Producing AWiFS Surface Reflectance Using General Empirical Relation Model (GERM) and MODIS Products

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Why Surface Reflectance ?

- Provides a consistent data stream for time-series analysis and a way to build long-term climate data record
- Eliminates atmospheric effects for land cover change detection
- Provides a basic input for vegetation canopy models for retrieving surface biophysical parameters

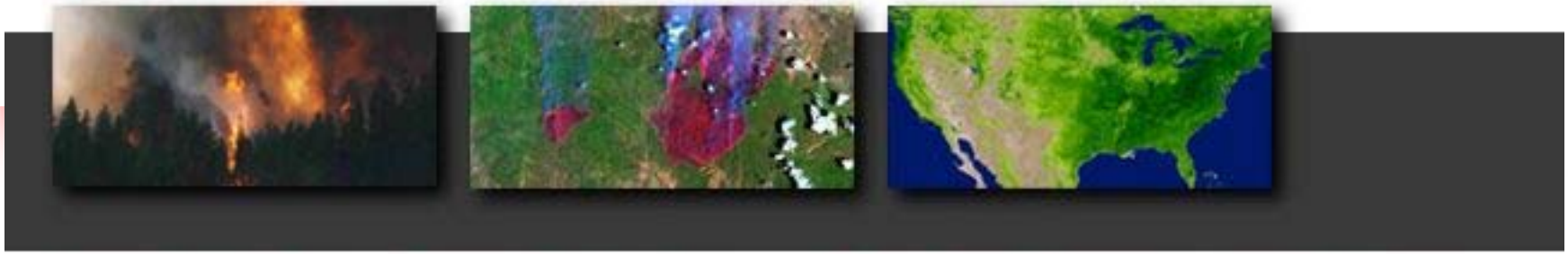
Background on Atmospheric Correction

- Physical approach
  - Radiative transfer model: 6S, MOTRAN, SHARM-3D
  - Aerosol optical depth is retrieved from dark dense vegetation (DDV)

$$\rho_1 = \rho_7 / 4$$
$$\rho_3 = \rho_7 / 2$$

- Empirical approach
  - Dark object subtraction (DOS): minimum DN or clear water DN is contributed from atmospheric effects
  - Relative atmospheric correction or radiometric rectification (RR) replies on pseudo-invariant features (PIFs) from time-series images

LEDAPS *For Landsat TM/ETM+ SR*

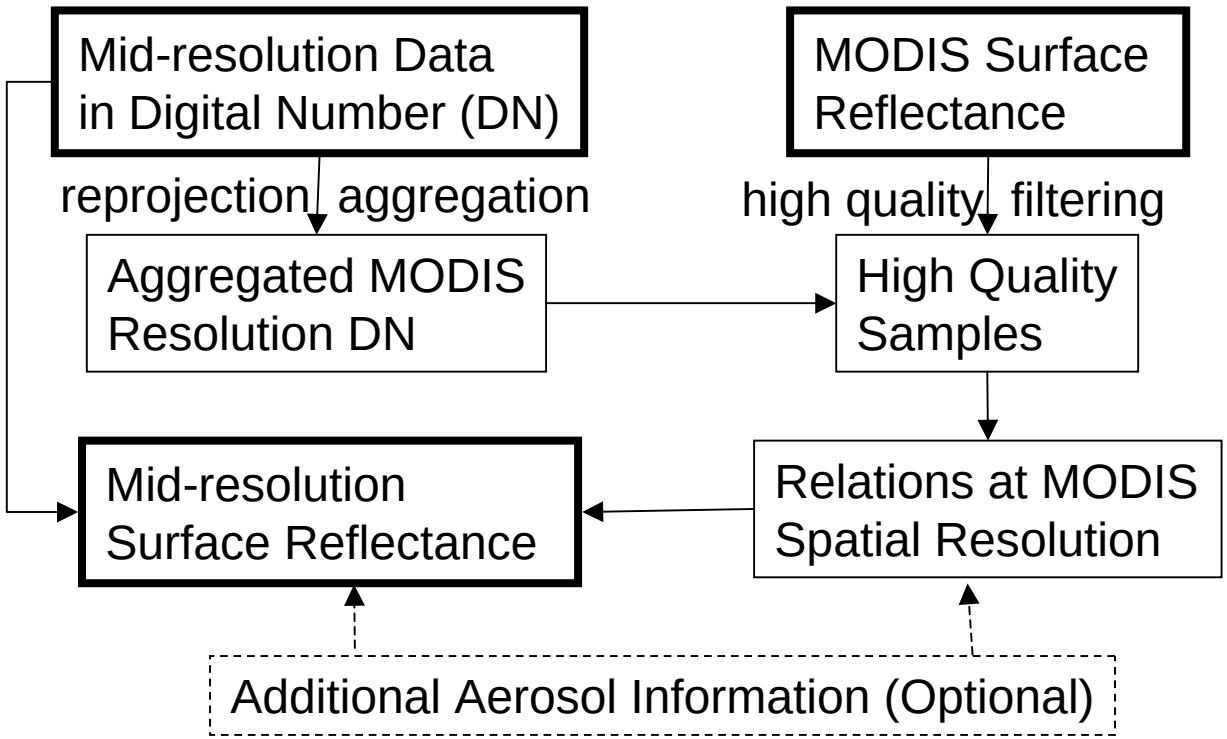


Landsat Ecosystem Disturbance Adaptive Processing System

- Adopt “MODIS-like” approach to Landsat TM/ETM+
  - Calibration
  - Cloud detection
  - 6S atmosphere correction (retrieve AOT from image)
  - Automated processing
- Process North America GeoCover data set (1990, 2000)
- Map forest disturbance and regrowth

General Empirical Relation Model (GERM)

GREM approach converts sensor digital number (DN) to surface reflectance directly using MODIS surface reflectance as a reference data set.



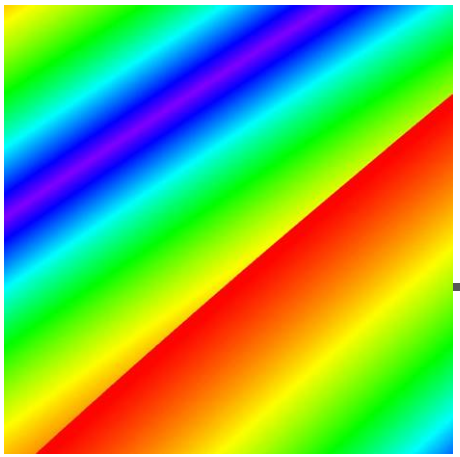
AWiFS, TM/ETM and MODIS

AWiFS	Bandwidth	ETM+	Bandwidth (nm)	MODIS	Bandwidth (nm)
		1	450-520	3	459-479
2	520-590	2	530-610	4	545-565
3	620-680	3	630-690	1	620-670
4	770-860	4	780-900	2	841-876
5	1550-1700	5	1550-1750	6	1628-1652
		7	2090-2350	7	2105-2155

Sensors	**Resolution**	**Passing time**
AWiFS	56m	10:30am
TM/ETM+	30m	10:00am
MODIS	250/500m	10:30am

MODIS Inputs

- 500m daily surface reflectance
  - MOD09GHK (reflectance)
  - MOD09GST (quality and cloud state)
- 16-day 1km Nadir BRDF-adjusted Reflectance (NBAR)
  - MOD43B4 / MCD43B4
  - 500m in collection 5 (8-day overlap rolling)
- Daily NBAR corrected by MODIS BRDF parameters using magnitude inversion approach

