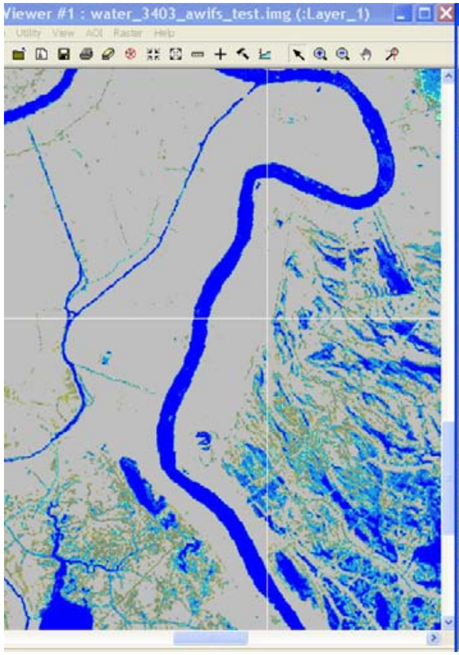
Comparison of Modeled Sub-Pixel Percent of Water



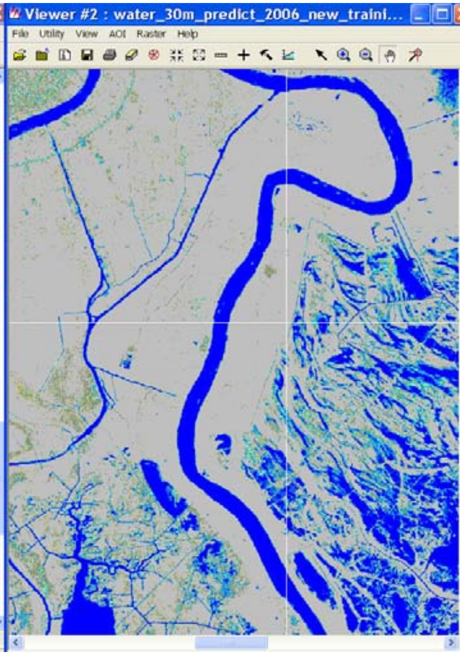
% water Sep. 27, 2006 using AWiFS



% water Sep. 26, 2006 using Landsat



% water Sep. 27, 2006 using AWiFS



% water Sep. 26, 2006 using Landsat

Input Imagery	# of training samples	# of test samples	Ave Error (%)	Relative Error (%)	Correlation Coeff. R
TM Image	5000	500	6.4	0.15	0.96
AWiFS Image	5000	500	9.8	0.23	0.90

USGS

Survey of Well-Established Site Selection Criteria for Radiometry Test Sites

- High spatial uniformity over a large area (within 3%)
  - Minimize misregistration and adjacency effects
- Surface reflectance [0, 1] greater than 0.3
  - To provide higher SNR and reduce uncertainty due to atmosphere
- Flat spectral reflectance spectrum
  - Reduce uncertainties due to different RSR
- Temporally invariant surface properties (within 2%)
  - To reduce BRDF, spectral, surface reflectance effects
- Horizontal surface with nearly lambertian reflectance
  - Minimize uncertainty due to different solar illumination & observation geometry
- At high altitude, far from ocean, urban, and industrial areas
  - Minimize aerosol loading and atmospheric water vapor
- In arid regions with low probability of cloud cover
  - Minimize precipitation that could change soil moisture

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)**

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 crosing 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 Sesnsor 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 (radiance)	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

EOTec website

http://www.eotec.com/images/R1_Pricing_As_Of_1-1-09.pdf

EOTec

RESOURCESAT-1 PRICING

RESOURCESAT-1 PRICING - Effective 1 January 2009							
Product Suite	Resolution	Band	Scene Size	Unit Price	Large Area Discount $50K-$100K (5%)	$101K-$250K (8%)	> $250 (10%)
Georectified - Path Oriented	5m	B&W	70 x 70 km	$2,500	$2,375	$2,300	$2,250
	5m	Multispectral	23 x 23 km	Quote	Quote	Quote	Quote
	23m	Multispectral	141 x 141 km	$2,500	$2,375	$2,300	$2,250
	56m	Multispectral	350 x 350 km	$700	$700	$700	$700
Georectified - Map Oriented	5m	B&W	70 x 70 km	$2,750	$2,613	$2,530	$2,475
	5m	Multispectral	23 x 23 km	Quote	Quote	Quote	Quote
	23m	Multispectral	141 x 141 km	$2,750	$2,613	$2,530	$2,475
	56m	Multispectral	350 x 350 km	$850	$808	$782	$765
Orthorectified	5m	B&W	70 x 70 km	$3,575	$3,396	$3,289	$3,218
	5m	Multispectral	23 x 23 km	Quote	Quote	Quote	Quote
	23m	Multispectral	141 x 141 km	$3,575	$3,396	$3,289	$3,218
	56m	Multispectral	350 x 350 km	$1,100	$1,045	$1,012	$990

