I 2 R Innovative Imaging & Research

Assessing and Removing AWiFS Systematic Geometric and Atmospheric Effects to Improve Land Cover Change Detection

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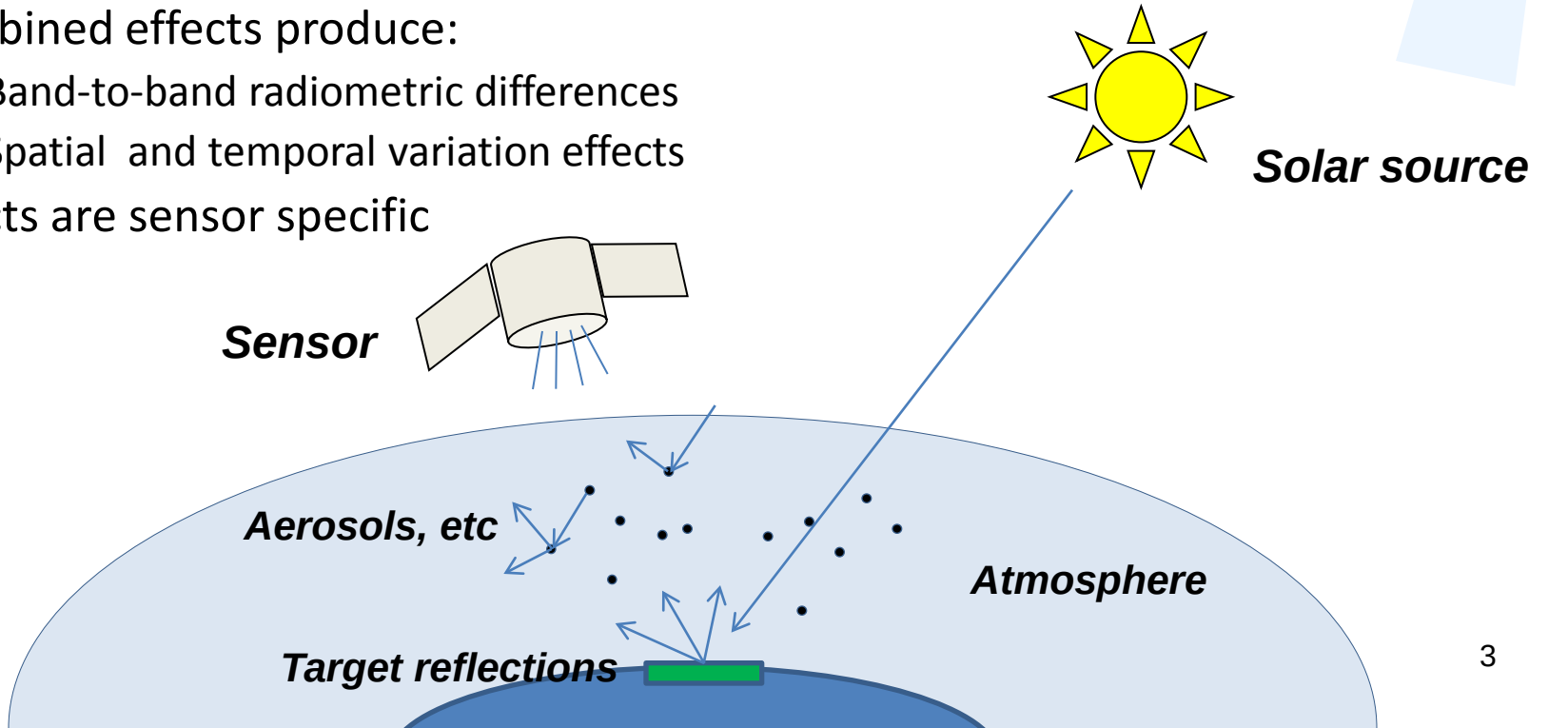
Background

- AWiFS and other data sets are being evaluated to fill the US archive until the next Landsat is operational
- Some US agencies are actively using AWiFS data for operational assessments
  - USDA Foreign Agriculture Service
- In order to use these new alternative data sets in concert with the long term Landsat archive, systematic geometric and atmospheric effects need to be understood and removed

Systematic Geometric and Atmospheric Effects

- All remotely sensed imagery is affected by:
  - Solar incidence and azimuth angles
  - Sensor viewing angle
  - Earth-sun distance
  - Atmosphere (aerosol, water vapor, ozone, etc.)
  - Land cover specific bi-directional reflectance properties
- Combined effects produce:
  - Band-to-band radiometric differences
  - Spatial and temporal variation effects
- Effects are sensor specific

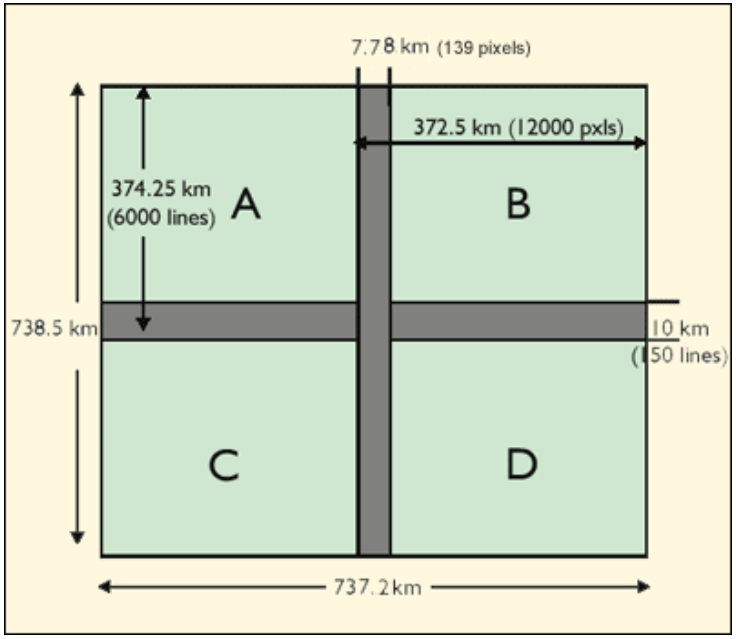


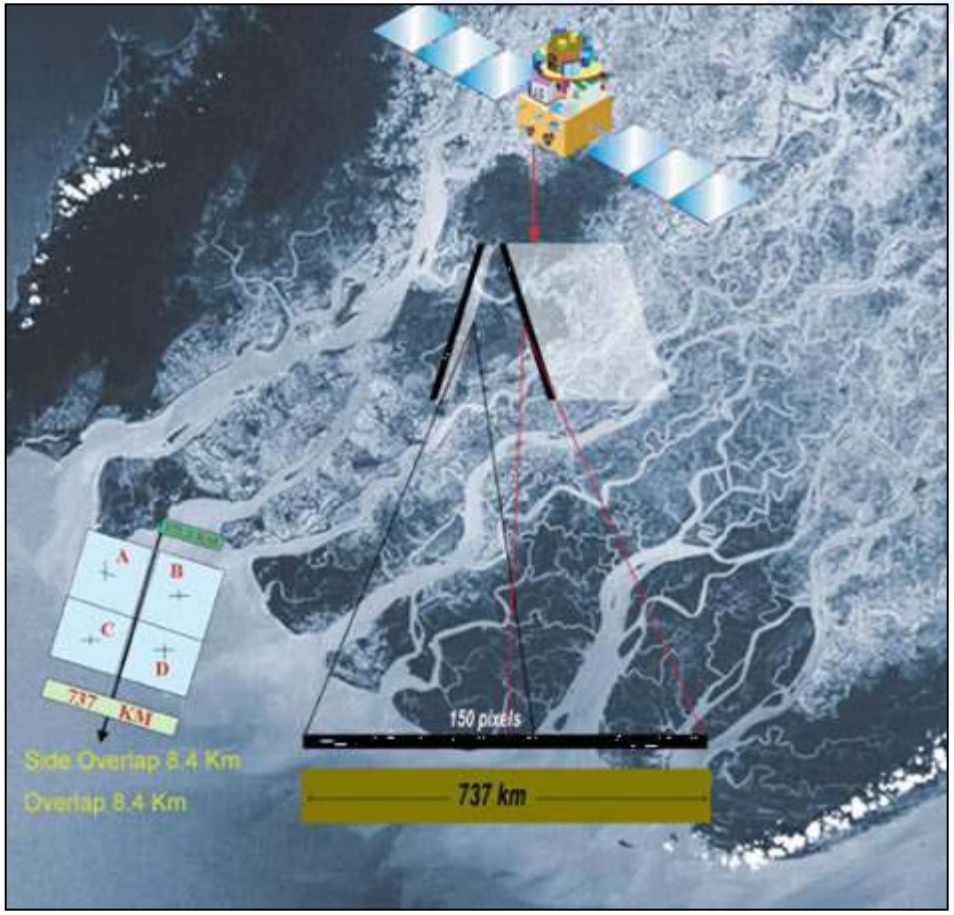
AWiFS – Advanced Wide Field Sensor

- Onboard IRS-P6 RESOURCESAT-1 satellite
  - Launched October 2003
  - Design life of 5 years
- Pushbroom architecture
- Four bands in the VNIR-SWIR spectral region
  - Green (0.52–0.59 µm), Red (0.62–0.68 µm), NIR (0.77–0.86 µm), SWIR (1.55–1.70 µm)
- Spatial resolution: 56 m (near nadir), 70 m (near edge)
- Radiometric resolution: 10 bit
- Swath: 740 km (two cameras)
- Repeat time: 5 days

