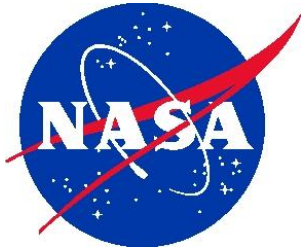

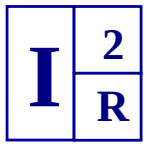

Innovative Imaging & Research

Complementarity of IRS-P6 AWiFS and Landsat TM/ETM+ sensors for Land Cover Change Analysis

2011 Civil Commercial Imagery Evaluation Workshop
Boulder, Colorado
March 29, 2011

Contributors

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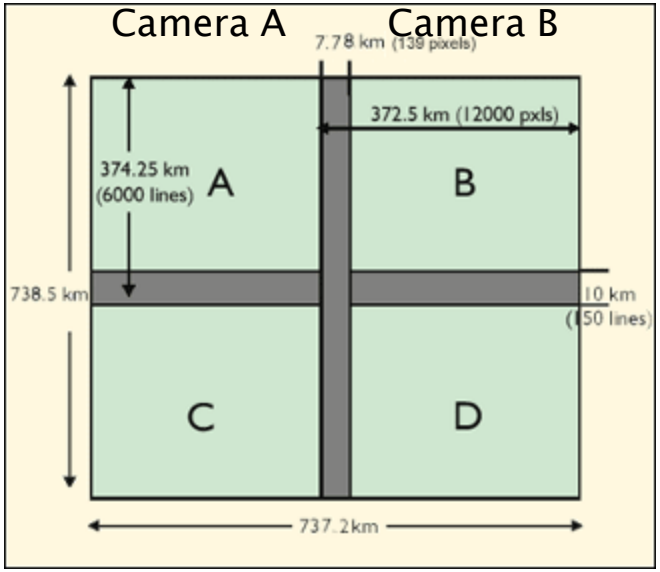
Outline

- Sensor Comparisons
- AWiFS Geometric Assessment
  - Image to image assessment
  - Band to band assessment
- Radiometric Assessment
  - AWiFS Dual Camera Radiometric Consistency Check
  - X-cal between ETM+ and AWiFS
  - AWiFS swath width induced bidirectional reflectance (BRDF) effects
- Sample Application Results
  - Forestry
- Summary and Comments

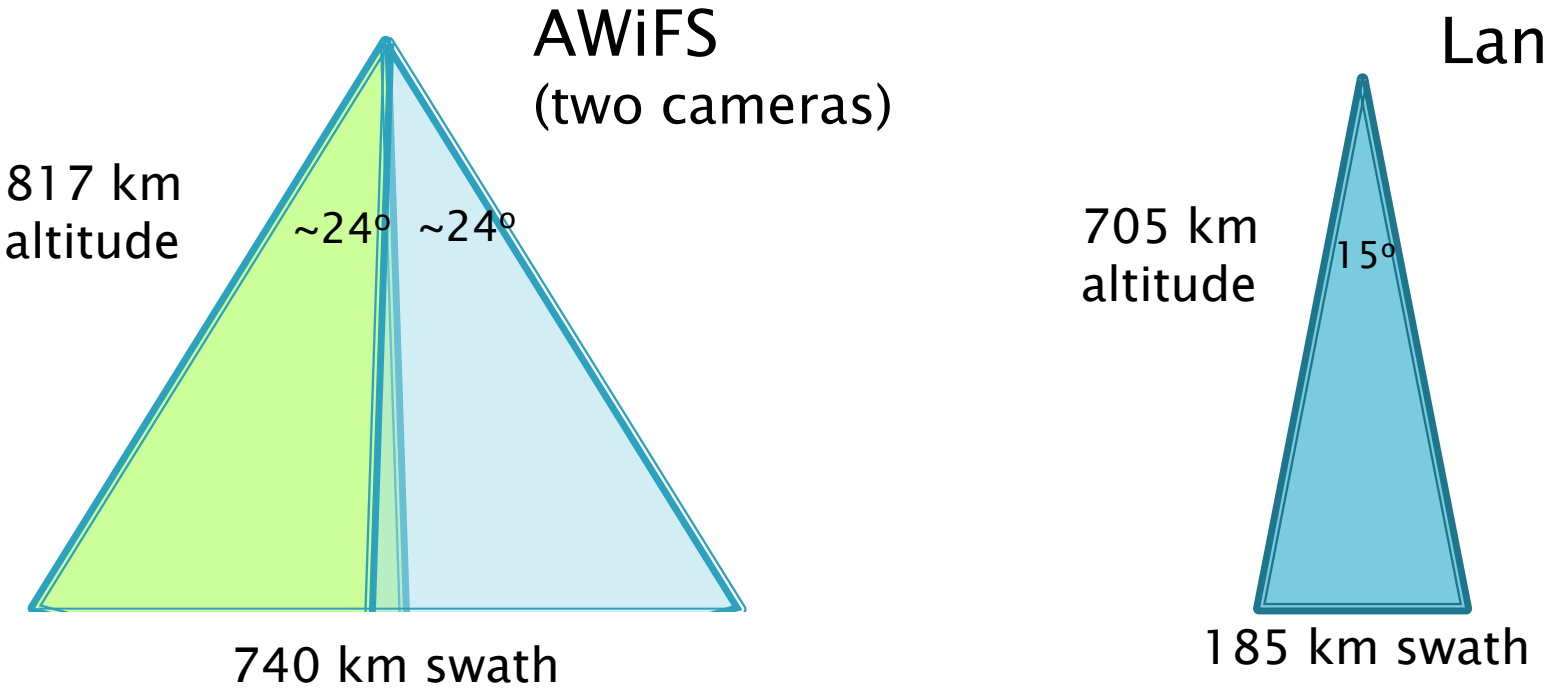
AWiFS Sensor Overview

- The IRS-P6 satellite was launched into a polar sun-synchronous orbit on Oct. 17, 2003, with a design life of 5 years
- 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

Platform	Landsat 7	IRS-P6
Sensor	ETM+	AWiFS
Launch Date	15-Apr-99	17-Oct-03
Number of Bands	8	4
Spatial Resolution (m)	15, 30, 60	56 (nadir), 70
Swath (km)	183	740
Spectral Coverage (µm)	0.4~12.5	0.52~1.7
Pixel Quantization (bits)	8	10
Orbit Type	Sun synchronous	Sun synchronous
Equatorial Crossing Time	10:00 AM	10:30 AM
Altitude (km)	705	817



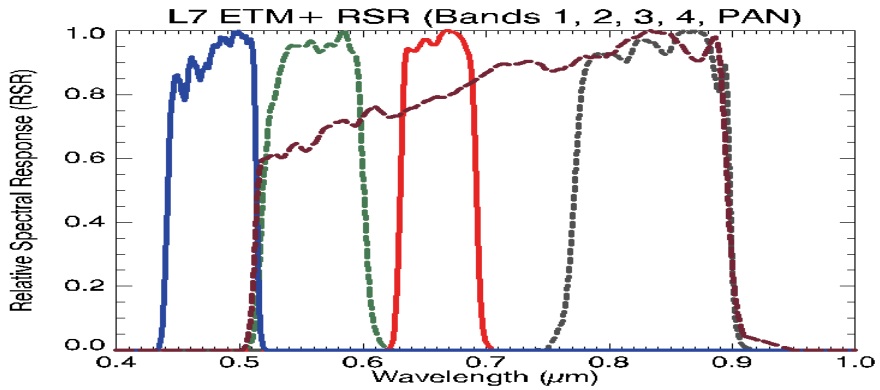
Landsat – AWiFS Swath Width Acquisition Differences

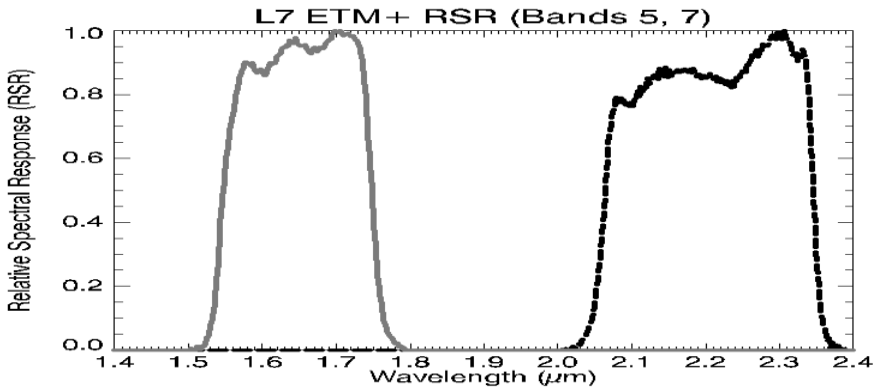


AWiFS imagery exhibits greater BRDF effects due to larger swath

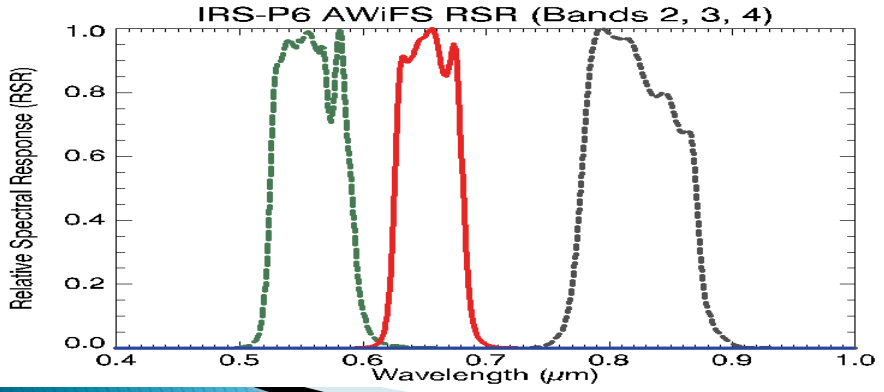
Relative Spectral Response (RSR) Comparison