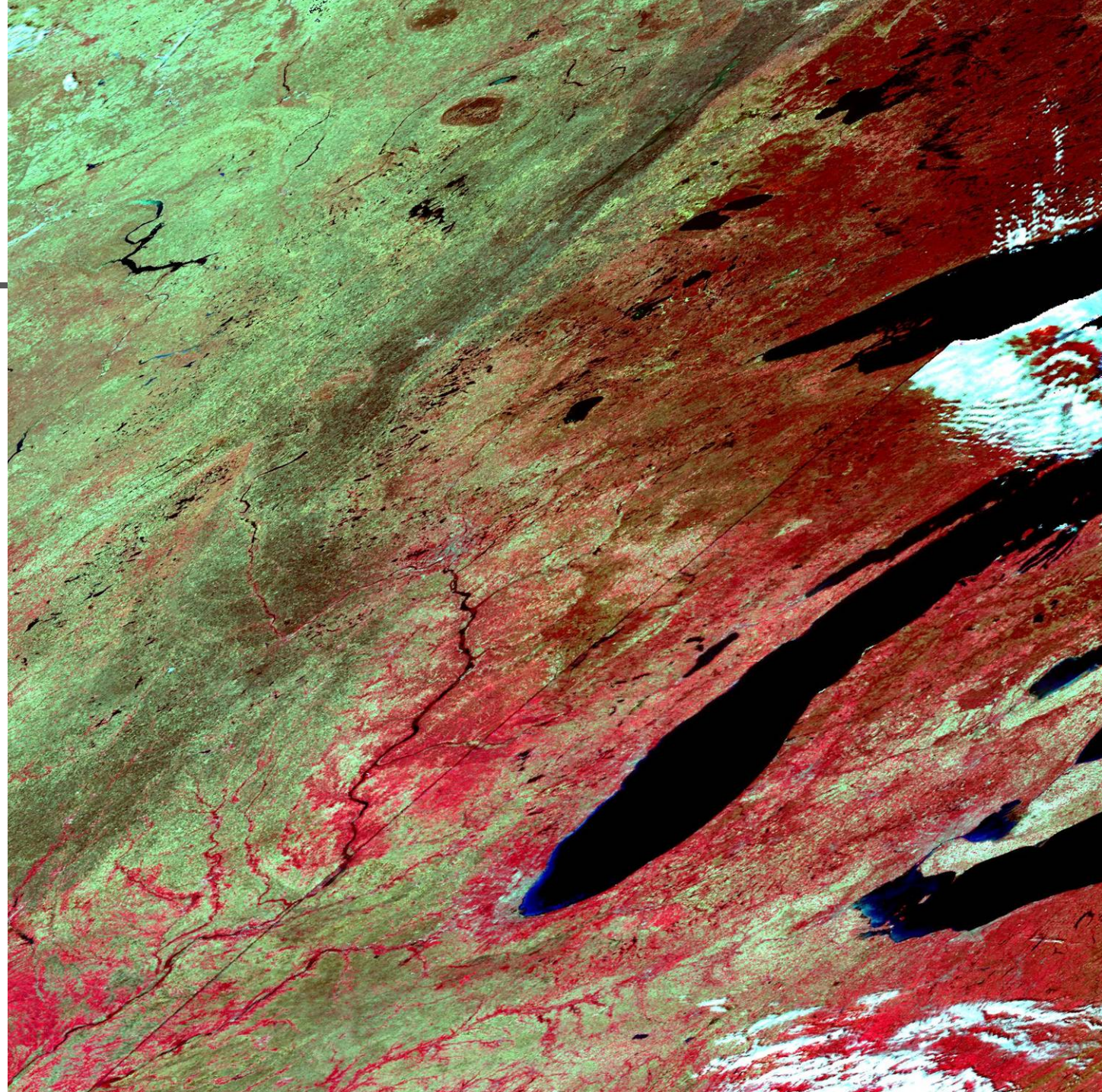


view zenith angle

0 32 65

MODIS
Daily SR
500m
(MOD09GHK)

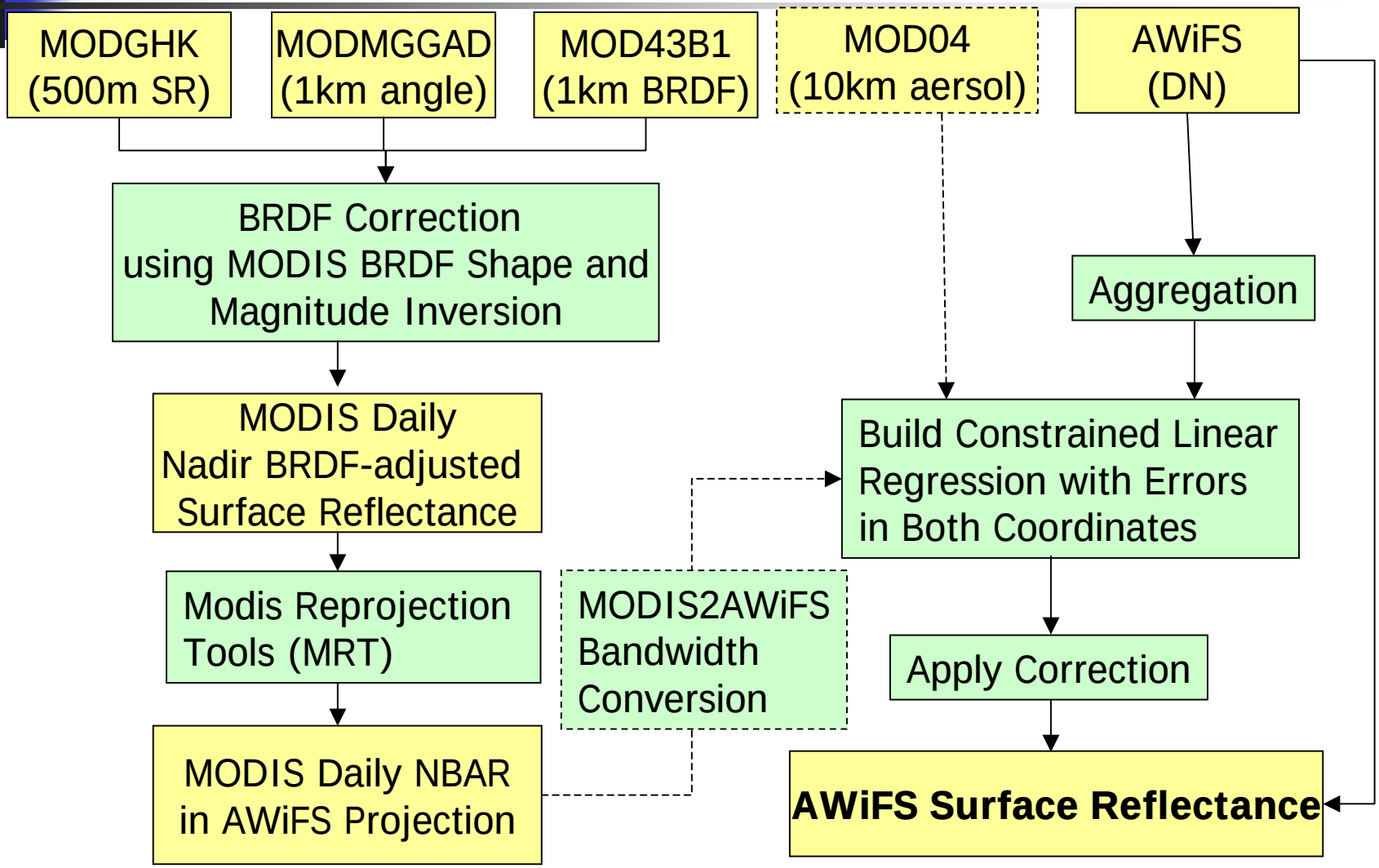
A2006116
4/26/2006



MODIS Daily NBAR

4/26/2006

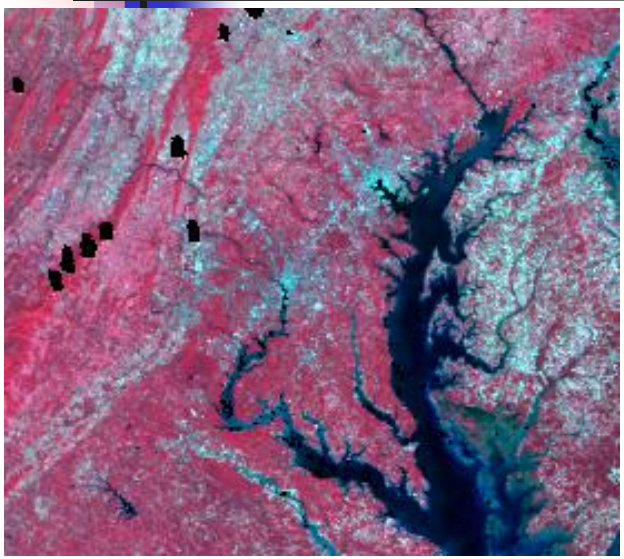
Processing Flow Chart



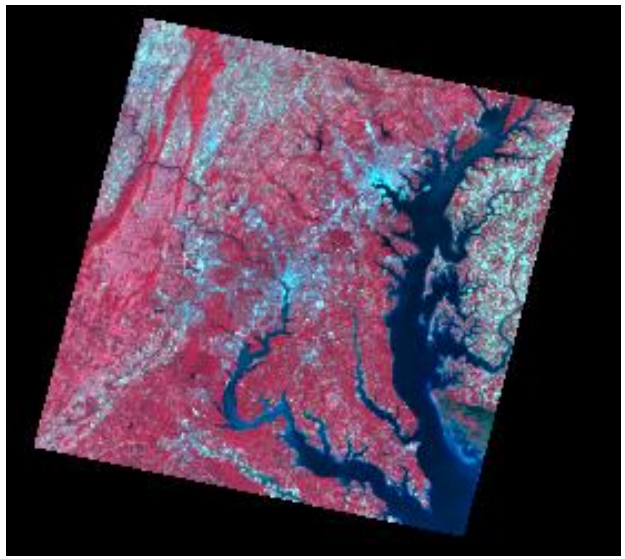
Linear Regression

- y = a*x + b
  - x: AWiFS DN aggregated to MODIS resolution
  - y: MODIS surface reflectance
  - samples are extracted in 2km resolution to reduce bowtie effects
- Consider errors from both x and y
  - Errors from x are caused by sensor noises, BRDF effects (vzn=0-25 degrees) etc.
  - Errors from y caused by calibration and atmosphere correction etc. The overall accuracy of MODIS surface reflectance are 0.005, 0.005, 0.014 and 0.006 for band 2-5 respectively.
  - Sample location matching errors from both x and y
  - Used numeric approach for straight-line data with errors in both coordinates (“numeric recipe in C”)