NOTES:
5m Multispectral orders must go through Collection Feasibility and Custom Quote Process prior to order acceptance.
Large Area Discount threshold calculations are based on Unit Price
Large Area Discounts apply to each order and are not cumulative
Large Area Discount does not apply to Path Oriented 56m Multispectral 350 x 350km scenes

Earth Observation Technologies, LLC
2123 LeRoy Place NW
Washington, DC 20008
TEL/FAX: 1-202-232-3138
Email for Orders/Inquiries: Info@eotec.com
Imagery Search: http://imagesearch.geoeye.com/

USGS

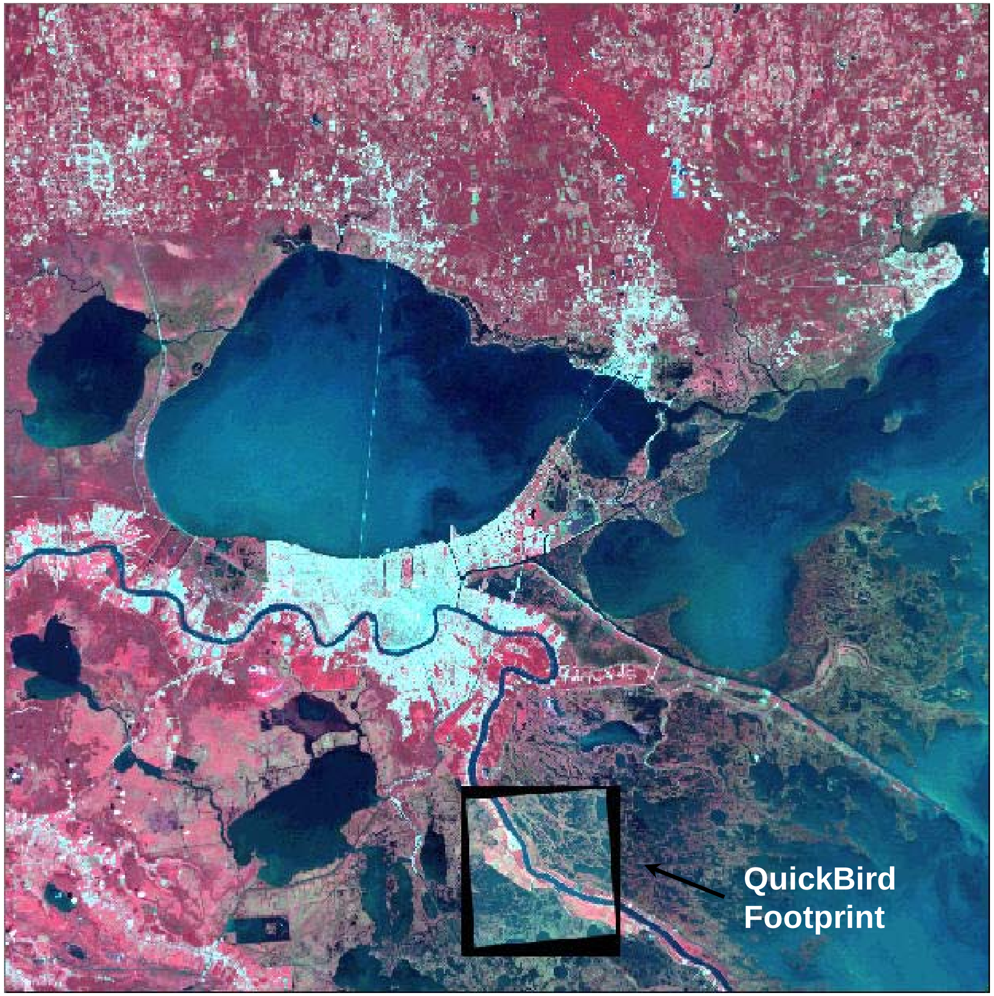
AWiFS Ortho Production

- Ancillary Data Compilation (CONUS)
  - DEM: 1-arcsecond NED
    - SRTM-3 used for scenes straddling US borders
  - Imagery: USGS DOQs
    - Reduced resolution DOQs used for AWiFS control (32 m GSD) ~12 m CE90 positional accuracy (1:24K)

- Ancillary Data Compilation (International)
  - DEM: SRTM-3
    - Alaska NED and Canada CDED used in high latitudes
  - Imagery: GeoCover2000 Landsat orthos
    - ~110 m CE90 positional accuracy
    - Reference image accuracy is limiting factor for international ortho products

NLCD Wetland Mapping and Monitoring
Data Sources

- Challenges
  - Composition of wetlands is complex and often with mixed components (vegetation species, soil, water, etc.)
  - Condition of wetlands are dynamic (seasonal, interannual)
  - Spatial distribution of wetlands are complex
- Remote Sensing Data
  - QuickBird: Sept 29, 2006
  - Landsat TM: Sept 26, 2006
  - IRS-P6 AWiFS: Sept 27, 2006
- Field data (Wetland type, vegetation, fraction of water, land/soil, etc.)



TM & AWiFS Imagery Footprint
Northern Gulf of Mexico (NGOM) study area
Coastal wetlands in LA, most dynamic environment

USGS