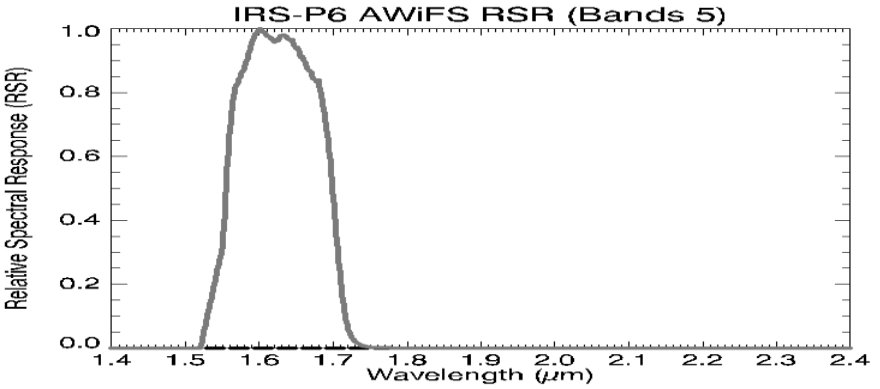
L7 ETM+





IRS P6 AWiFS





AWiFS Radiometric Calibration

- IRS-provided calibration coefficients used during this assessment
  - Developed pre-launch and have never been updated
  - Provided with imagery
  - Calibration coefficients for both the A and B cameras are the same

Band	Green	Red	NIR	SWIR
Calibration Coefficient [W/m^2 sr μm DN]	0.512	0.398	0.278	0.045

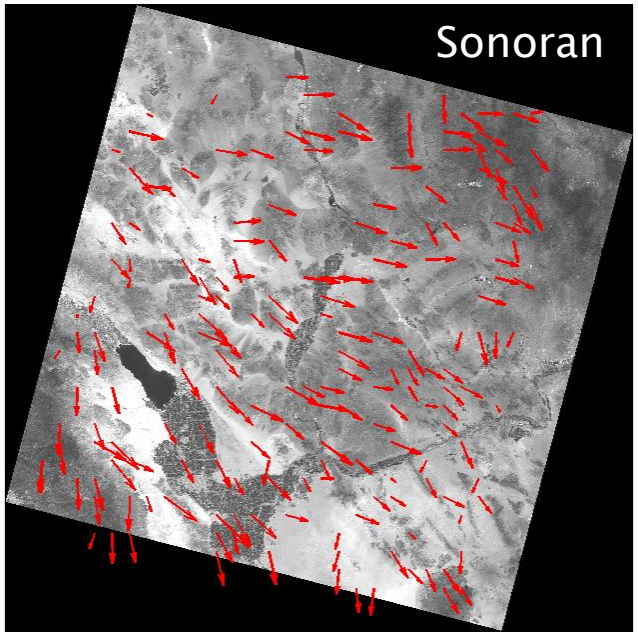
- NASA-funded vicarious calibrations performed in 2005-2006 indicate calibration differences
  - Limited calibration (21 targets within 10 scenes)

Geometric Assessment

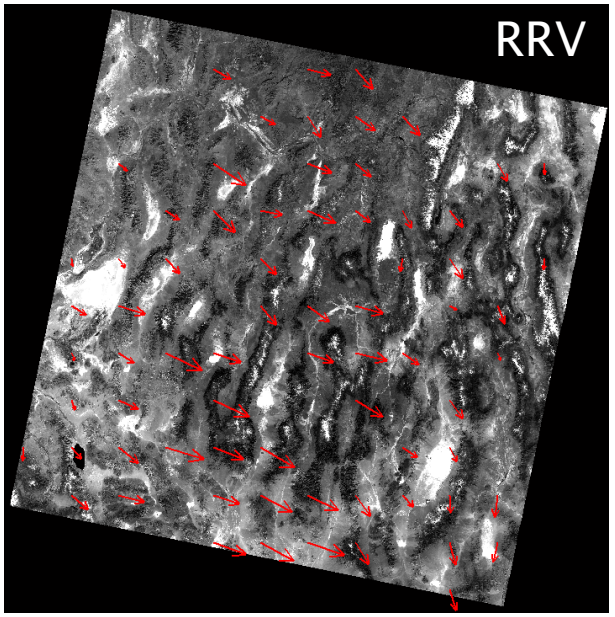
Geometric Assessment

- Completed using the Image Assessment System
  - Developed for Radiometric and Geometric Characterization and Calibration for the Landsat Program
- Image to Image registration
  - Compares the registration between two images (reference and test image)
  - Image chips selected from reference image and correlated with test image
  - Relative accuracy assessment
  - Can be used to detect any systematic bias in the test image
- Band to Band registration
  - Performed to ensure proper band alignment
  - Performed by registering each band against every other band within a test image

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



252_045_D_20090420



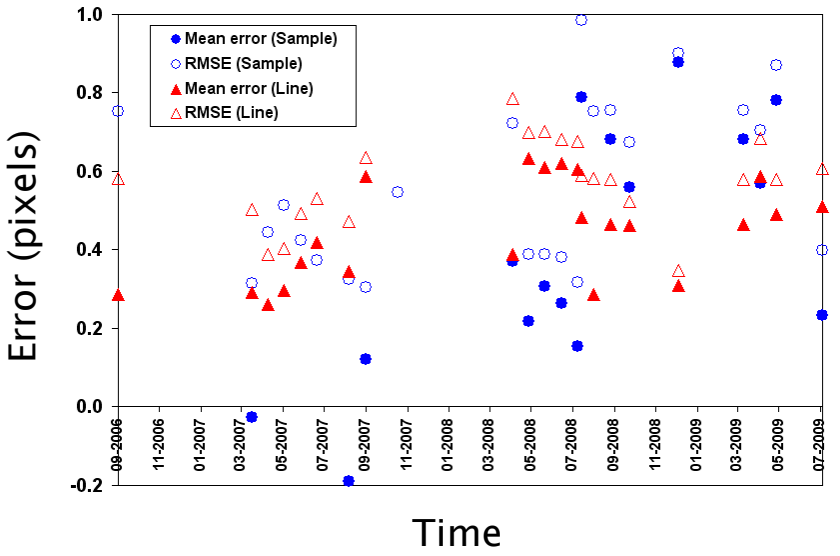
248_040_D_20081014

- The characterization was performed to compare the accuracy of AWiFS against the GLS2000 dataset
  - 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

Vector scale: 1:2800

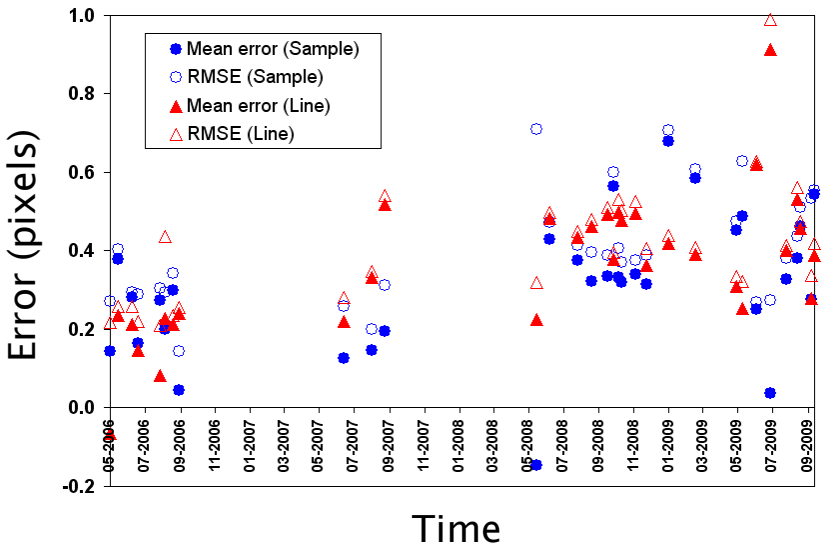
Image to Image Assessment (Sonoran & Railroad Valley Test Sites)

Mean Error & RMSE (Sonoran)



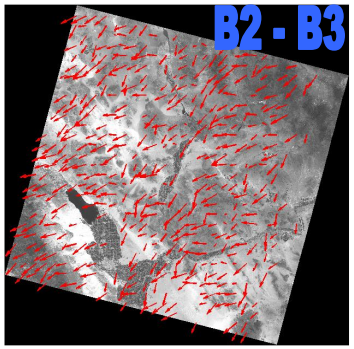
Sonoran	Pixels		Meters	
	Line	Sample	Line	Sample
Mean	0.48	0.18	26.69	10.25
Standard Deviation	0.34	0.38	18.82	21.00
RMSE	0.60	0.56	33.65	31.63