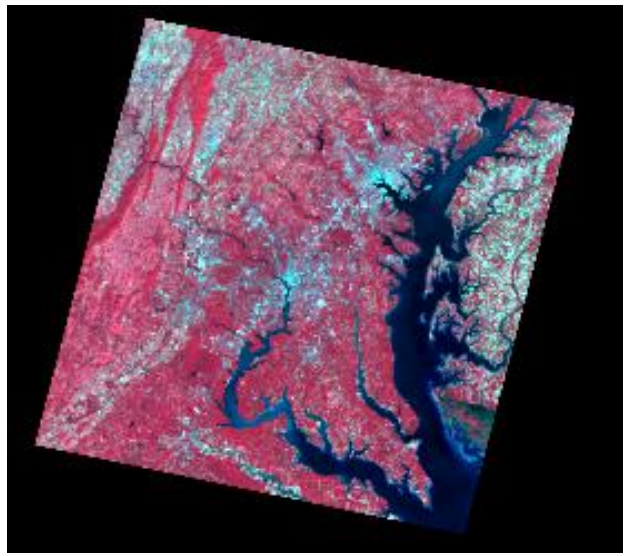
GERM vs. LEDAPS on ETM+



(a) MODIS



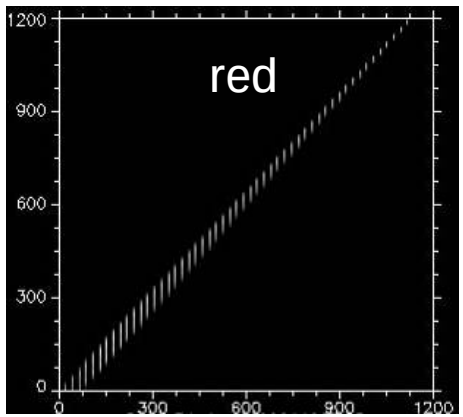
(b) GERM

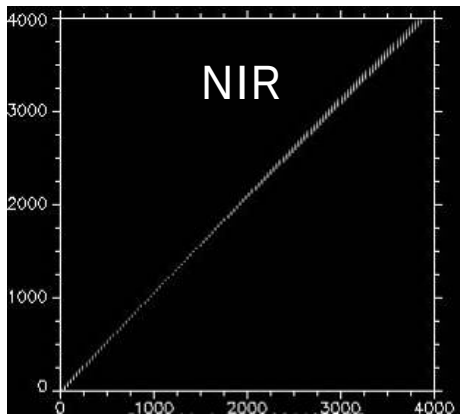


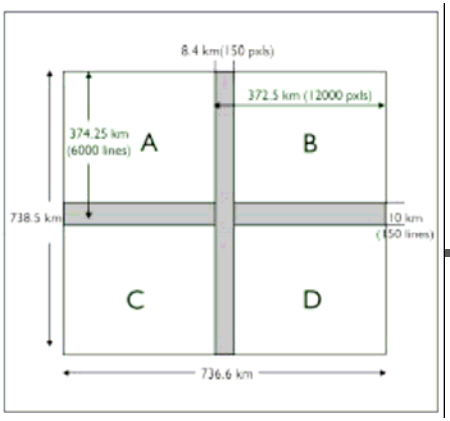
(c) LDEAPS

P015R033

Oct. 15, 2001

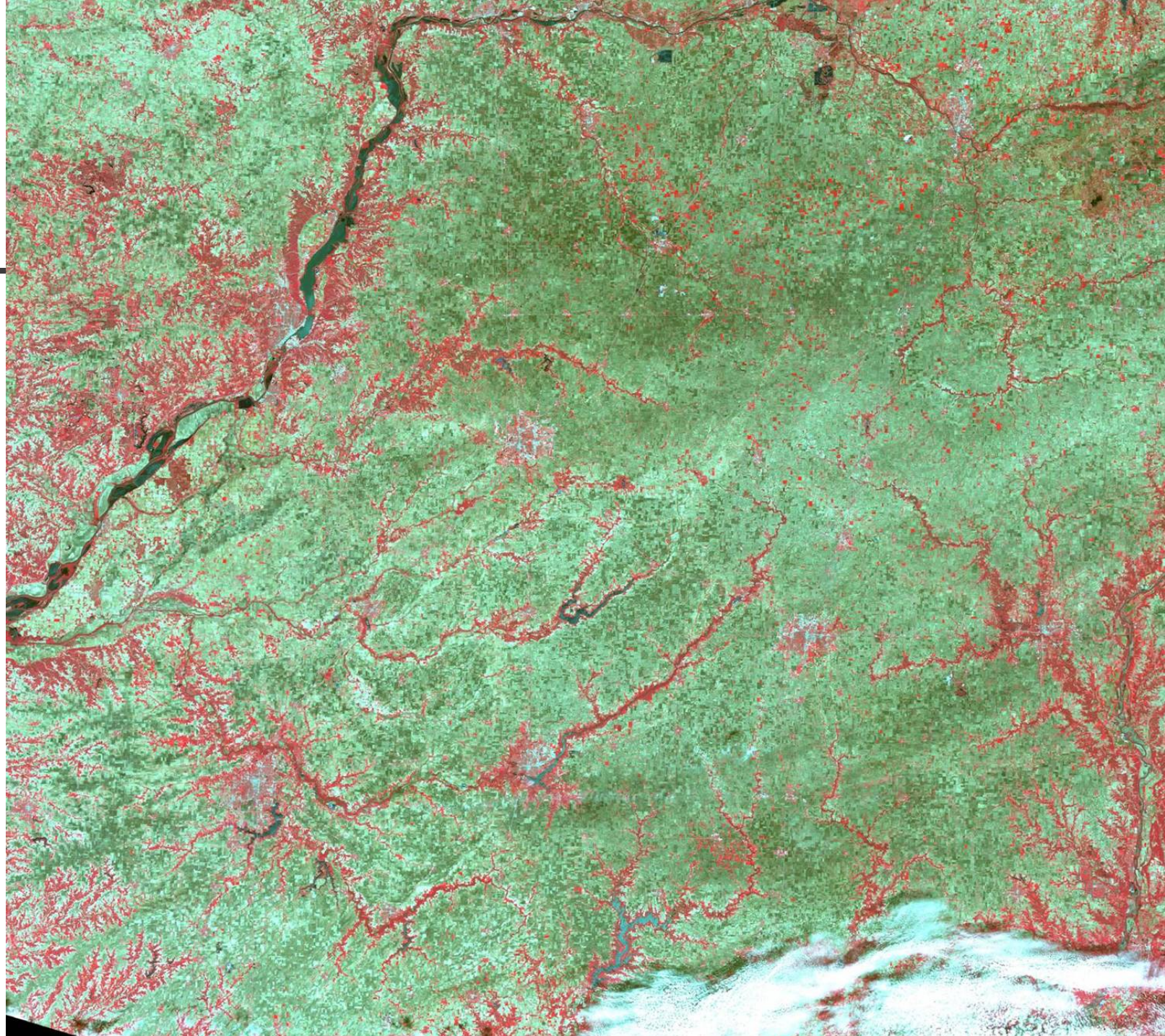






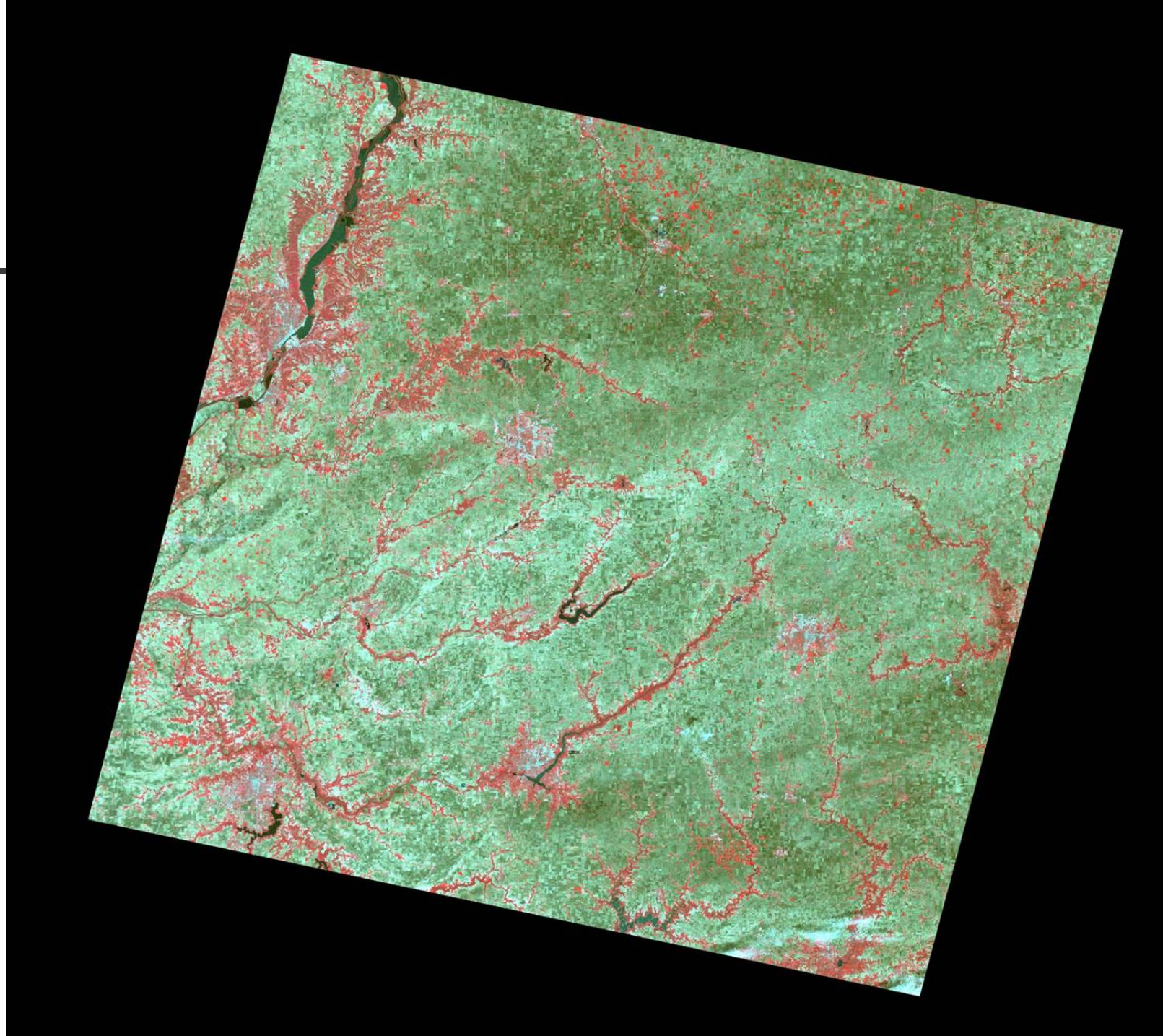
AWiFS
Digital number