AWiFS Collection Mode

The AWiFS camera is split into two separate electro-optic modules (AWiFS-A and AWiFS-B) tilted by 11.94 degrees with respect to Nadir





Source: http://www.spaceimaging.com/products/irs/RESOURCESAT/products.htm

Landsat 7 – AWiFS Comparison

GSD at Nadir

- Landsat 7: 30 m
- AWiFS: 56 m

Repeat Coverage

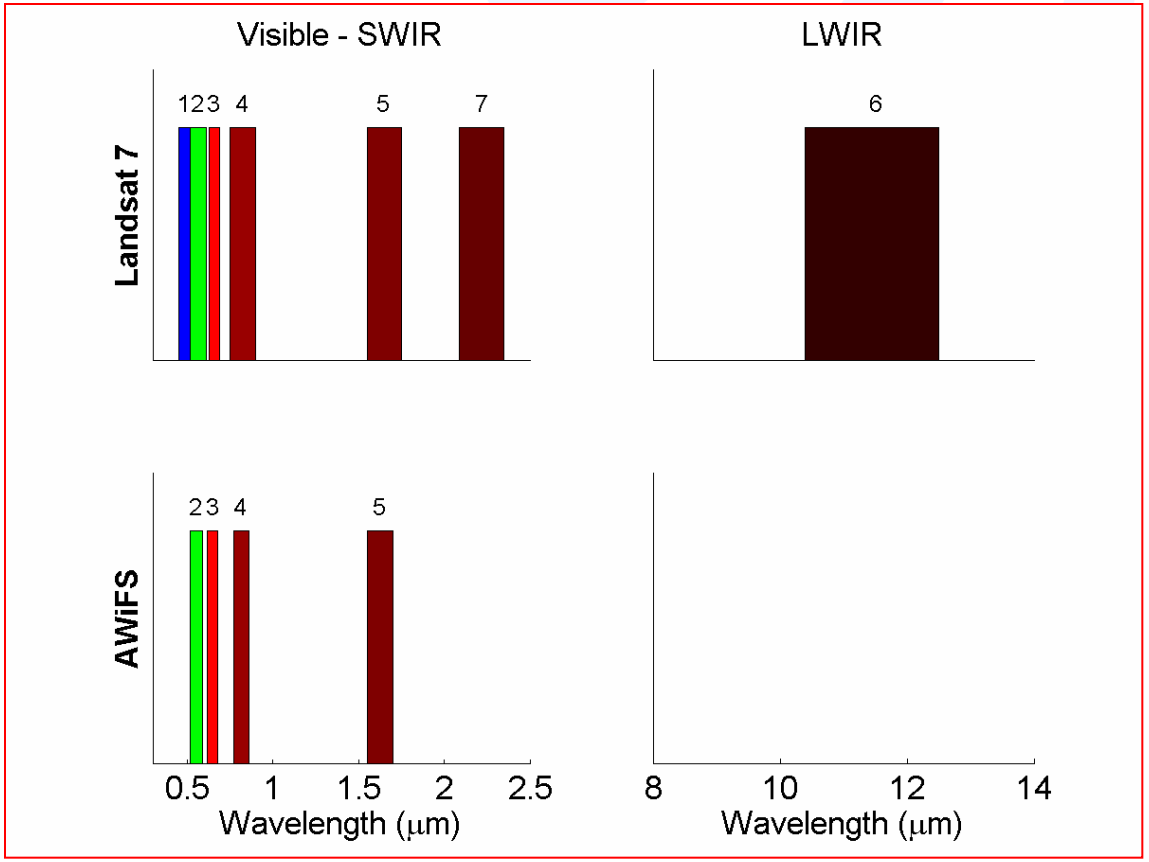
- Landsat 7: 16 days
- AWiFS: 5 days

Swath

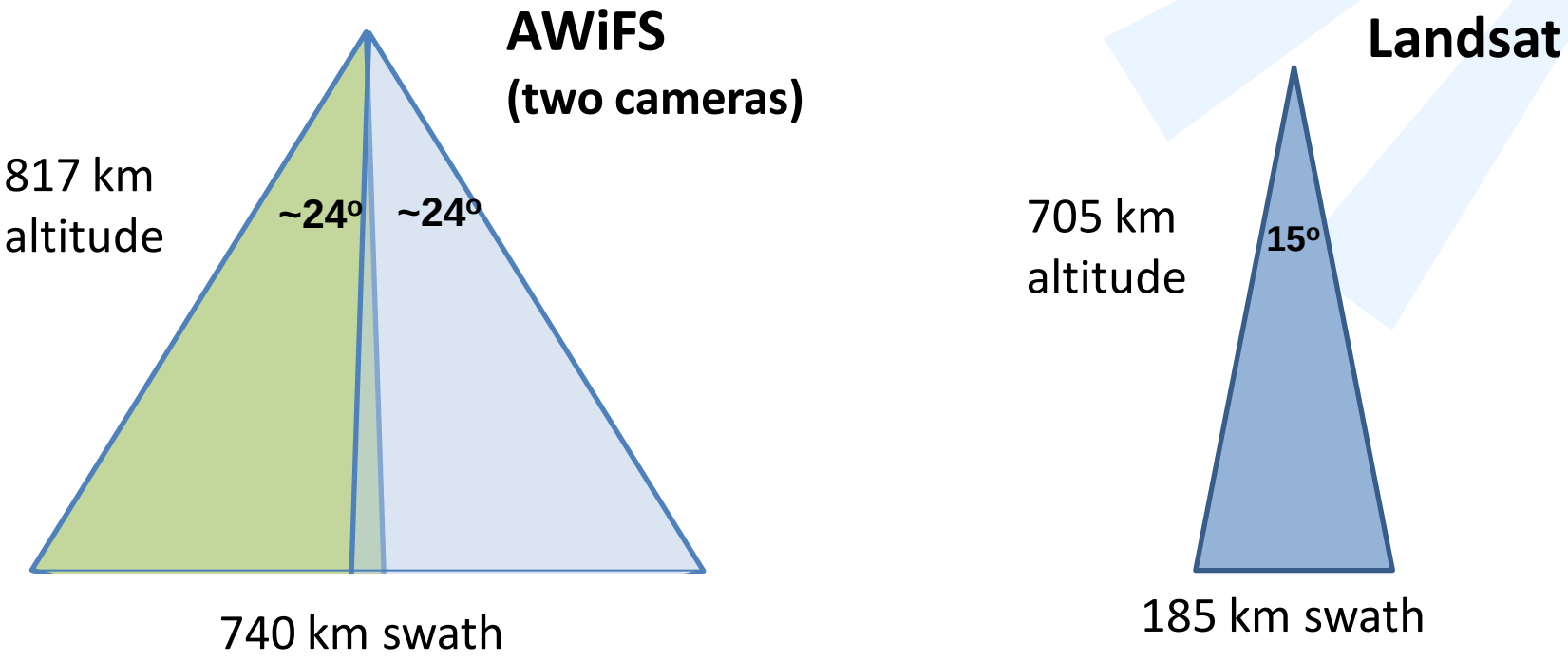
- Landsat 7: 185 km
- AWiFS: 737 km

Bands

- Landsat 7: 7 bands
- AWiFS: 4 bands (no blue, second SWIR, or thermal)