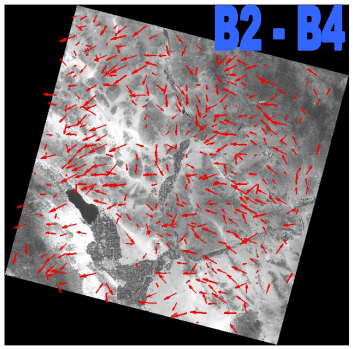
Mean Error & RMSE (RVPN)

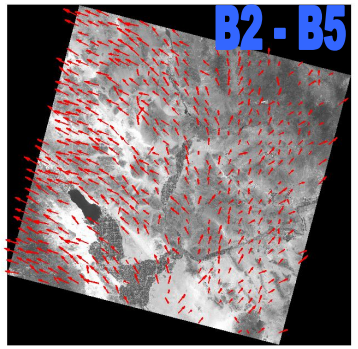


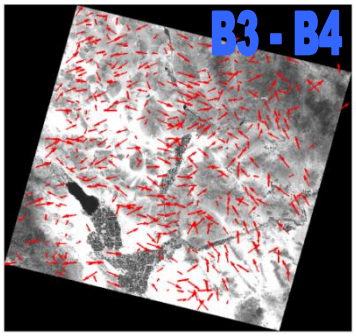
RVPN	Pixels		Meters	
	Line	Sample	Line	Sample
Mean	0.36	0.30	20.15	16.92
Standard Deviation	0.15	0.22	8.48	12.56
RMSE	0.41	0.40	22.87	22.33

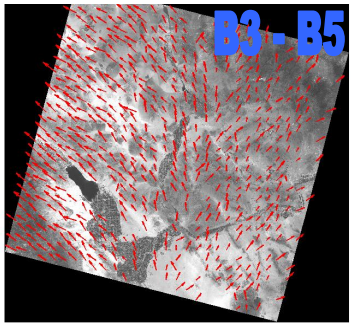
Band to Band Assessment Sonoran

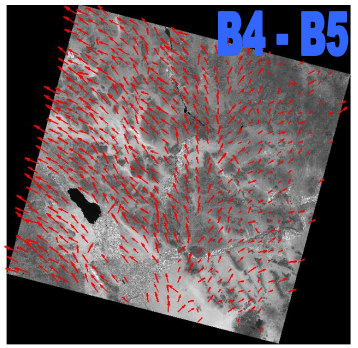












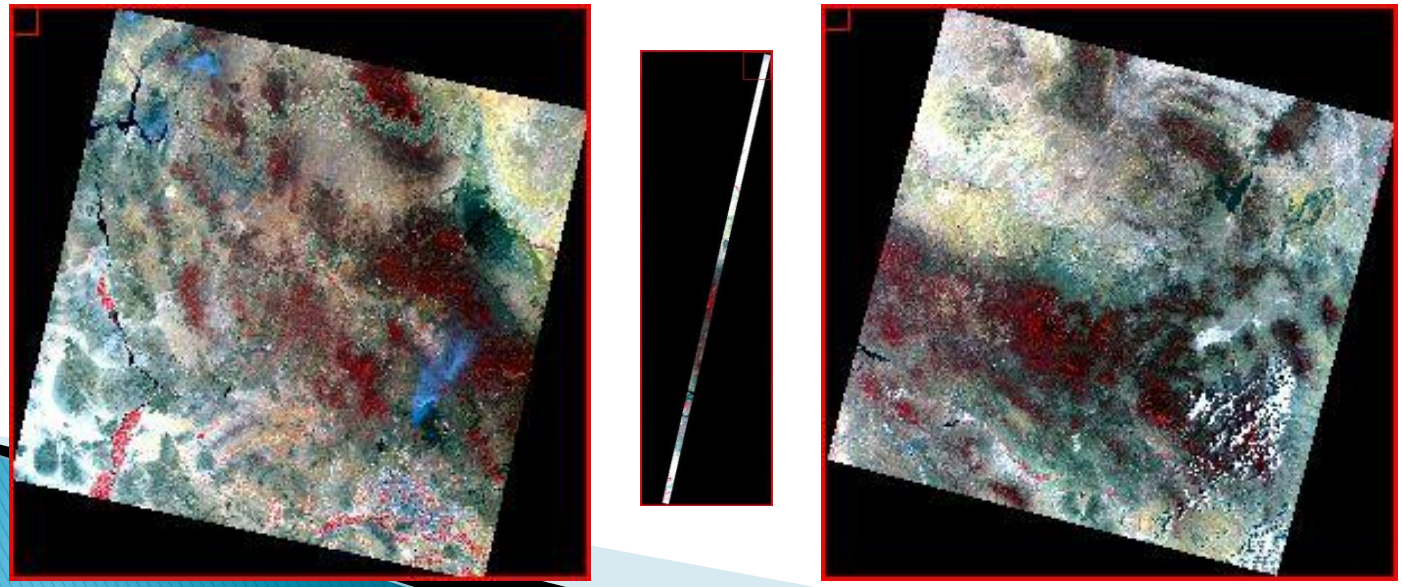
- The MS bands are registered to sub-pixel accuracy
- The results show that alignment between bands 2, 3 and 4 is very good, while the alignment errors with band 5 are higher

Vector scale: 1:2800

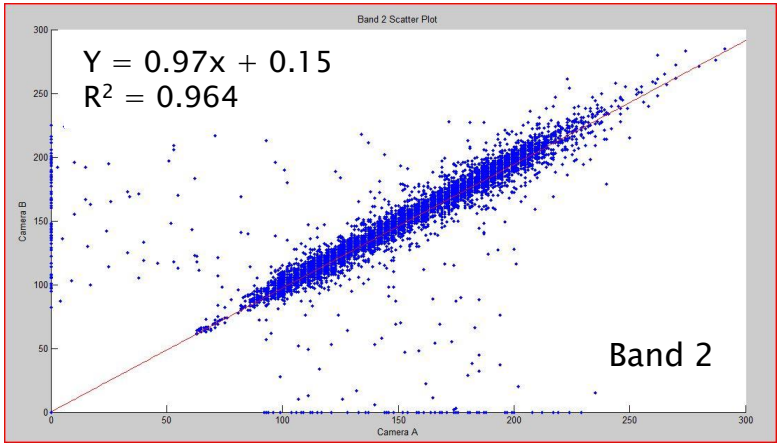
Radiometric Assessment

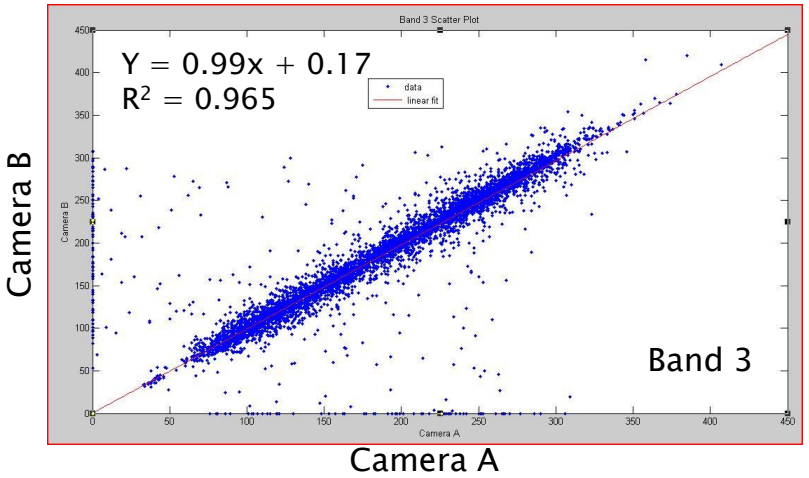
AWiFS Dual Camera Radiometric Consistency Check

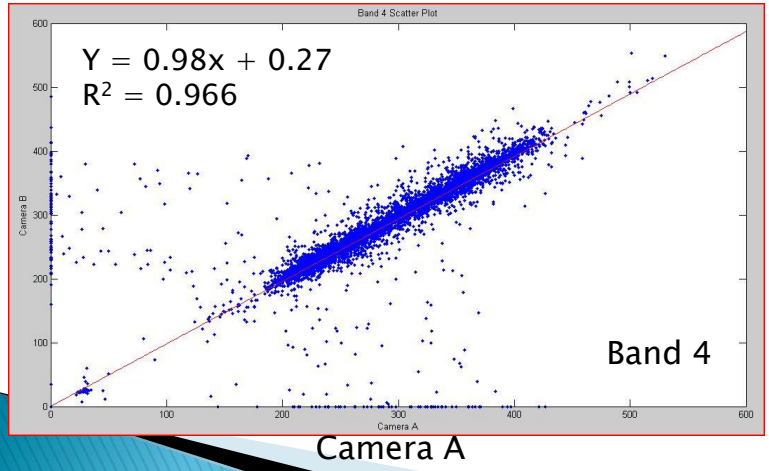
- Evaluated the 7.8 km overlap area between the A & B cameras
  - A and B Quads
  - Mesa, AZ scene provided by USGS (GeoEye archive)
    - Path/row 257/47, acquired 06/29/05