(sub-scene D)

4/26/2006



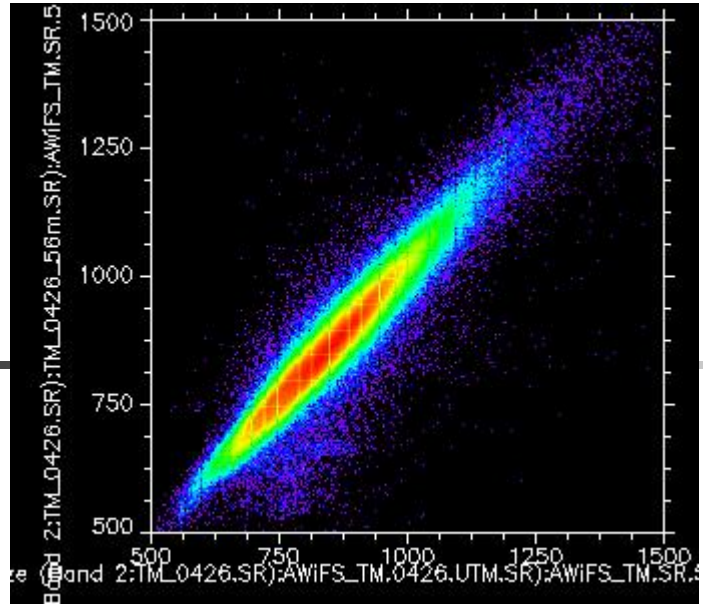
AWiFS surface reflectance using GERM and MODIS daily NBAR as reference

4/26/2006

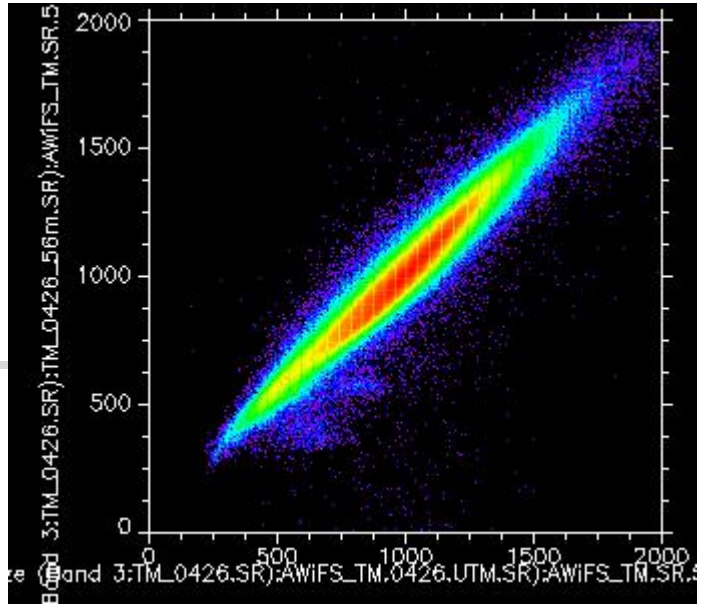


L5 TM surface reflectance using GERM and MODIS daily NBAR as reference

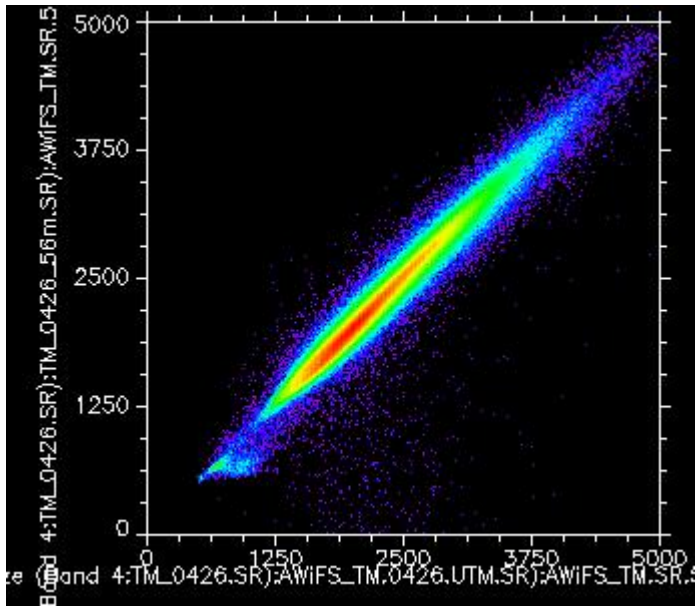
4/26/2006



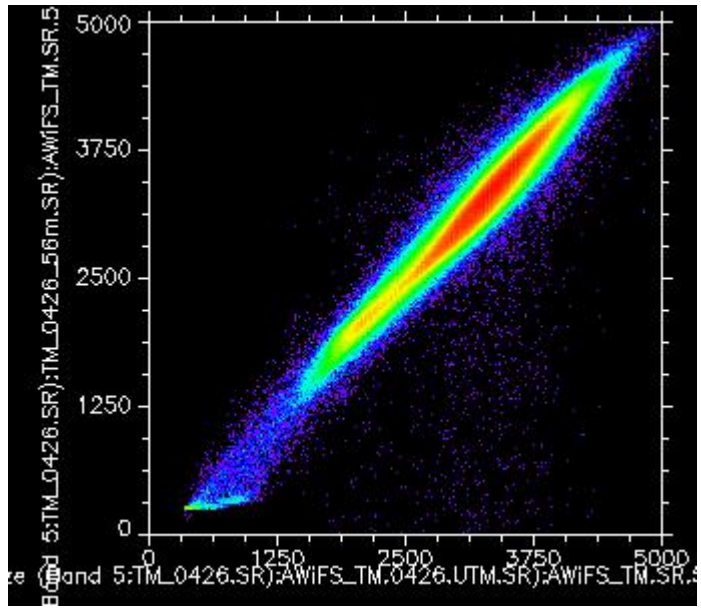
Green (B2)