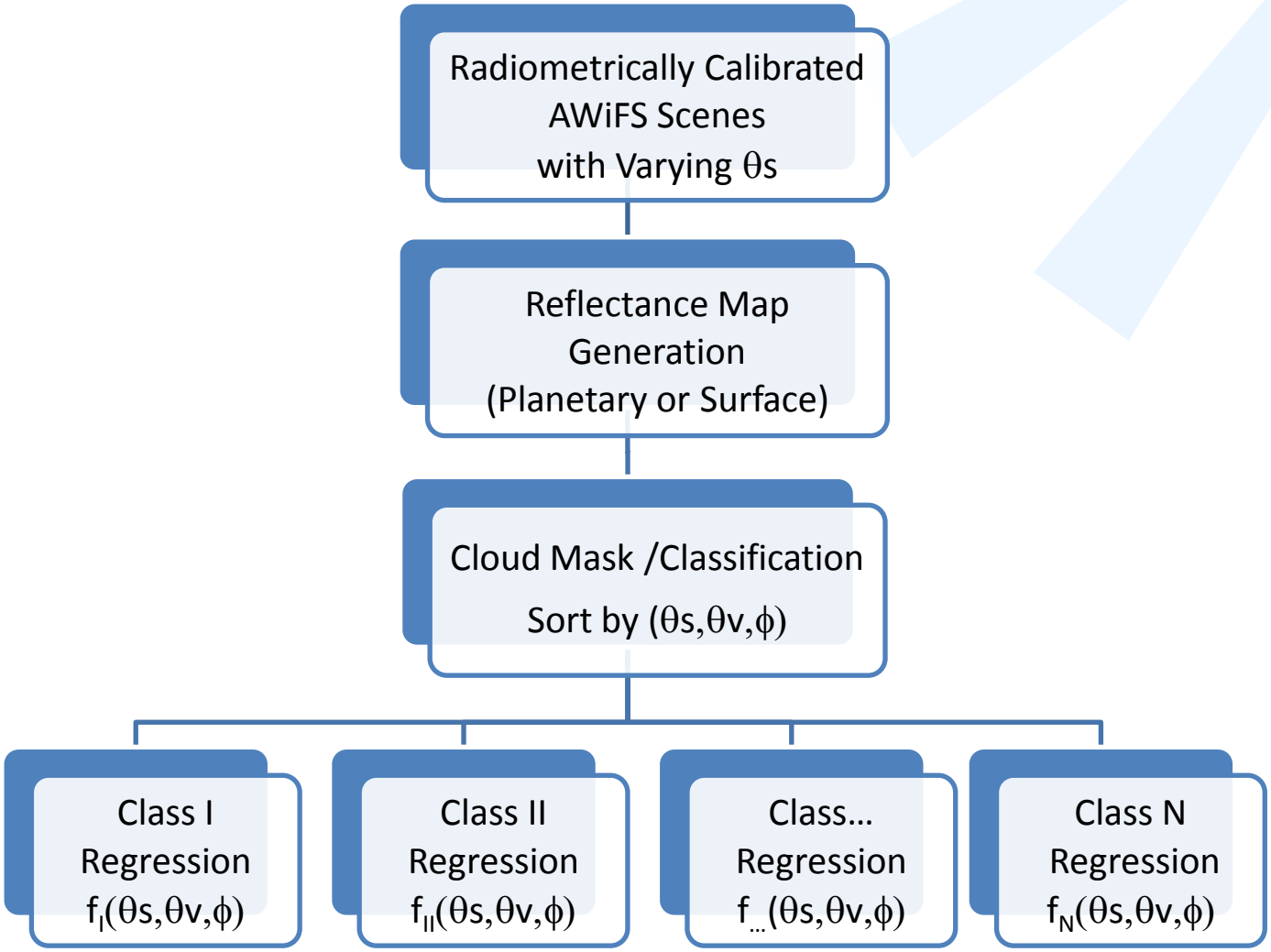


Landsat – AWiFS Geometry Differences



AWiFS imagery exhibits greater BRDF effects due to larger swath

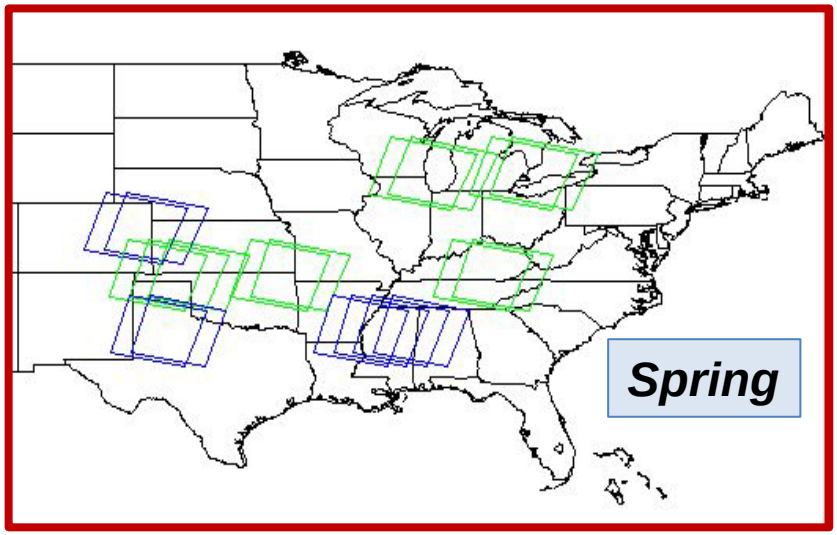
General Approach to Assess and Remove AWiFS Systematic Geometric and Atmospheric Effects

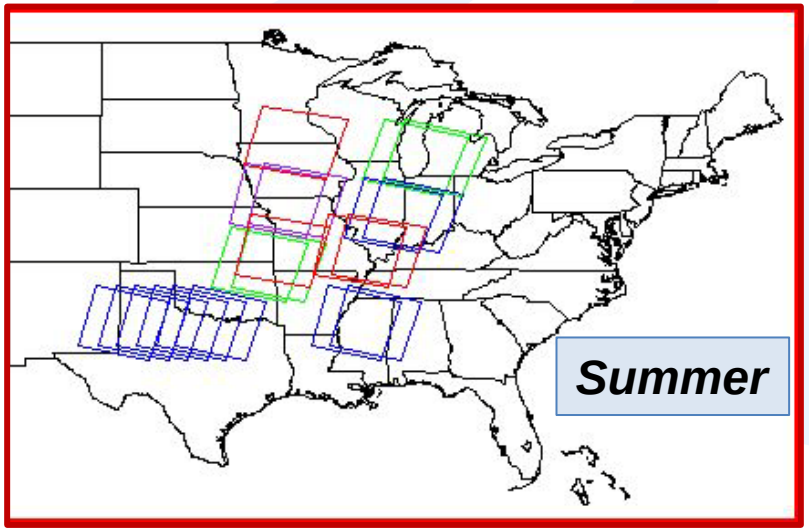


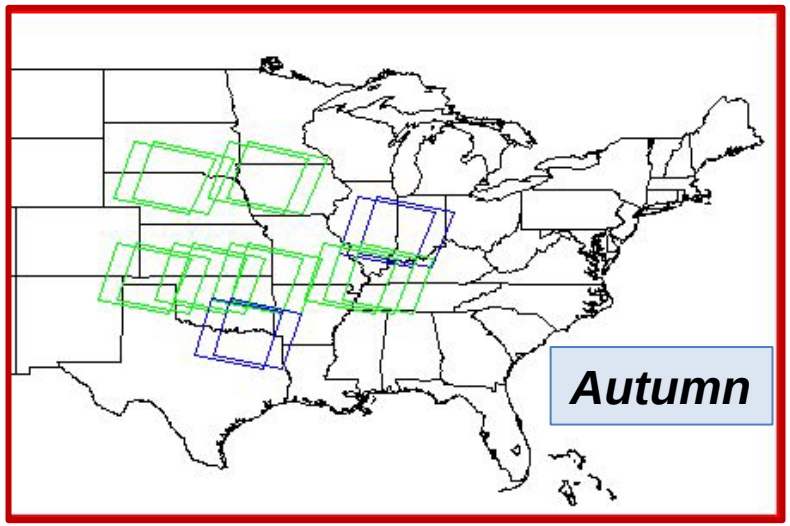
AWiFS Data Sources

- Obtained 60 scenes from the USDA Satellite Imagery Archive
  - 10 bit data acquired in 2008
  - Orthorectified products
  - Predominately US mid-west scenes over agricultural areas
  - Predominantly B and D Quads
  - Adjacent scenes binned according to season
- Access to the 104 scenes that the NASA SSC team used to perform imagery evaluations
  - 8 and 10 bit data predominately acquired in 2004-2006
  - Predominantly georectified products
  - Acquired from the USDA Satellite Imagery Archive and the Space Imaging / GeoEye archive via NGA
- Sharing limited number of scenes from the USGS archive as part of this project's collaboration