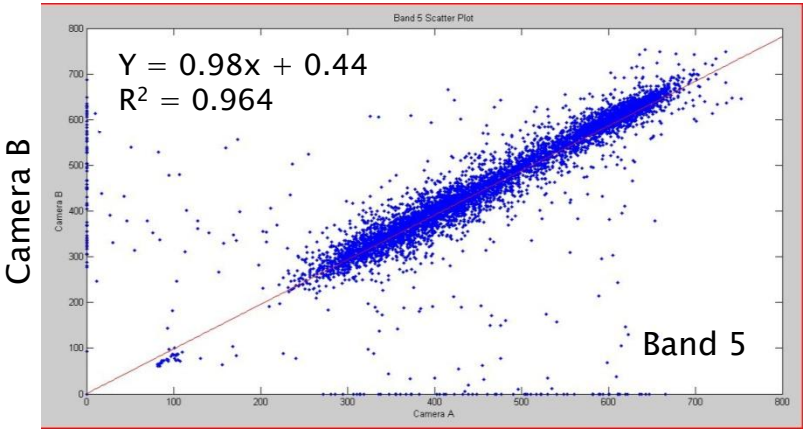


Overlapping Area Scatter Plots – Individual Pixel Comparison





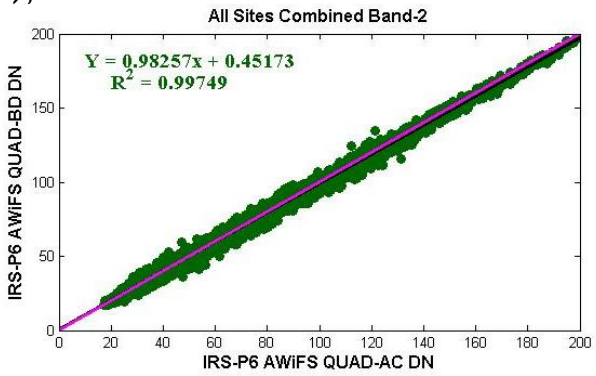


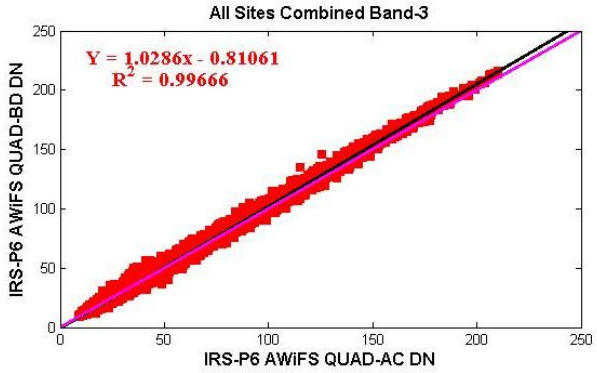


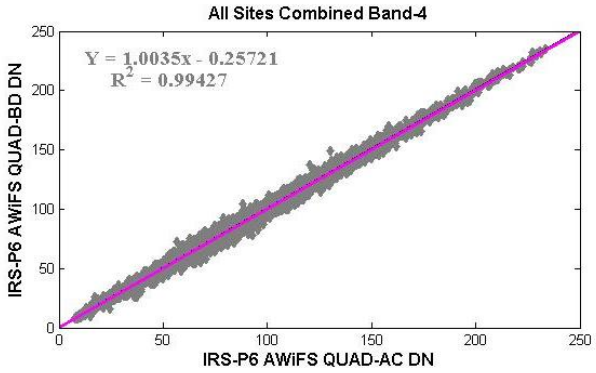
Excellent agreement between camera modules

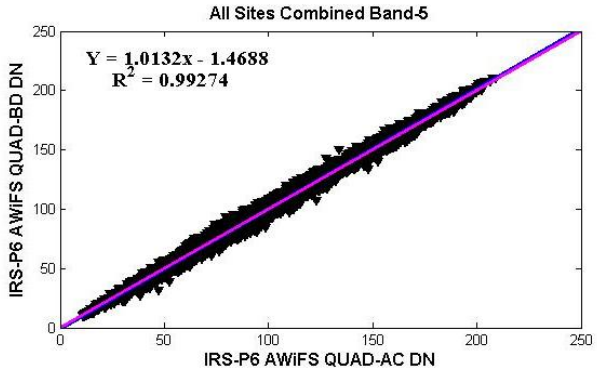
AWiFS Dual Camera Radiometric Consistency Check – 50 Pixel Avg

- Evaluated the 7.8 km overlap area between the A & B cameras
  - 2004-08-04 (P268/R036); 2004-08-24 (P272/R046), 2005-04-27 (P278/R047); 2005-08-18 (P267/R040),
  - 2006-07-15 (P266/R039); 2006-07-31 (P274/R039), 2007-04-15 (P268/R040); 2007-06-20 (P262/R035);
- Excellent agreement between camera modules
- Band 2 was observed to have the largest difference (2%) between camera AC/BD
- In all other bands, the difference is within 1% in most cases









Reflectance Map Generation

- Planetary Reflectance / Top of Atmosphere
  - First-order approximation – no knowledge of atmosphere
  - Corrects for solar zenith and Earth-Sun distance

$$\rho_{TOA} = \frac{\pi d^2 L_{TOA}}{E_{sun} \cos\theta}$$

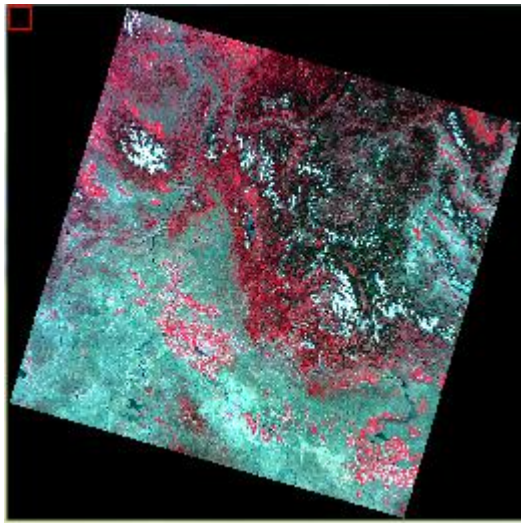
- Surface Reflectance
  - Atmospheric correction is the process of converting satellite signals (at-sensor radiance) to surface reflectance
  - In general, surface reflectance yields more accurate results than planetary reflectance
  - Spherical albedo formulation *(Tanre et. al, 1979)*

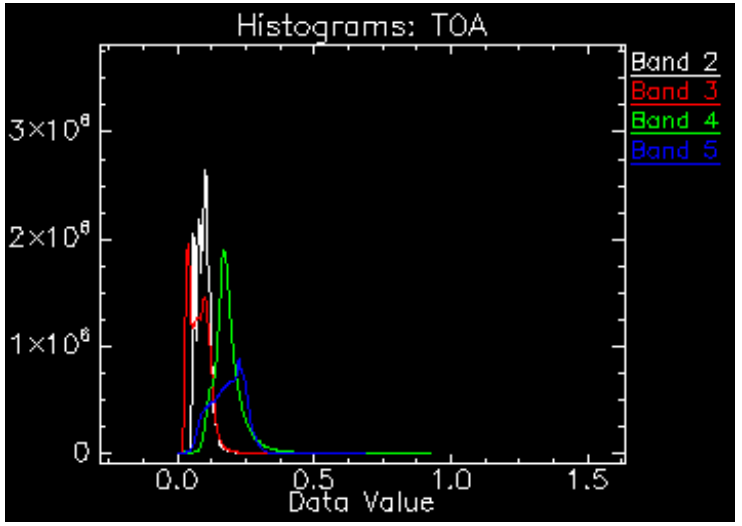
$$\rho_{T} = \left(\rho_{TOA} - \rho_0 - \frac{B\rho_{bg}}{1 - s\rho_{bg}} \right) \frac{(1 - s\rho_{bg})}{A}$$

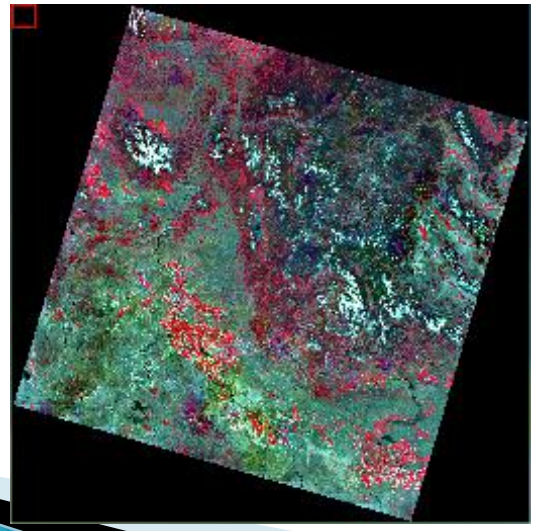
AWiFS Reflectance Maps

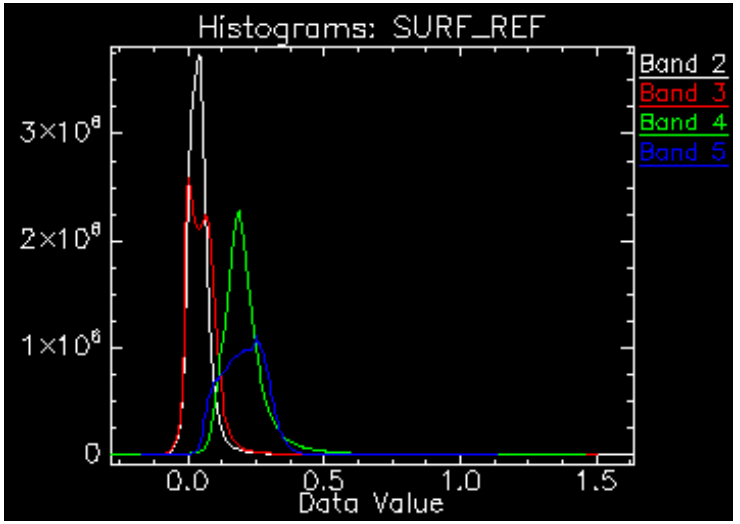
RGB using NIR, green, and red

Path 247,
Row 36,
Quad D,
Acquired
June, 22 2006.