Red (B3)



NIR (B4)

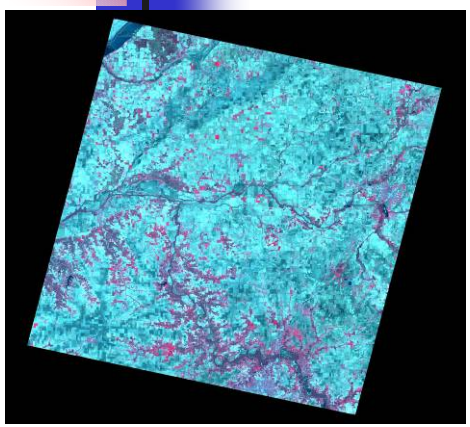


MIR (B5)

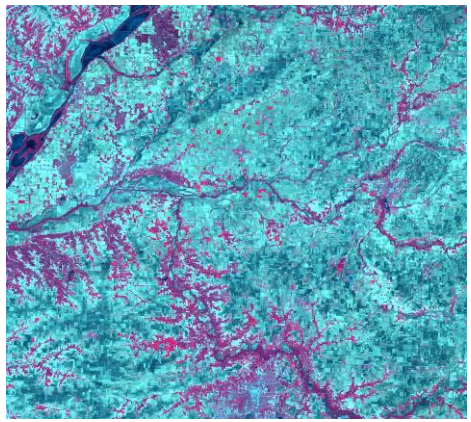
TM

AWiFS

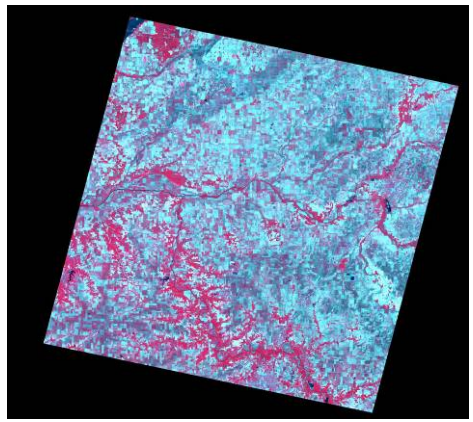
Combing Data from Multiple Sensors



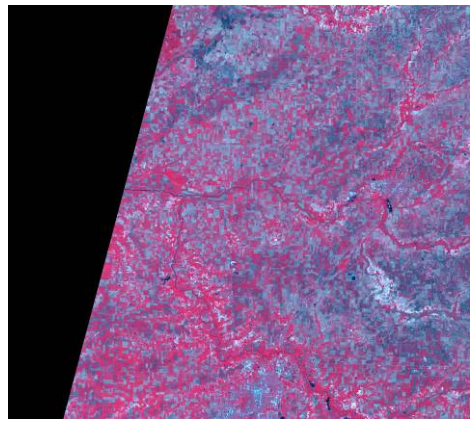
(a) 4/18/06, ASTER



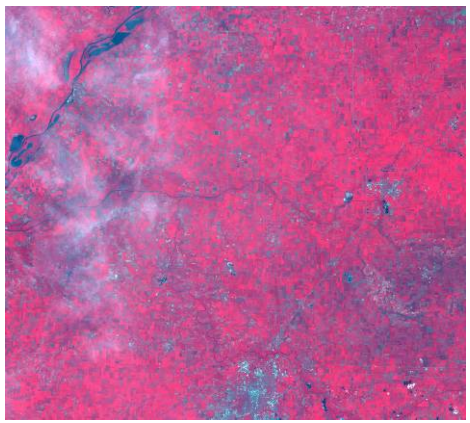
(b) 4/26/06, AWiFS



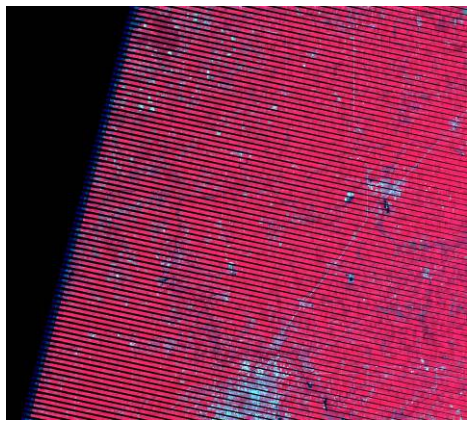
(c) 6/5/06, ASTER



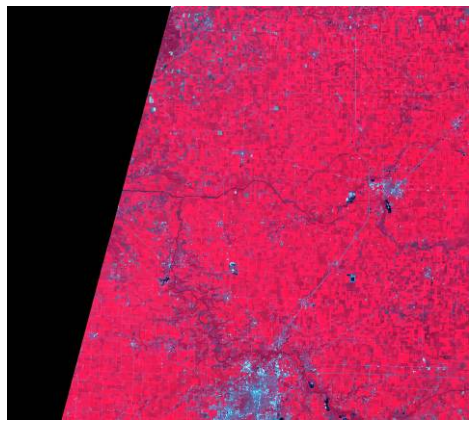
(d) 6/13/06, TM



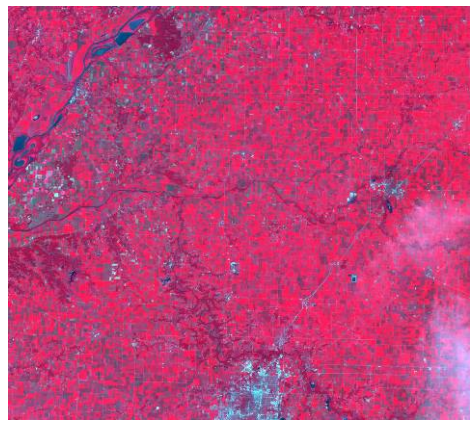
(e) 7/7/06, AWiFS



(f) 7/23/06, ETM+

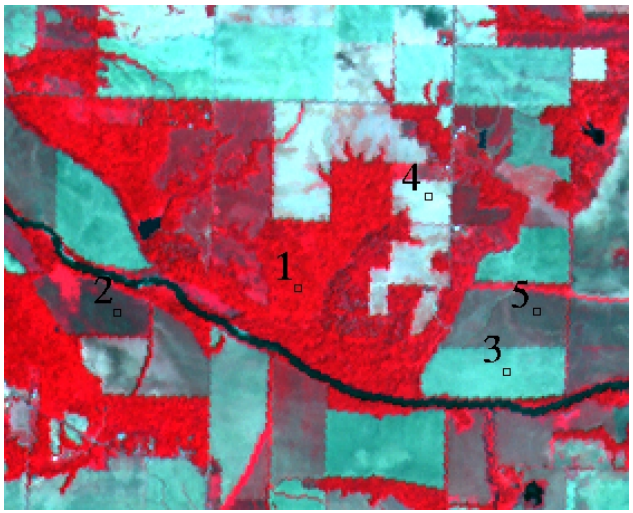


(g) 7/31/06, TM

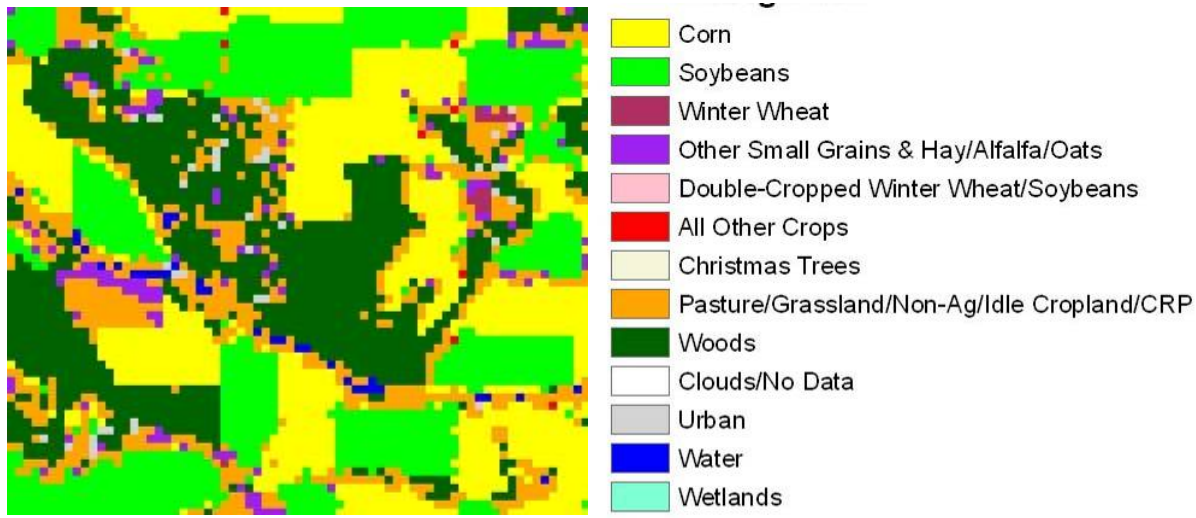


(h) 8/24/06, AWiFS

Four Typical Surface Types

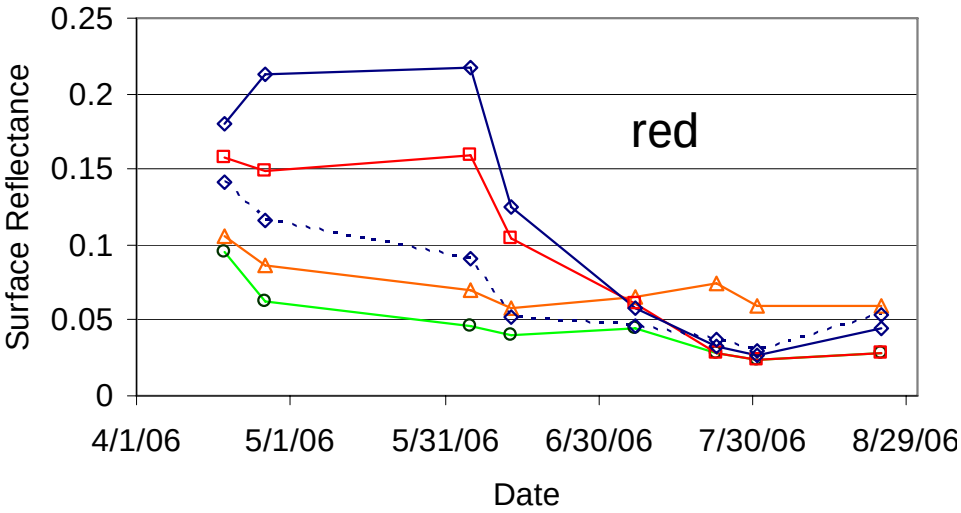


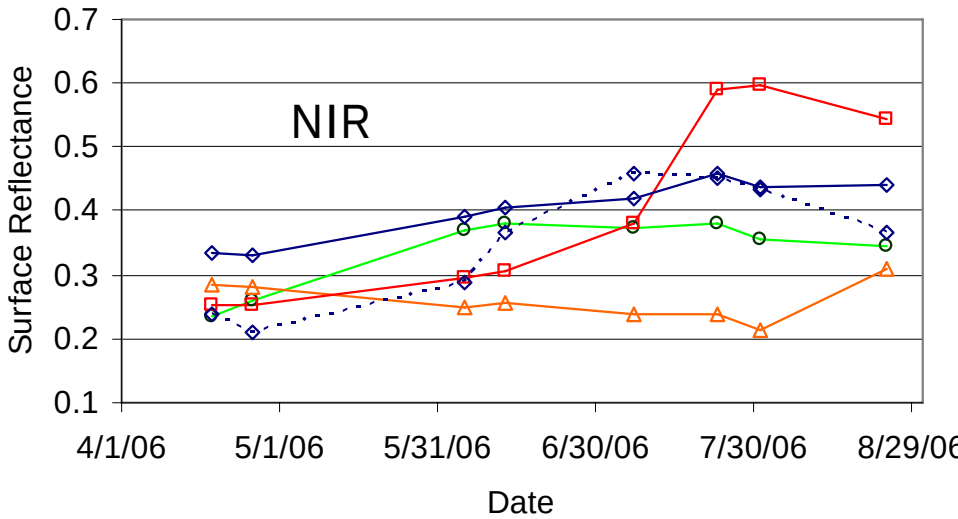
Samples Location
(ASTER, June 5, 2006)

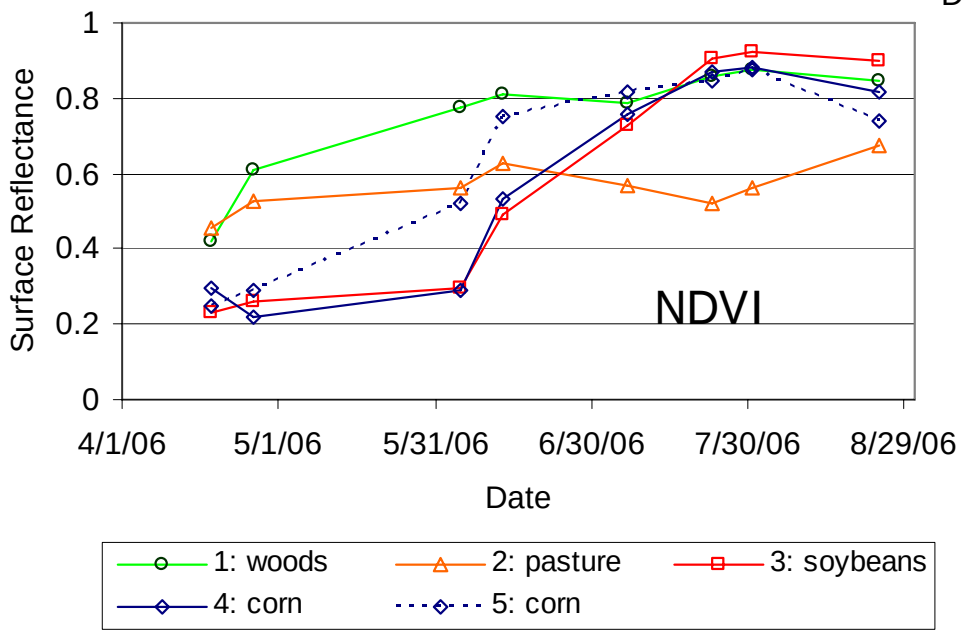


USDA 2006 Crop Data Layer

Natural Veg.	1: woods	2: pasture	
Crops	3: soybeans	4: corn	5: corn



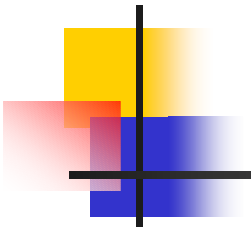




Date	4/18/06	4/26/06	6/5/06	6/13/06	7/7/06	7/23/06	7/31/06	8/24/06
Sensors	ASTER	AWiFS	ASTER	TM	AWiFS	ETM+	TM	AWiFS
MODIS	MOD09	D_NBAR	MOD09	D_NBAR	MOD09	MOD09	D_NBAR	MOD09

Conclusions

- GERM approach uses one step conversion – easy to implement
- MODIS is an appropriate surface reference since it provides
  - Similar bandwidth
  - Daily global coverage
  - Easy and free online access
  - Pixel level quality control and is the best available global remote sensing products so far.
- GERM approach produces the MODIS-like surface reflectance
  - A consistent data set from multiple sensors
  - May be used as a direct input to the MODIS algorithms and thus retrieve biophysical parameters such as leaf area index
- Further improvements
  - Spatial variant aerosol loading (aerosol distribution map)
  - Accurate automatic detection on cloud mask