USDA Imagery Archive Data







- A-Quad
- B-Quad
- C-Quad
- D-Quad

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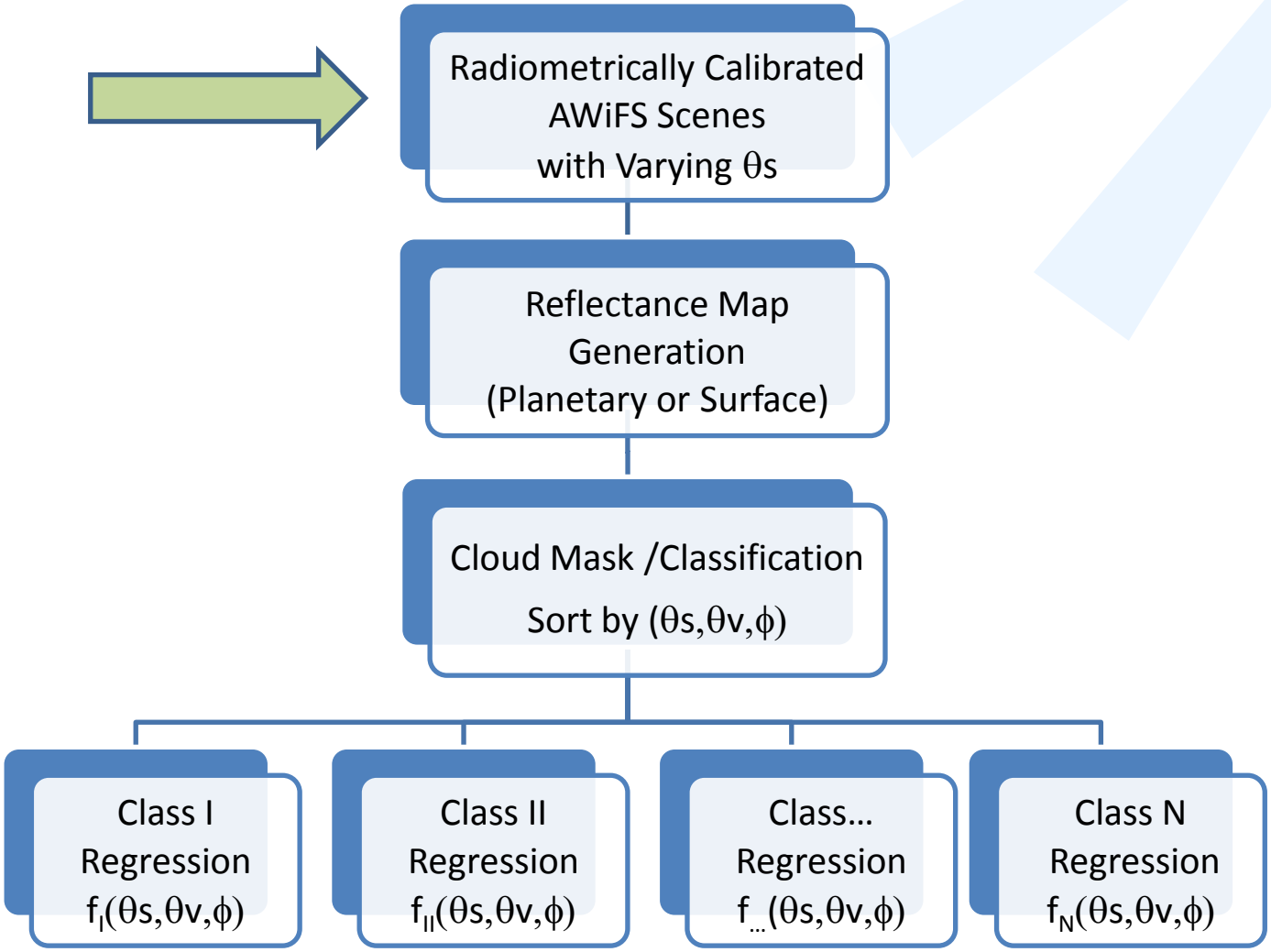
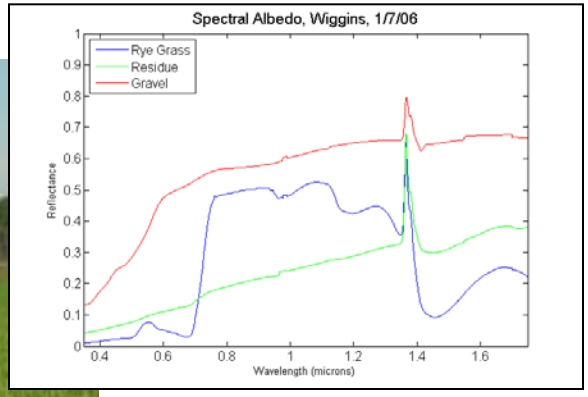
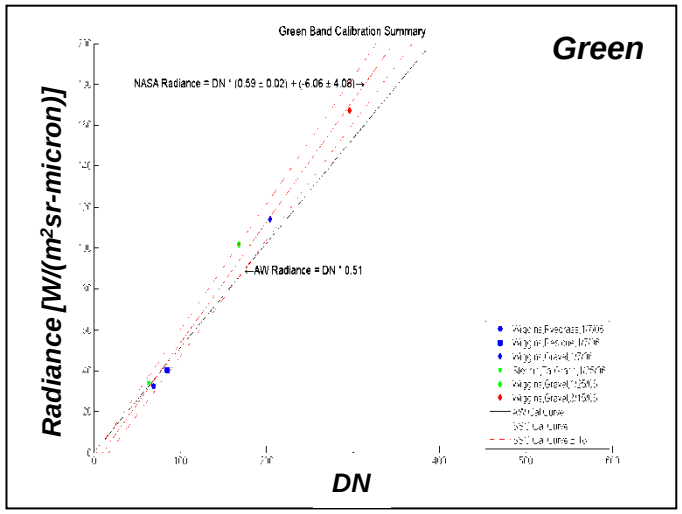


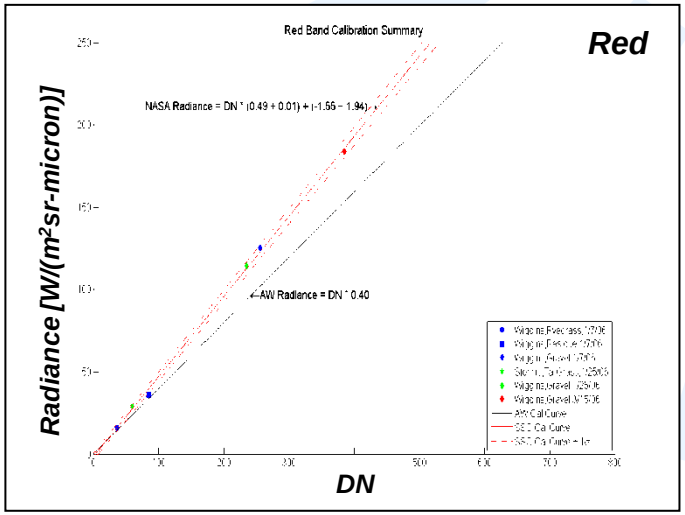
NASA-funded AWiFS Radiometric Characterization Overview

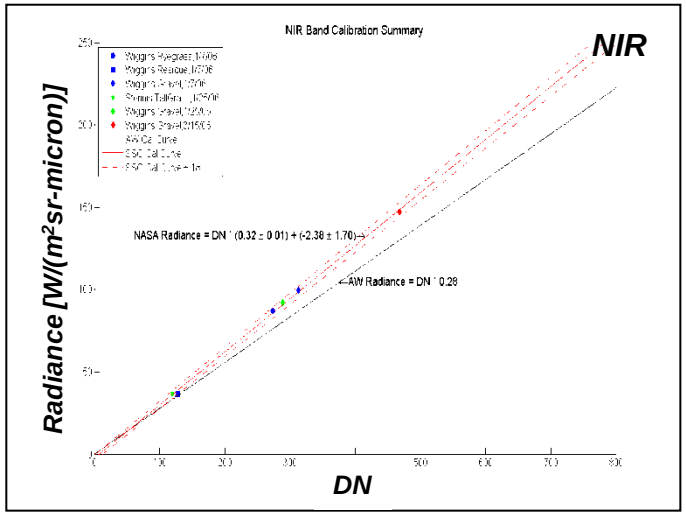
- Vicarious reflectance-based approach
  - Ground truth collection
    - Characterize target reflectance at time of satellite overpass
    - Characterize atmosphere at time of satellite overpass
  - MODTRAN radiative transport code used to predict at-sensor radiance
  - Predicted at-sensor radiance compared to actual radiance acquired by sensor
- Performed at NASA Stennis Space Center in 2005-2006
  - 10 scenes and 21 targets total