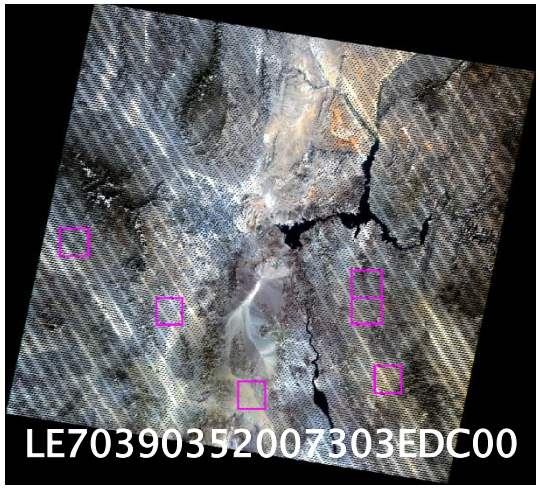


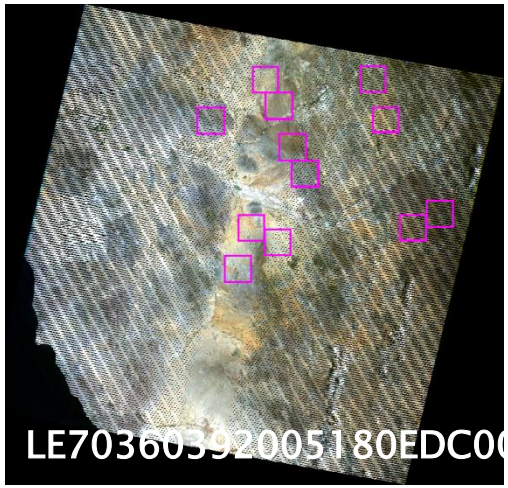


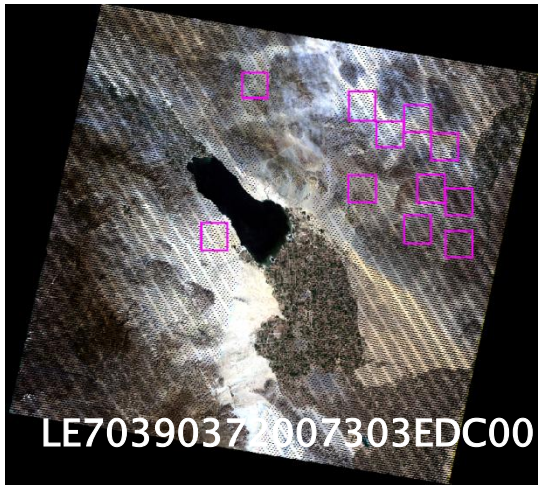


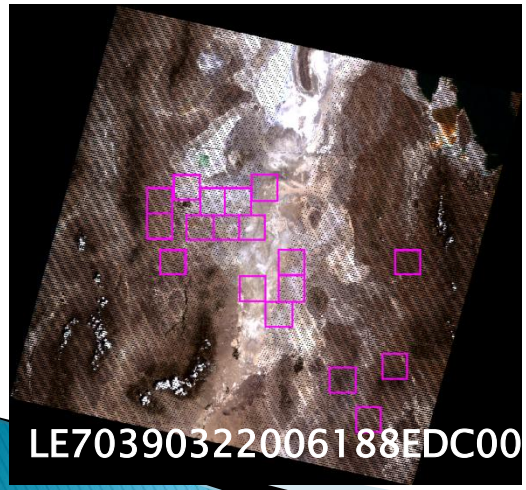


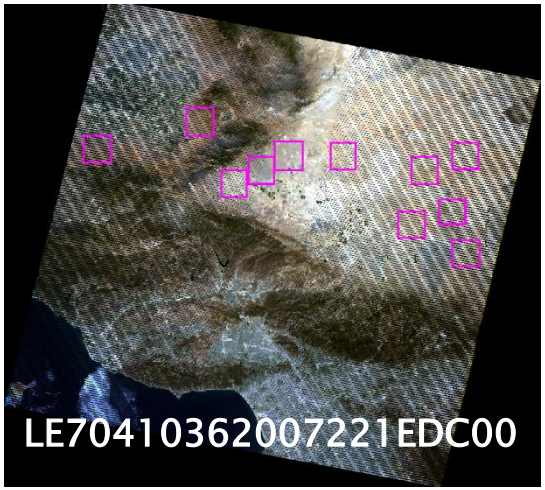
L7 ETM+ and AWiFS-BD Quads (ROI)