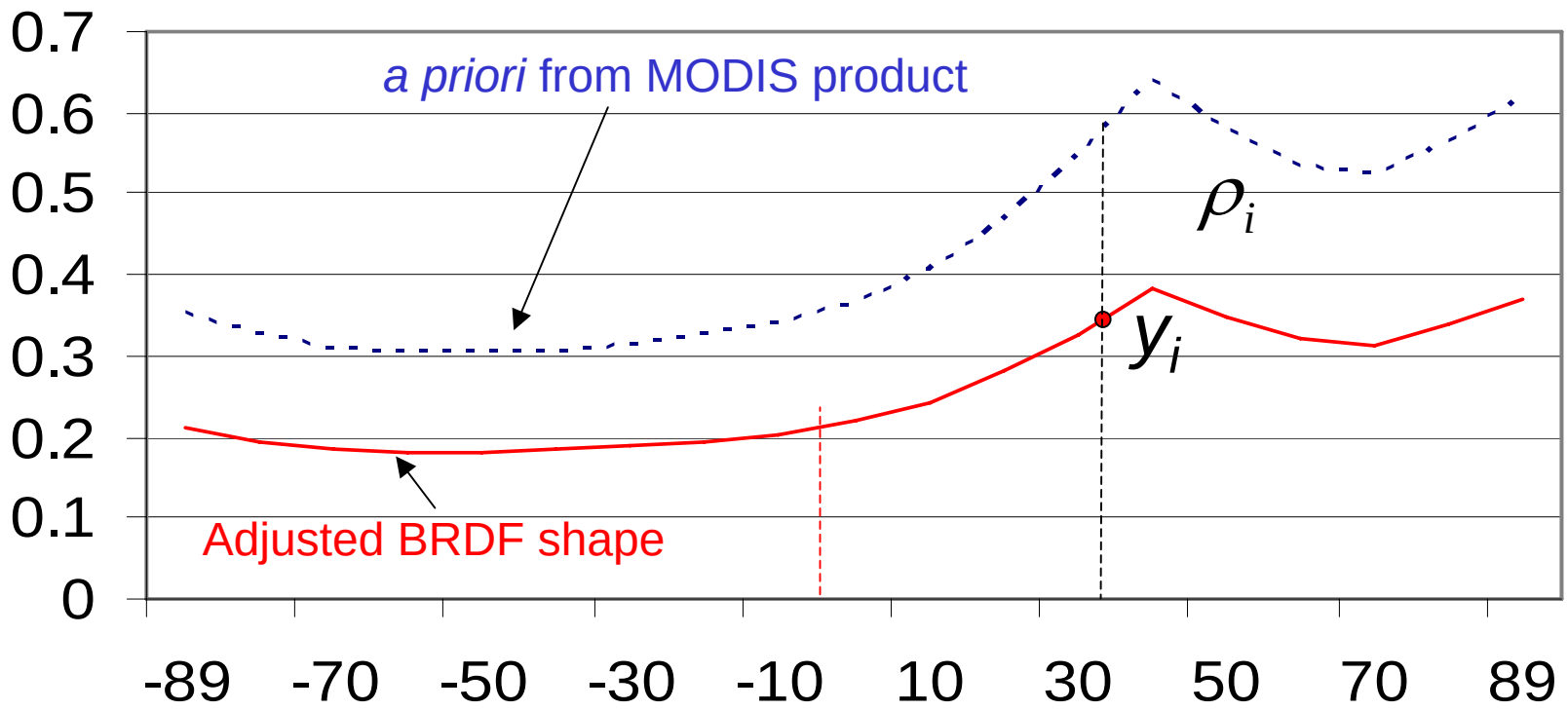
Backup Slides (22-27)

BRDF Correction

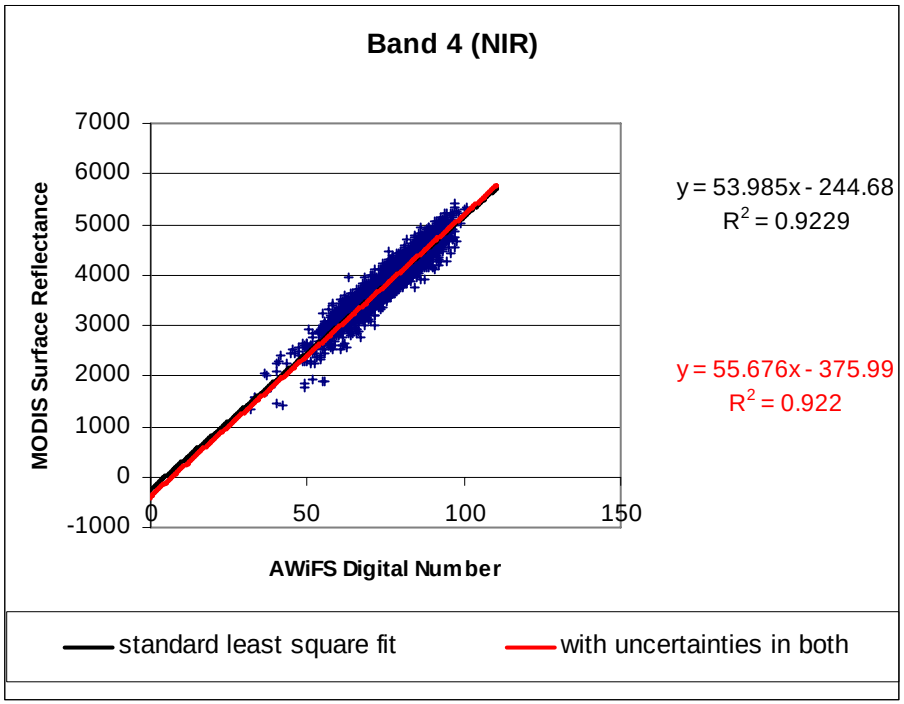
Magnitude inversion

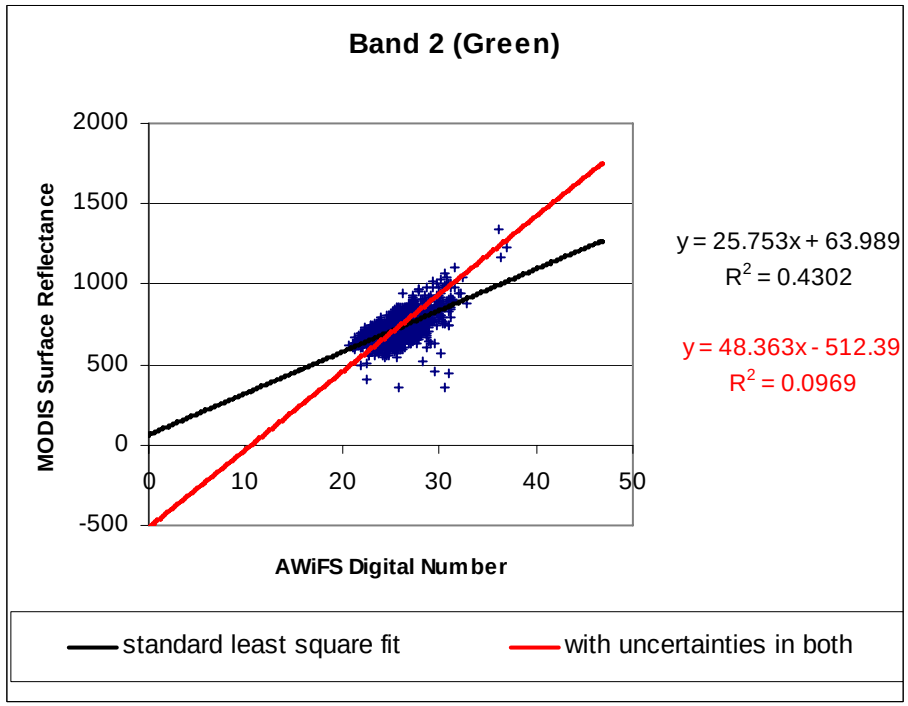
$$y_i = a \cdot \rho_i$$

$$y_{nadir} = a \cdot \rho_{nadir}$$



Linear Regressions





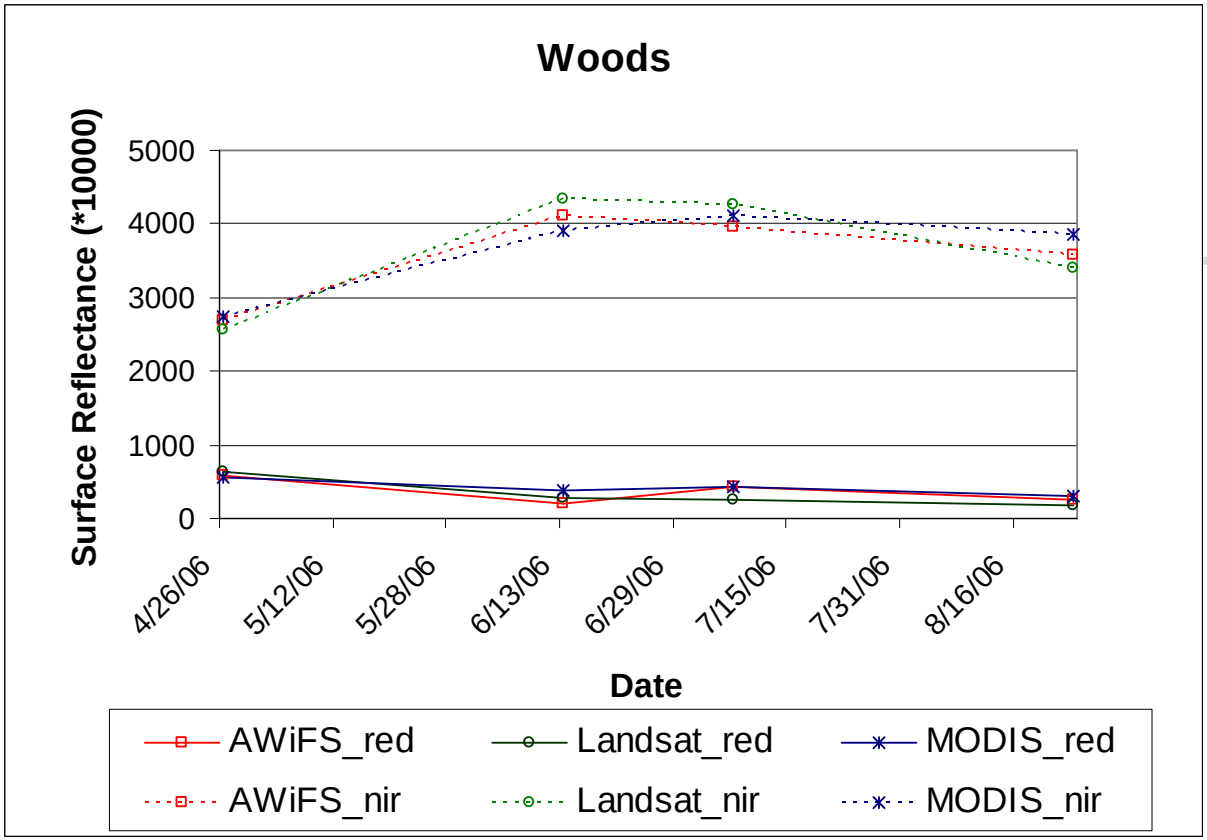
Good Case (Band 4)