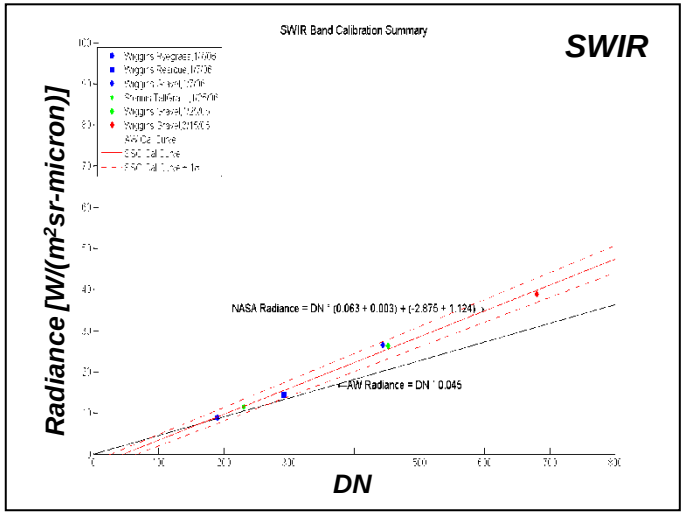


NASA-funded AWiFS Radiometric Calibration Results-2006









Radiometric Calibration

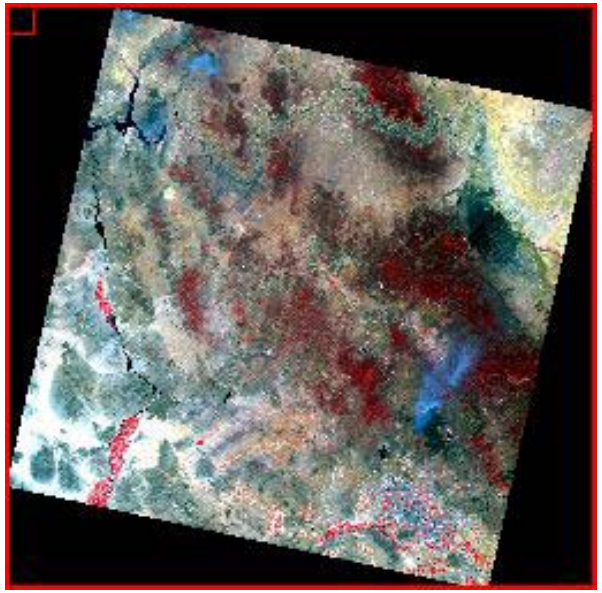
- Utilize the IRS-provided calibration coefficients
  - Currently available to science users
  - Calibration coefficients for both the A and B cameras are the same

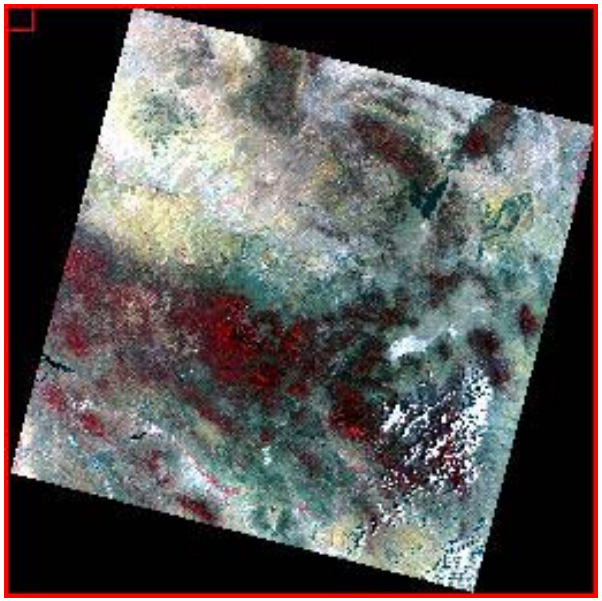
Band	Green	Red	NIR	SWIR
Calibration Coefficient [W/m^2 sr μm DN]	0.512	0.398	0.278	0.045

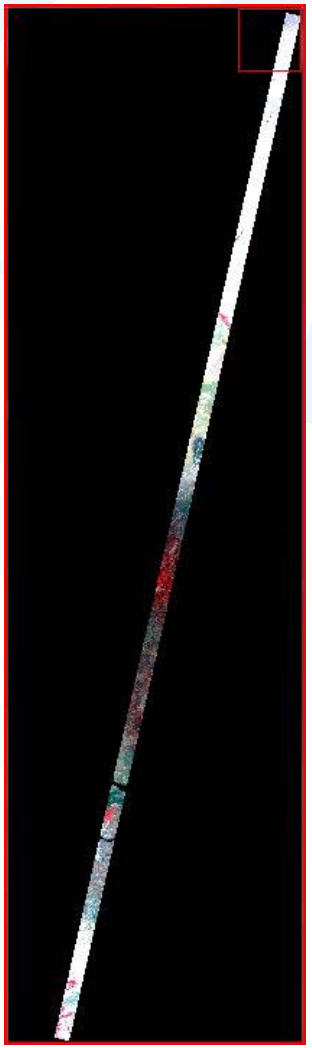
- Recognize inconsistencies
  - Cross comparisons with Landsat (Chander, et al) indicate calibration differences between the two systems beyond spectral response
  - Initial NASA-funded vicarious calibrations performed in 2005-2006 indicate calibration differences
    - Limited calibration (21 targets within 10 scenes)
    - No differentiation made between A and B cameras
- Plan to revisit

AWiFS Dual Camera Radiometric Consistency Check

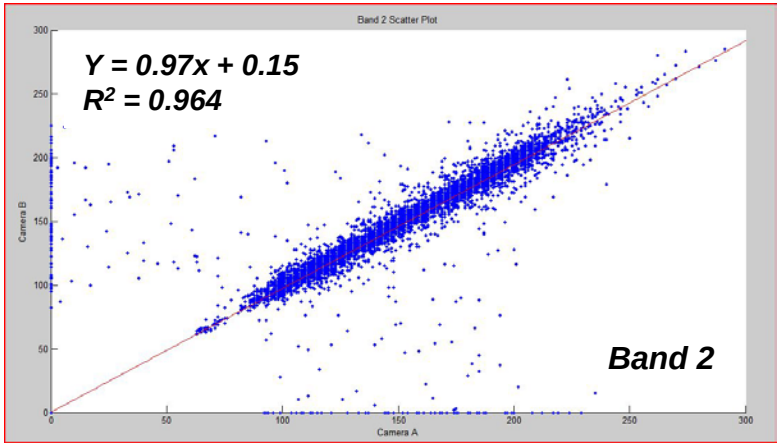
- Evaluated the 7.8 km overlap area between the A & B cameras
  - A and B Quads
  - Mesa, AZ scene provided by USGS (GeoEye archive)
    - Path/row 257/47, acquired 06/29/05