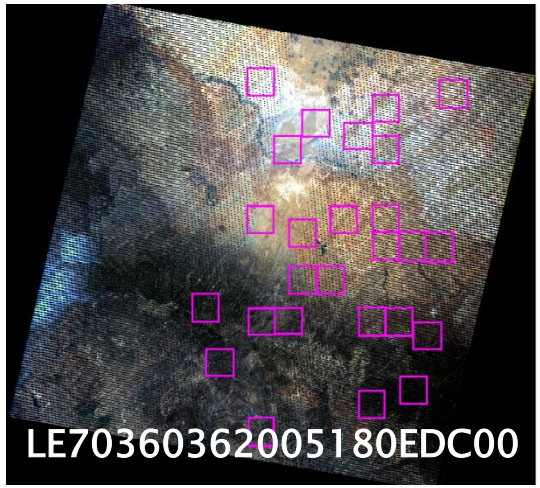


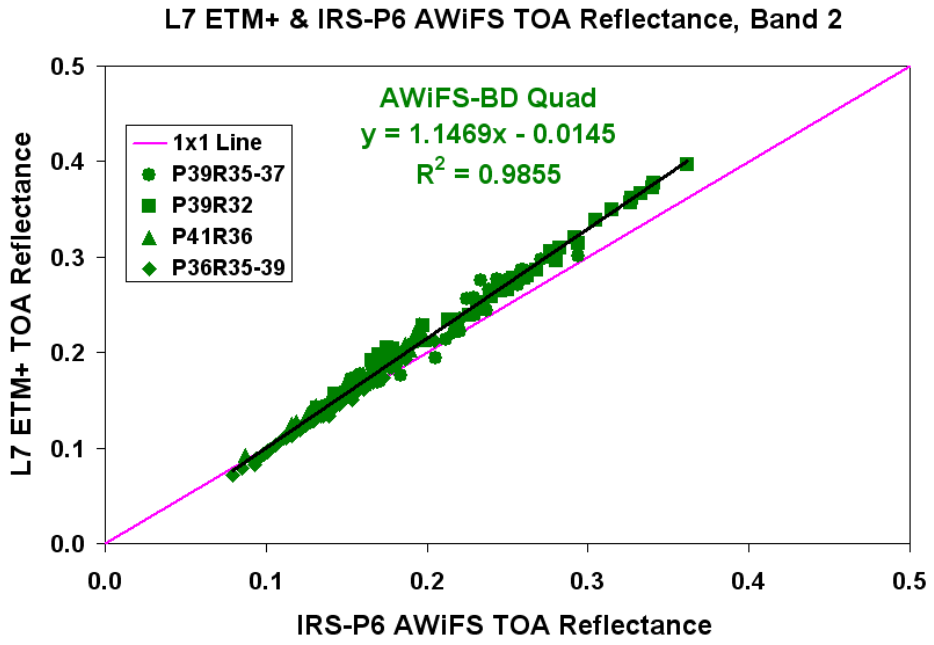


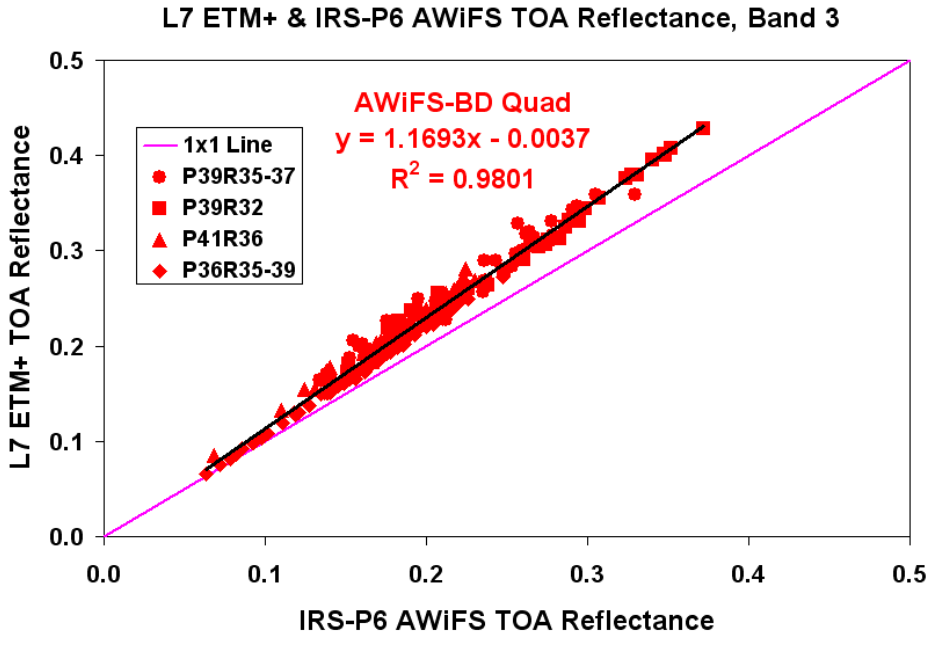


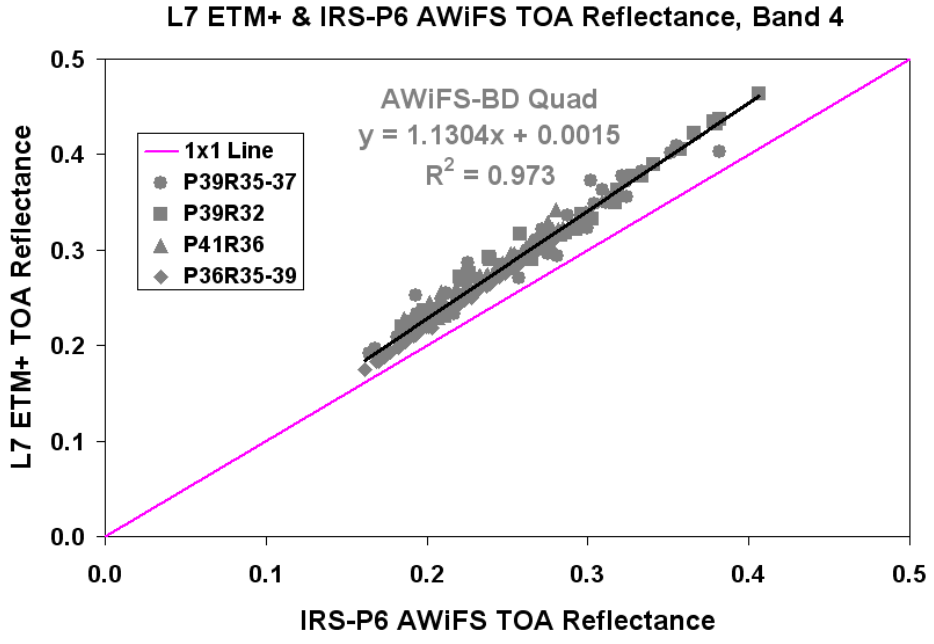


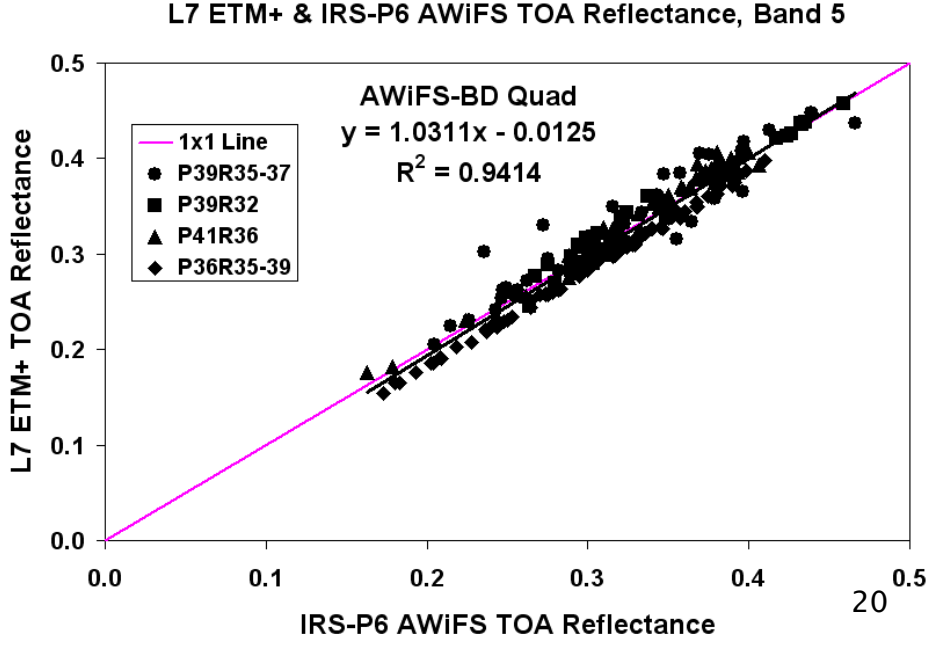





L7 ETM+ & IRS-P6 AWiFS TOA Reflectance, Band 2
AWiFS-BD Quad
y = 1.1469x - 0.0145
R2 = 0.9855
1x1 Line
P39R35-37
P39R32
P41R36
P36R35-39
L7 ETM+ TOA Reflectance
IRS-P6 AWiFS TOA Reflectance
0.0
0.1
0.2
0.3
0.4
0.5

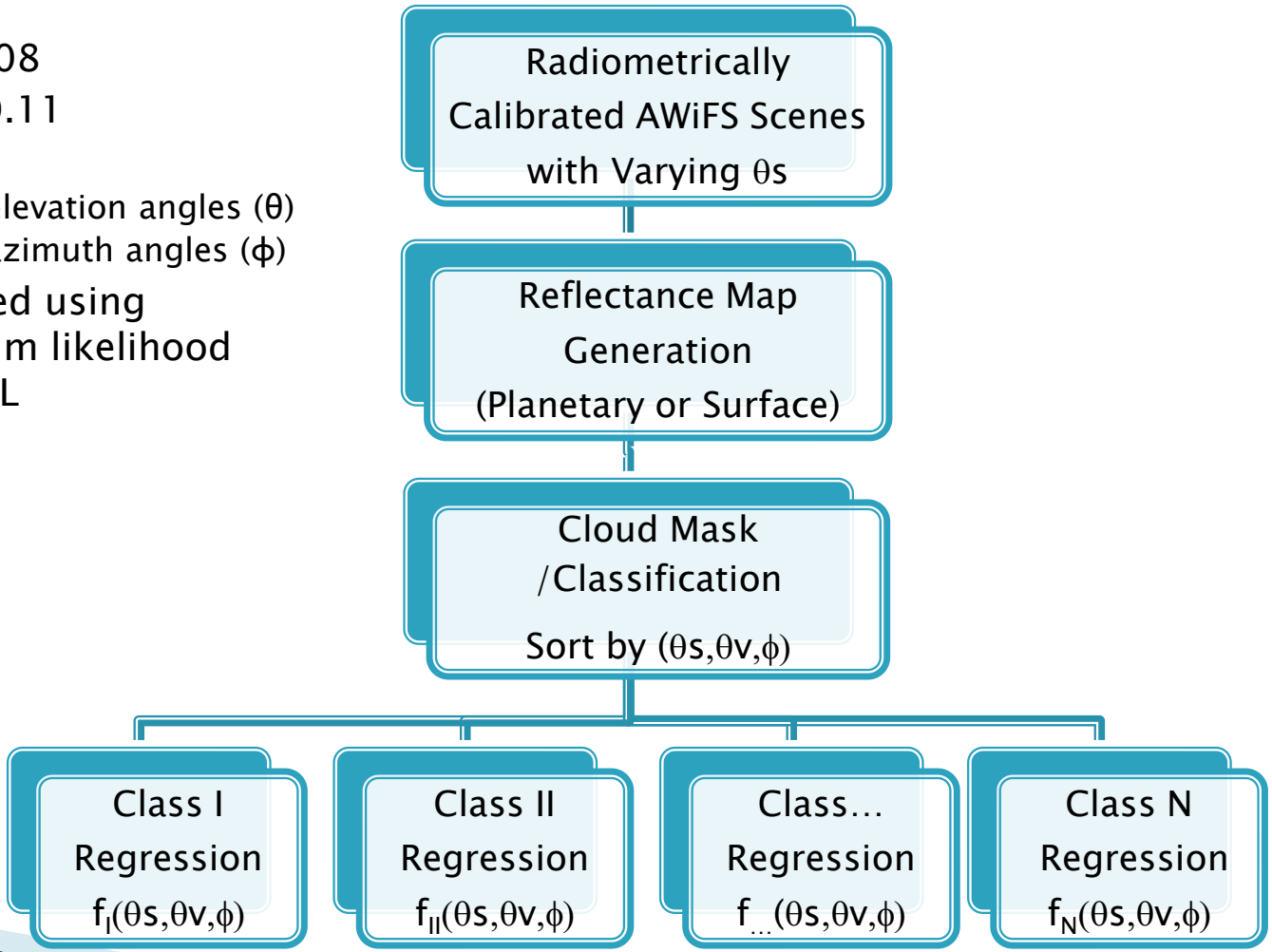

L7 ETM+ & IRS-P6 AWiFS TOA Reflectance, Band 3
AWiFS-BD Quad
y = 1.1693x - 0.0037
R2 = 0.9801
1x1 Line
P39R35-37
P39R32
P41R36
P36R35-39
L7 ETM+ TOA Reflectance
IRS-P6 AWiFS TOA Reflectance
0.0
0.1
0.2
0.3
0.4
0.5