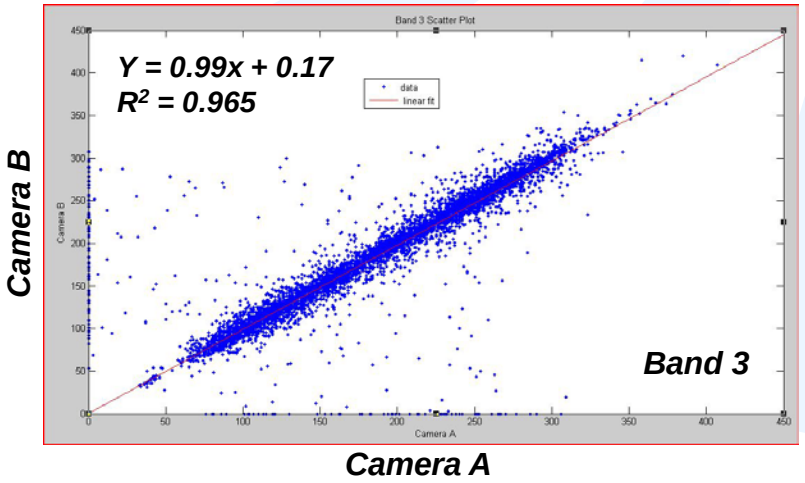


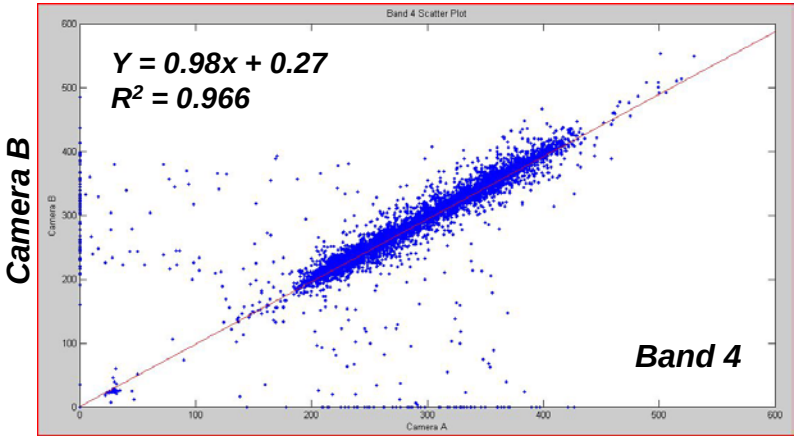


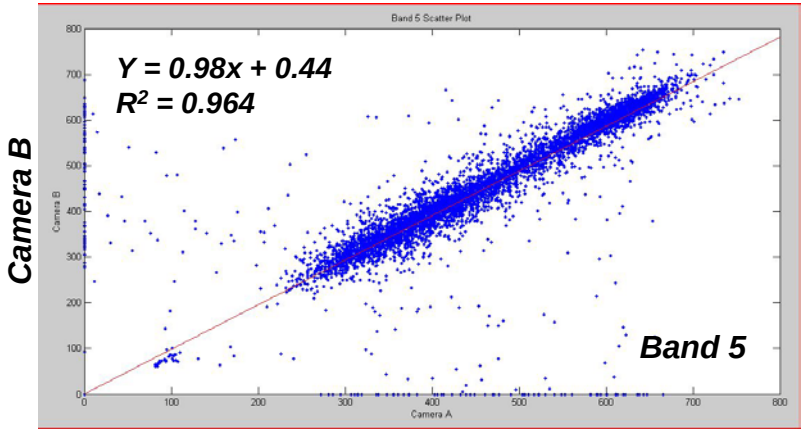


Overlapping Area Scatter Plots



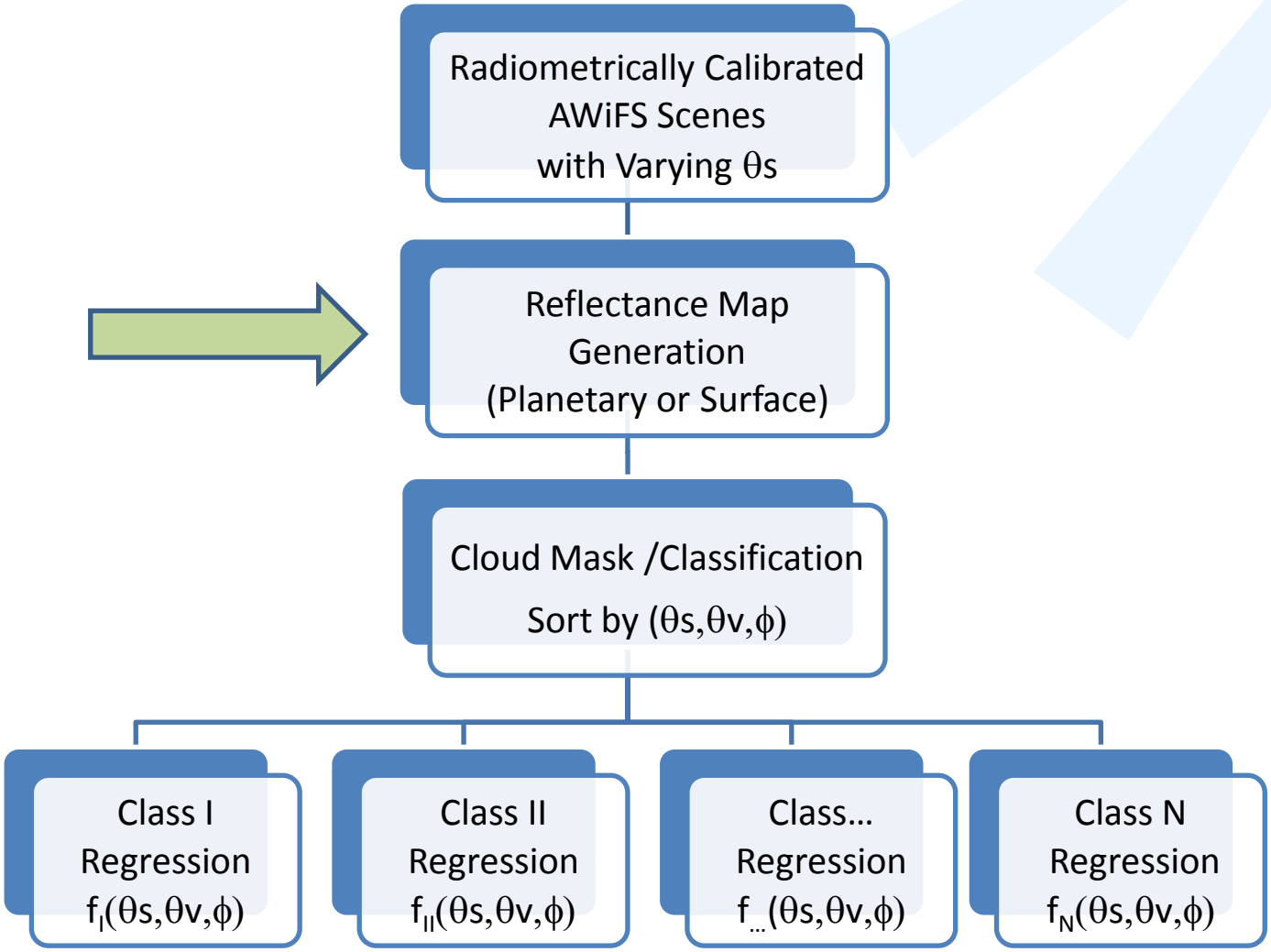






Excellent agreement between camera modules

General Approach to Assess and Remove AWiFS Systematic Geometric and Atmospheric Effects



Reflectance Map Generation

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

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

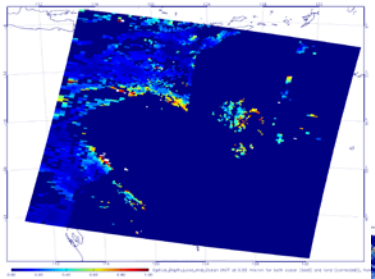
- Surface Reflectance
  - Atmospheric correction is the process of converting satellite signals (at-sensor radiance) to surface reflectance
  - In general, surface reflectance yields more accurate results than planetary reflectance

AWiFS Surface Reflectance

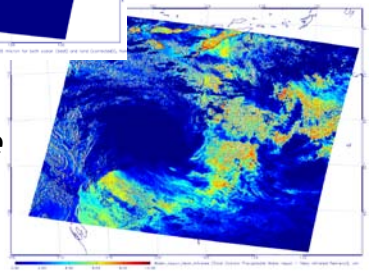
- Atmospheric correction algorithms to retrieve aerosol based on Landsat 2nd SWIR and blue bands are not possible with AWiFS
- Alternative surface reflectance approaches are required
  - Empirical approaches
    - Pseudo-invariant targets
    - Regression with surface reflectance derived from other systems
  - Radiative transfer approach with alternative method to obtain aerosol information - *new technique selected for this study*
    - Accounts for adjacency effects
    - Incorporates unique AWiFS spectral bandpass properties
    - Extensible to other systems
    - Checked for consistency using NASA SSC ground truth data

Radiative Transfer Atmospheric Correction Approach

MOD04 Aerosol Optical Thickness



MOD05 Total Precipitable Water (Water Vapor)



MODIS data products MOD04, MOD05

Radiometrically Corrected Imagery
(IRS provided cal coef)

Radiative Transfer Model
(Spherical Albedo Formulation)

Surface Reflectance Map

Pagnutti, M., K. Holekamp, R.E. Ryan, R.D. Vaughan, J.A. Russell, D. Prados, D., T. Stanley, "Atmospheric Correction of High-Spatial-Resolution Commercial Satellite Imagery Products Using MODIS Atmospheric Products", 2005 International Workshop on the Analysis of Multi-Temporal Remote Sensing Images, pp 115-119

Comparison of Ground Truth Measurements with Surface Reflectance

- Surface reflectance values were compared to ground truth ASD reflectance measurements taken of 12 targets within 5 scenes (based on NASA derived calibration coefficients)
  - Two gravel pit sand sites
  - Two large monoculture fields
  - Large tall grass field

	Green	Red	NIR	SWIR
Avg (ASD – Surface Reflect)	-0.018±0.012	-0.007±0.013	-0.008±0.023	0.004±0.045

- Newly developed automated surface reflectance algorithm yields promising results

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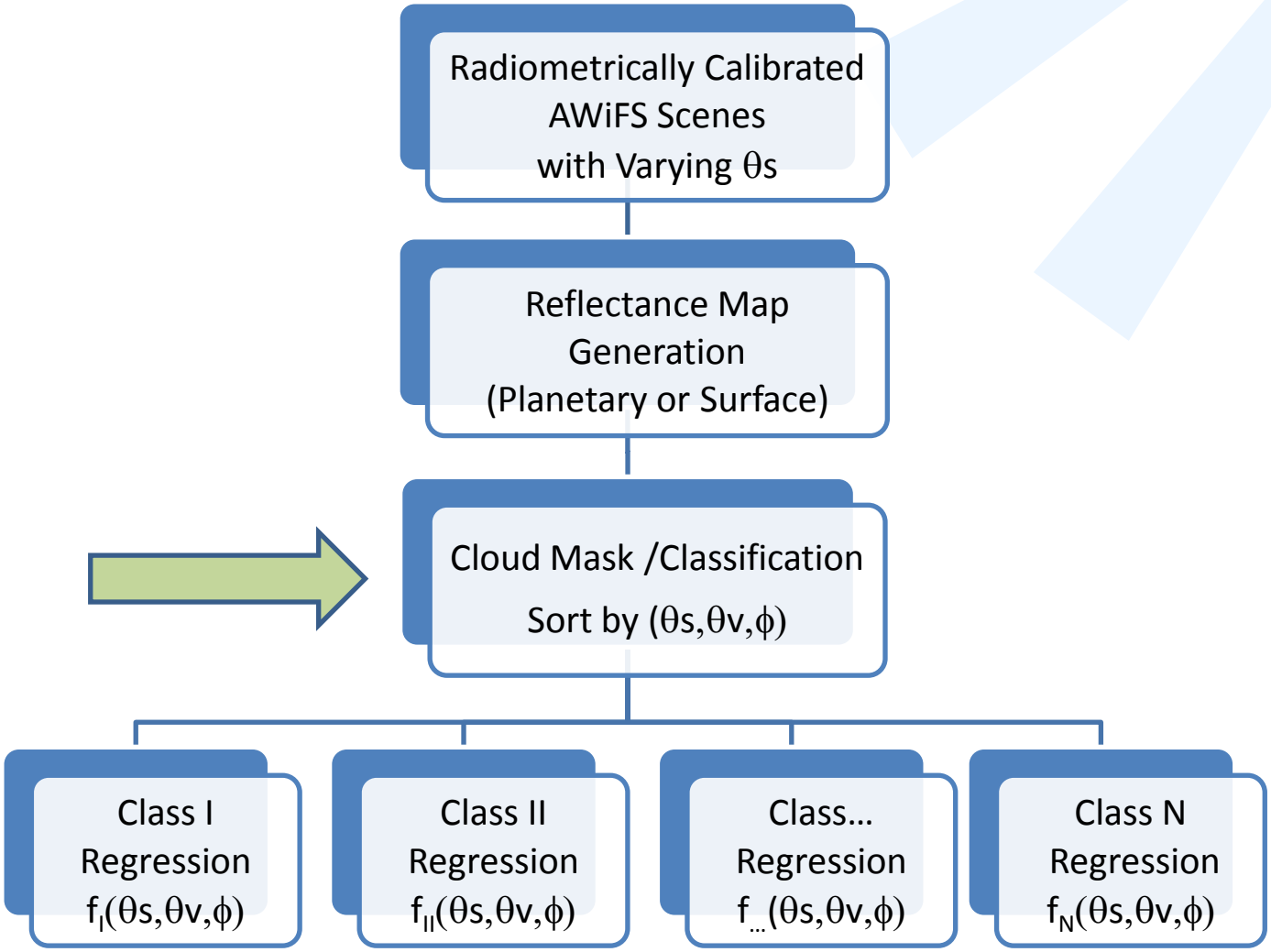


Land Cover Classifications

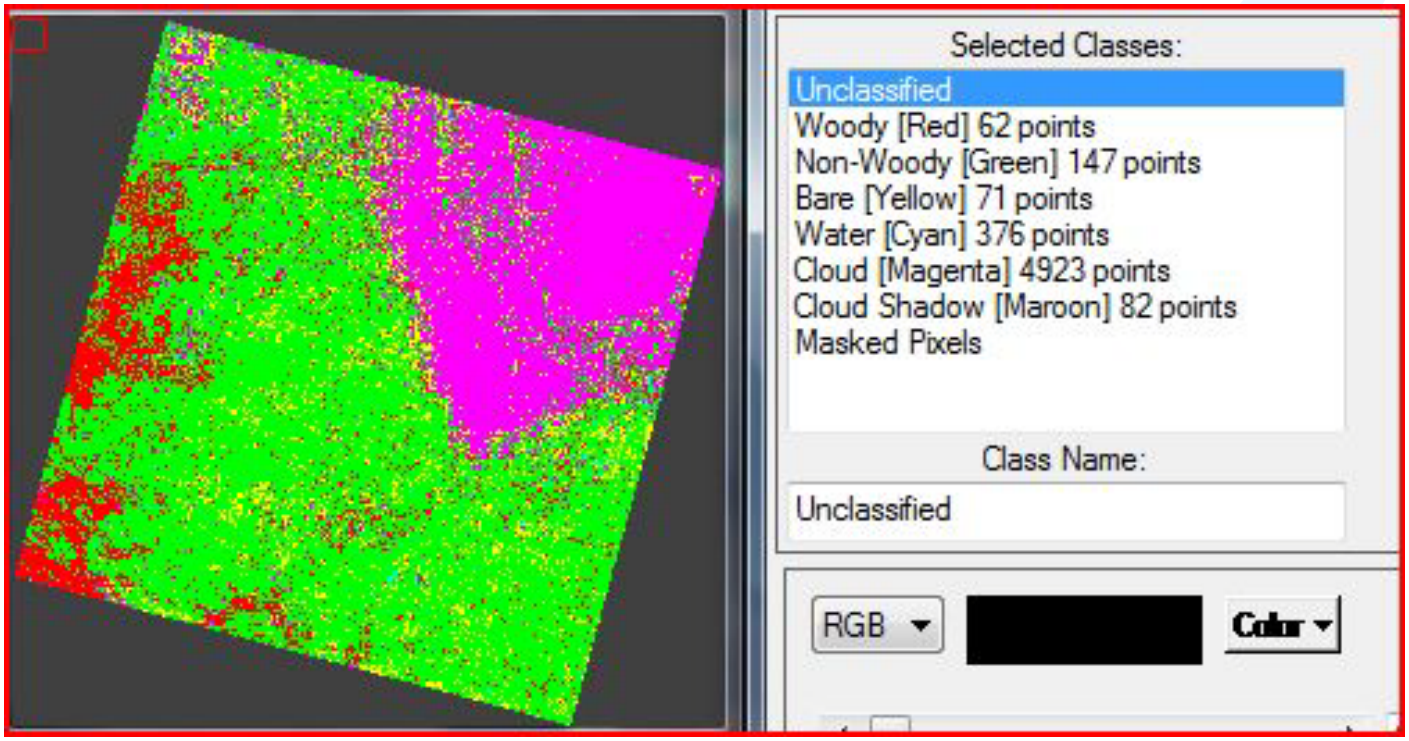
- Performing land cover classifications of
  - Planetary reflectance maps
  - Surface reflectance maps
- Evaluating different classification algorithms
  - Unsupervised ISO-data clustering algorithm
  - Supervised maximum likelihood classification algorithm
  - Supervised maximum likelihood classification algorithm using the NLCD to support training
  - USDA NASS Cropland Data Layer
- Broad classes (initially)
  - Water
  - Bare earth
  - Clouds
  - Woody vegetation (forest)
  - Non-woody vegetation (grassland, pasture, crops)
  - Cloud shadows