L7 ETM+ & IRS-P6 AWiFS TOA Reflectance, Band 4
AWiFS-BD Quad
y = 1.1304x + 0.0015
R2 = 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

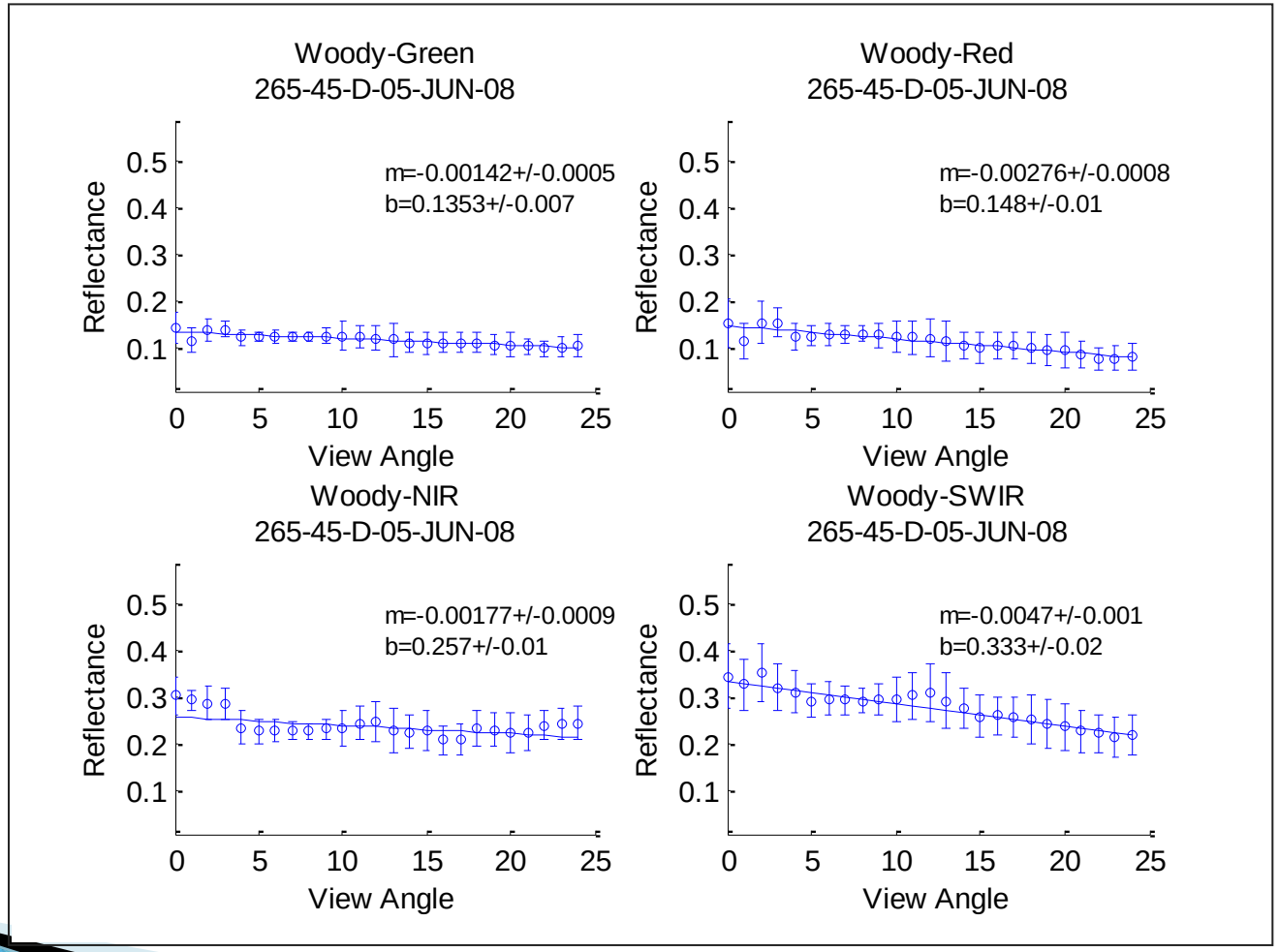

L7 ETM+ & IRS-P6 AWiFS TOA Reflectance, Band 5
AWiFS-BD Quad
y = 1.0311x - 0.0125
R2 = 0.9414
1x1 Line
P39R35-37
P39R32
P41R36
P36R35-39
L7 ETM+ TOA Reflectance
IRS-P6 AWiFS TOA Reflectance
0.0
0.1
0.2
0.3
0.4
0.5

BRDF Model Approach

- 11 AWiFS scenes
- June 2006-Sept 2008
- Clear days: AOT <0.11
- Vary geometries
  - Solar and viewing elevation angles (θ)
  - Solar and viewing azimuth angles (ϕ)
- 4 classes determined using supervised maximum likelihood and USDA NASS CDL
  - Woody
  - Non-woody
  - Bare
  - Water



Example Reflectance Variation as a Function of View ANgle



Statistical BRDF Model

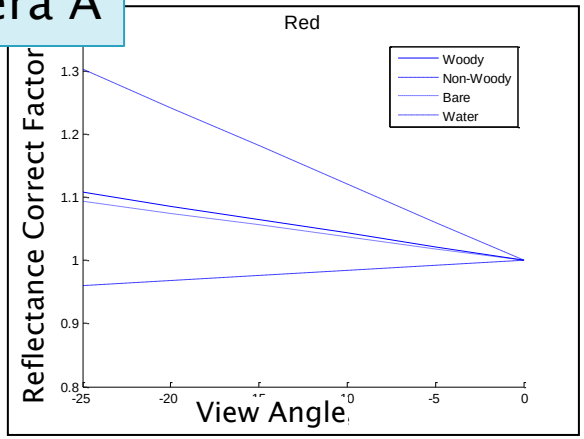
- Modified Walthall model

$$\rho(\theta_s, \theta_v, \phi) = a_0 + a_1\theta_s + a_2\theta_v\cos(\phi)$$

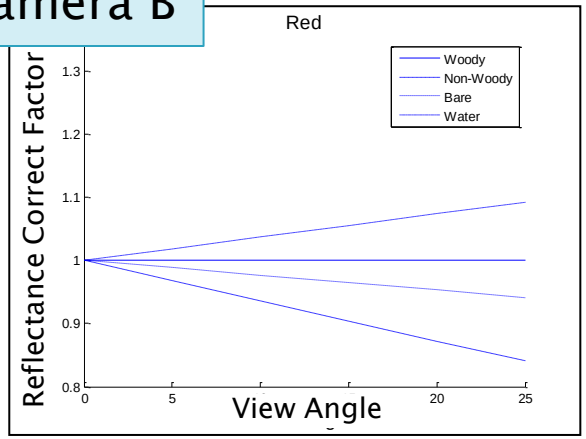
  - Each camera treated separately
  - Determined a_0, a_1 and a_2 for each land cover class

Example modified Walthall fit results at θ_s=37° and ϕ=108° for Camera A and ϕ=-49° for Camera B