Example Land Cover Classification

263/45/B 08Apr08 North Texas-Oklahoma-Kansas

Surface reflectance product

Supervised maximum likelihood classification algorithm



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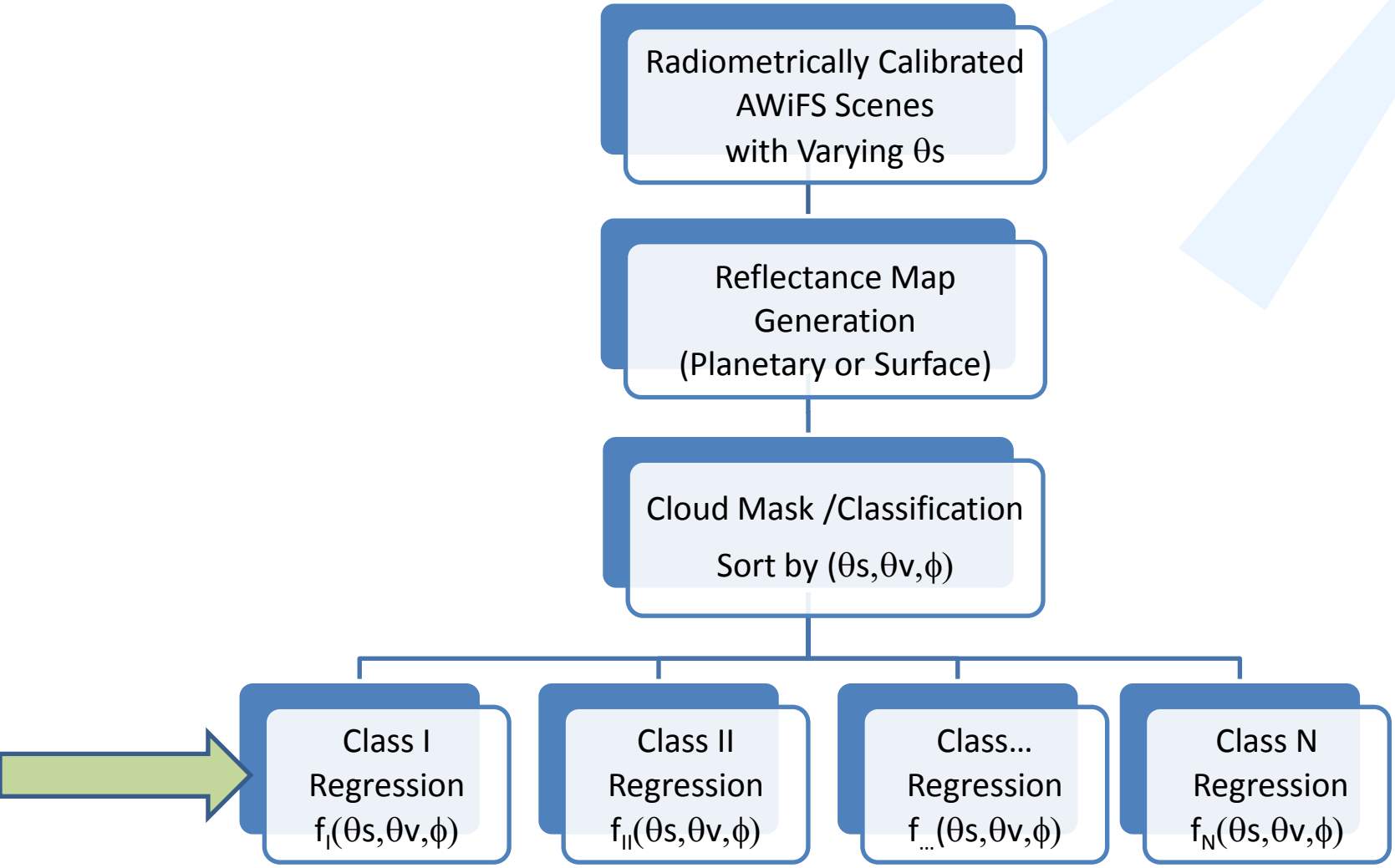
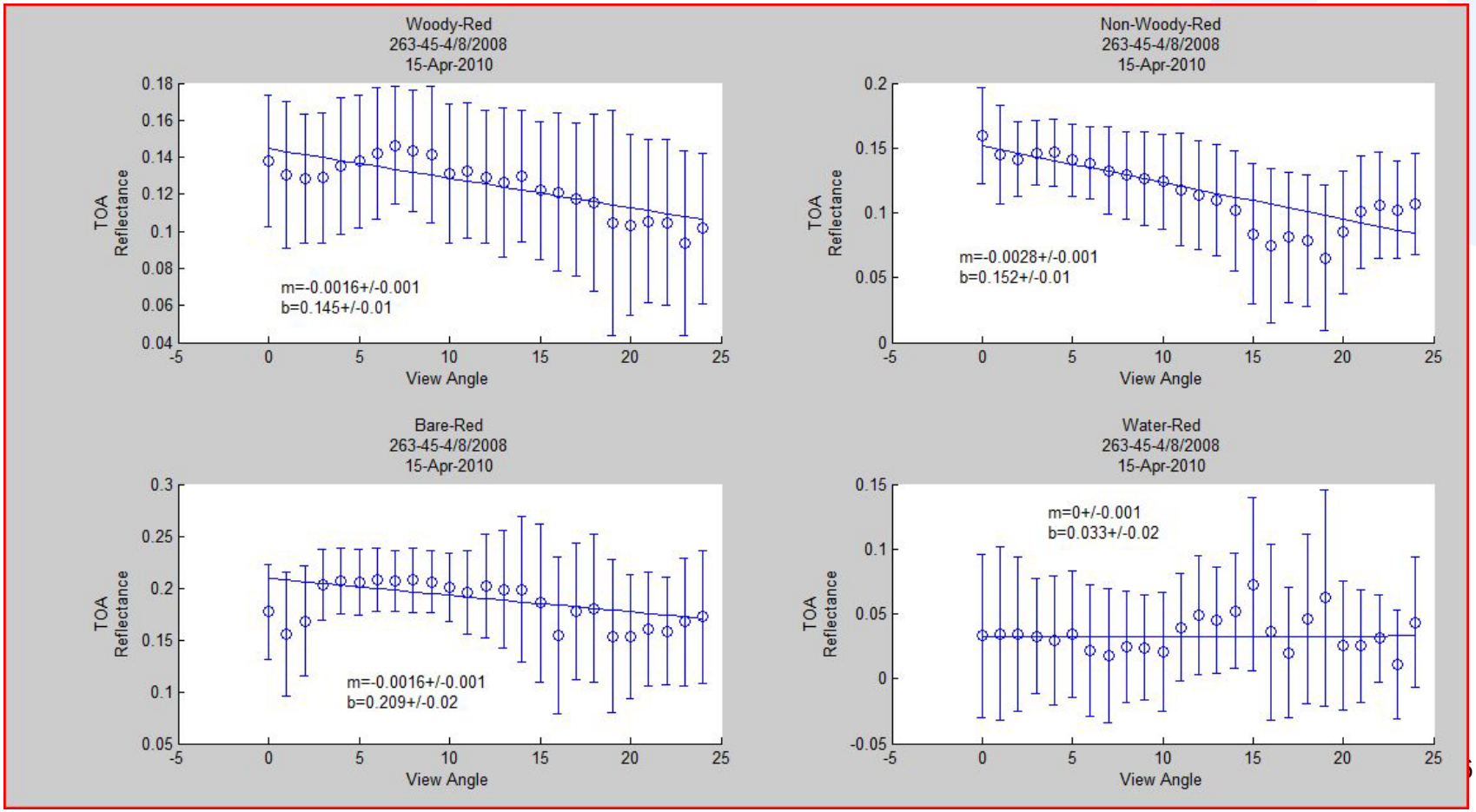


Example Surface Reflectance Variation Across Focal Plane within Each Class

263/45/B 08Apr08

Supervised maximum likelihood classification algorithm



Framework for Next Steps

- Estimate BRDF land cover correction factor for each land cover class using the following functional forms (may consider others)
  - Modified Walthall formulations

$$f = a + b\theta_s + c\theta_v \cos(\varphi)$$

$$f = a\theta_s^2\theta_v^2 + b(\theta_s^2 + \theta_v^2) + c\theta_s\theta_v \cos(\theta_s - \theta_v) + d$$

C.L. Walthall, J.M. Norman, J.M. Welles, G. Campbell, and B.L. Blad, "Simple equation to approximate the bidirectional reflectance from vegetation canopies and bare soil surfaces," Applied Optics, vol. 24, pp 383-387, 1985.

Concluding Remarks

- AWiFS radiometric calibration is uncertain
  - Perform sensitivity analysis using different calibration coefficients to determine impact on BRDF correction
- Majority of AWiFS imagery acquired with B Camera
  - Work with USDA to obtain additional imagery acquired with A Camera
- Near coincident MODIS aerosol optical thickness and water vapor data streams show promise to produce accurate surface reflectance maps
- An algorithm to correct for BRDF effects becomes increasingly important when comparing multiple data sources with different viewing geometries to solve remote sensing problems
  - Land Surface Imaging Constellation

Collaborators

- USGS EDC – Gyanesh Chander
- University of MD team – Sam Goward
- USDA FAS – Bob Tetrault
- NASA SSC team – Kara Holekamp