Camera A



Camera B

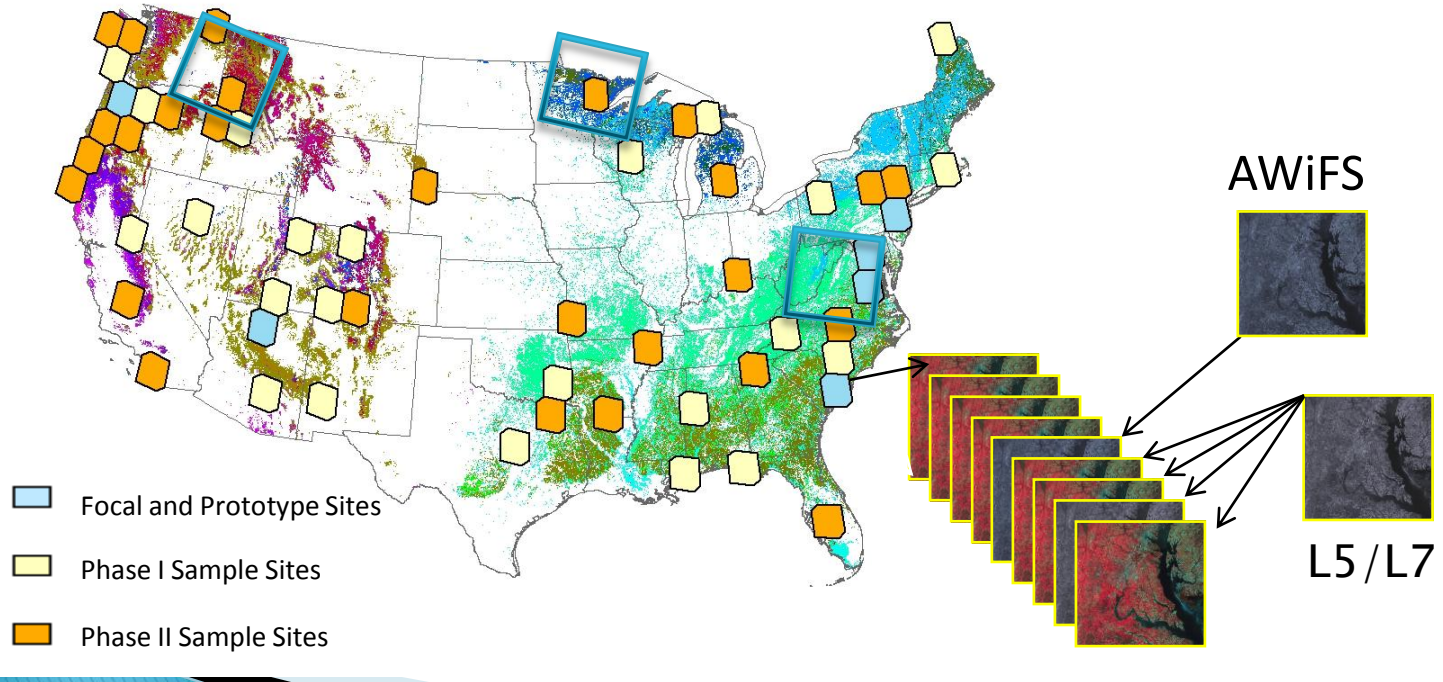


(Walthall et al., 1985, Liang and Strahler 1994, Danaher et al. 2001, Danaher et al. 2002)

Forestry Application

Assess Applicability of using AWiFS data to generate LCLUC products

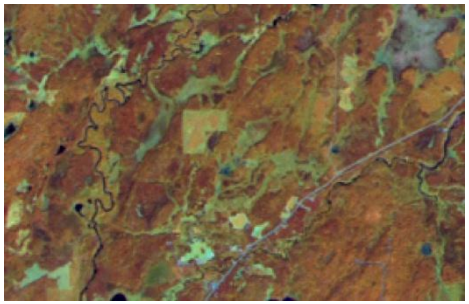
- North American Forest Dynamics (NAFD)
  - Vegetation Change Tracker (VCT) exploits time series stacks of Landsat imagery (1984 – 2008) to detect forest disturbance
  - Test substitution of a single date of AWiFS imagery into the Landsat Time Series Stack at 3 locations



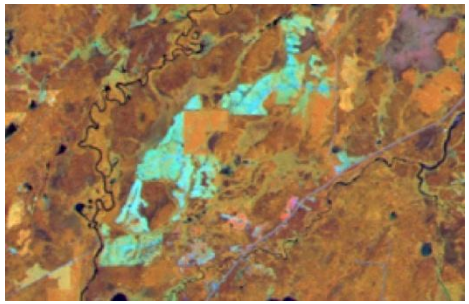
Kennedy et al., submitted

VCT Test: Minnesota Site (p27r27)

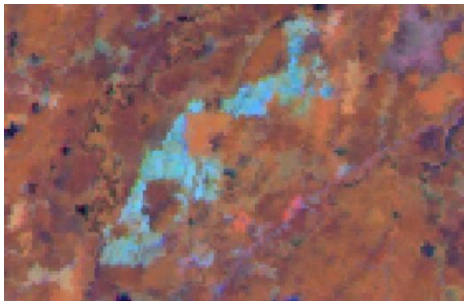
2003 TM



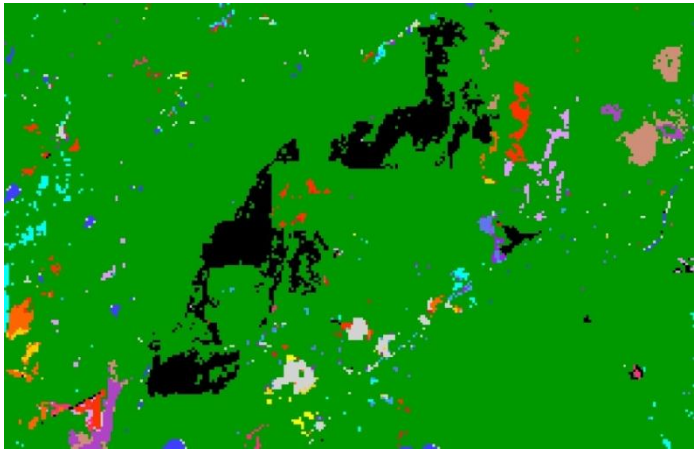
2005 TM



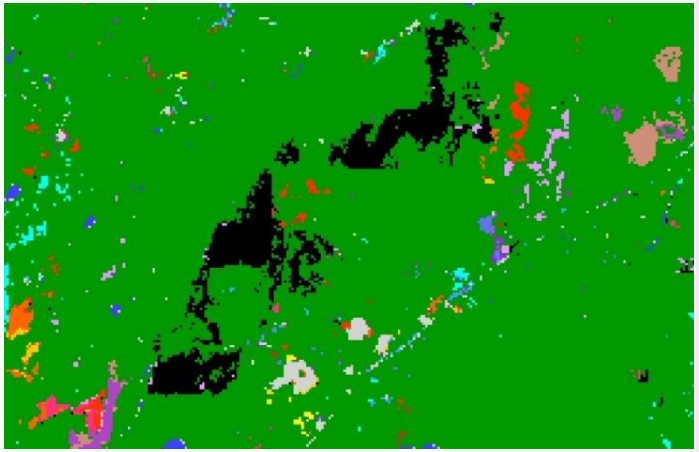
2005 AWiFS

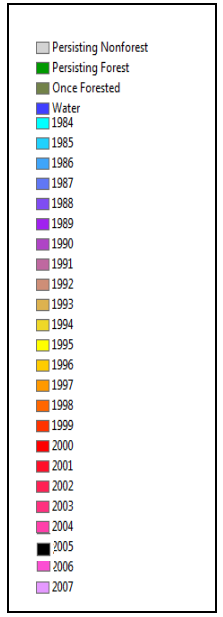


Disturbance Map: TM input



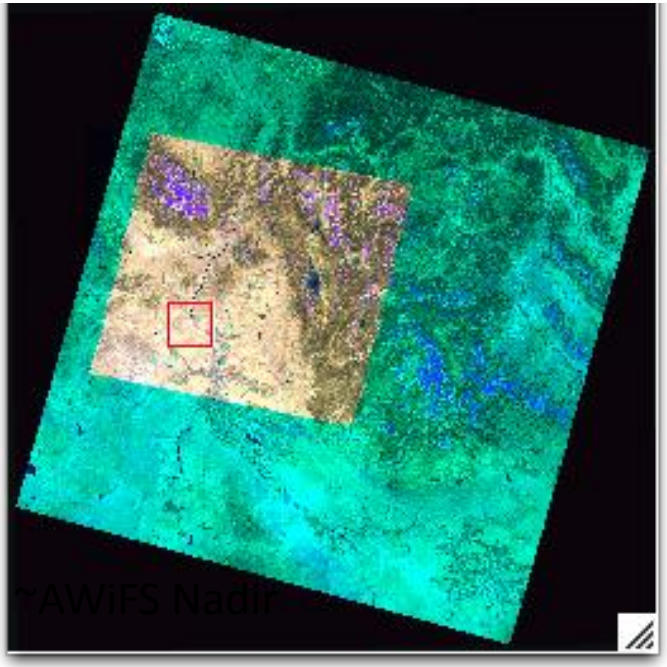
Disturbance Map: AWiFS substitution





Application Results

- How does AWiFS substitution affect map accuracy?
  - Visual inspection shows close match using AWiFS for all 3 test sites
  - Stand-clearing disturbances are captured successfully with both data stacks
- Next Steps
  - Quantify accuracy results of both AWiFS and non-AWiFS maps (standard error matrix form)
  - Quantify affects of IFOV, BRDF, and radiometric calibration



L5 / AWiFS Scene Overlay

AWiFS-Landsat Comparison Summary

- Geometric Assessment
  - Image to Image Assessment
    Registered to within one pixel
  - Band to Band Assessment
    Registered to within sub-pixel
- AWiFS Dual Camera Radiometric Consistency Check
  - Within 1% in most cases
- X-cal between ETM+ and AWiFS
  - B2=14.69%; B3=16.93%; B4=13.04%; B5=3.11%
- BRDF Effects (Non-principle plane geometries)
  - Linear dependence on viewing angle
  - Can expect BRDF affect to be ~3x greater than Landsat

Summary Comments

- Scientific research and application assessments can often benefit by more frequent high temporal data
  - Weather/clouds
  - Quickly changing phenomena
- Increased data frequency can be accomplished with
  - Multiple same sensors (constellations)
  - Multiple sources with potentially different spectral band passes and spatial resolution
- **All Source Solutions** are only possible when data sets are well understood
  - Separate phenomena differences from sensor differences
- The assessments and cross calibrations performed herein represent the types of analyses that are required to interchange and combine data streams