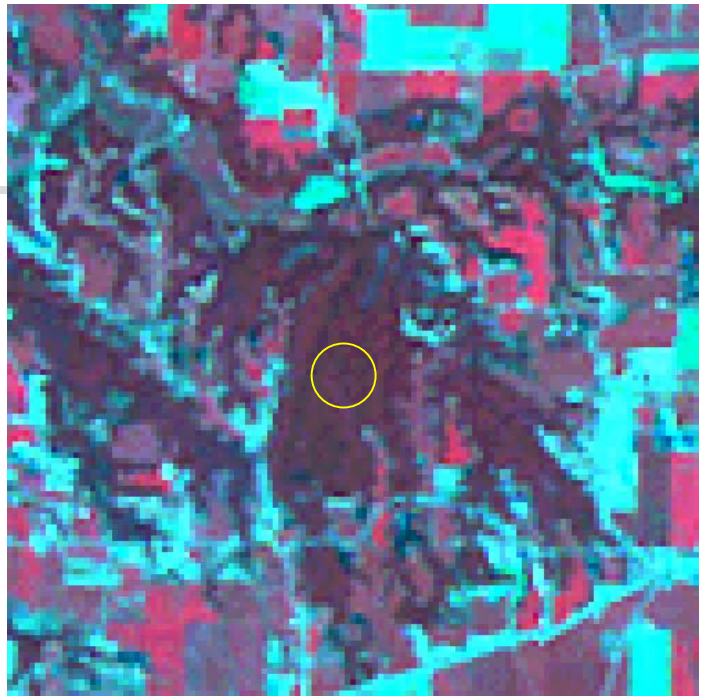
Ill-posed Case (Band 2)

Differences of MODIS SR, Landsat ETM+ SR from GERM and LEDAPS approaches

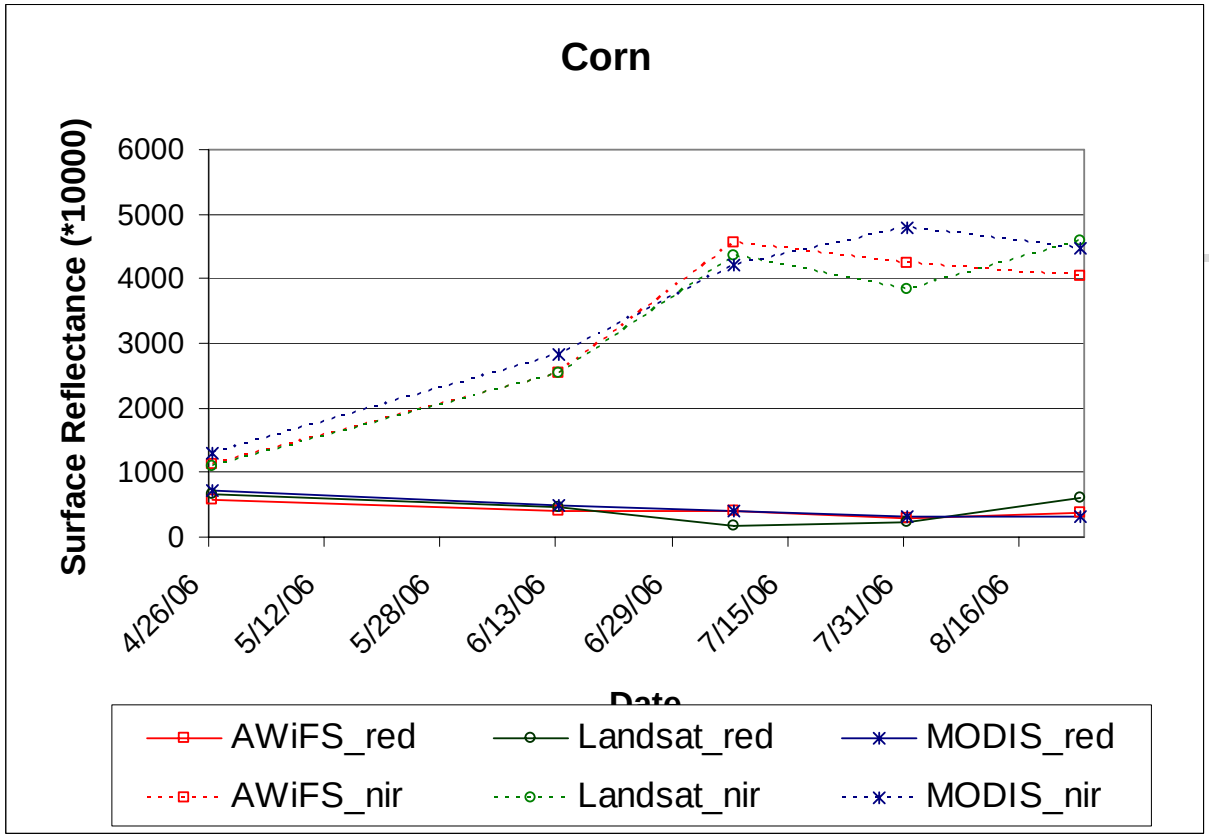
Mean absolute difference (*ad*) and difference (*d*) between MODIS (*m*) and Landsat surface reflectance from GERM approach (*g*) and LEDAPS (*l*)

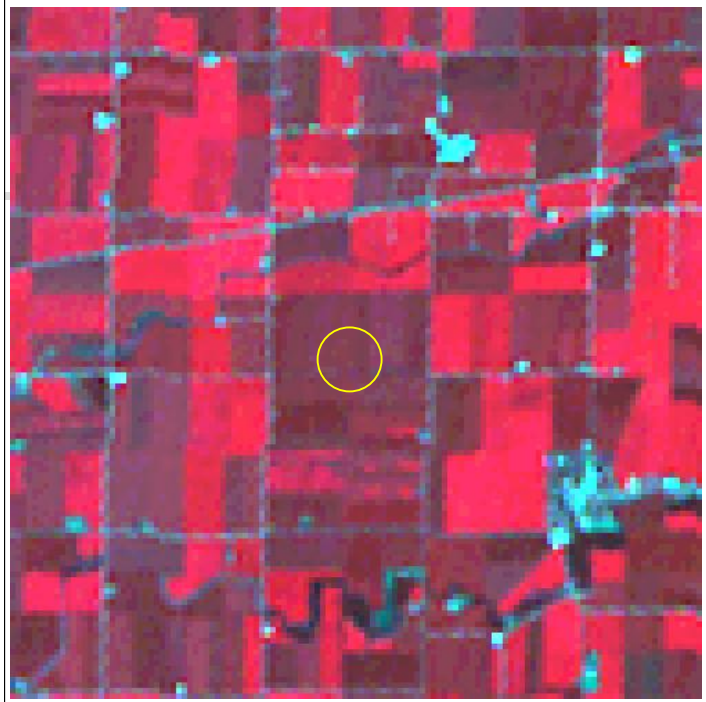
ETM+	**Band 1**	**Band 2**	**Band 3**	**Band 4**	**Band 5**	**Band 7**
d(m, l)	-0.0075	0.0012	0.0005	-0.0093	0.0141	-0.0011
d(g, l)	-0.0075	0.0012	0.0004	-0.0099	0.0139	-0.0014
d(m, g)	-0.0001	-0.0001	0.0000	0.0002	-0.0004	-0.0001
ad(m, l)	0.0080	0.0046	0.0055	0.0157	0.0177	0.0089
ad(g, l)	0.0077	0.0023	0.0032	0.0105	0.0139	0.0023
ad(m, g)	0.0050	0.0050	0.0053	0.0105	0.0108	0.0080



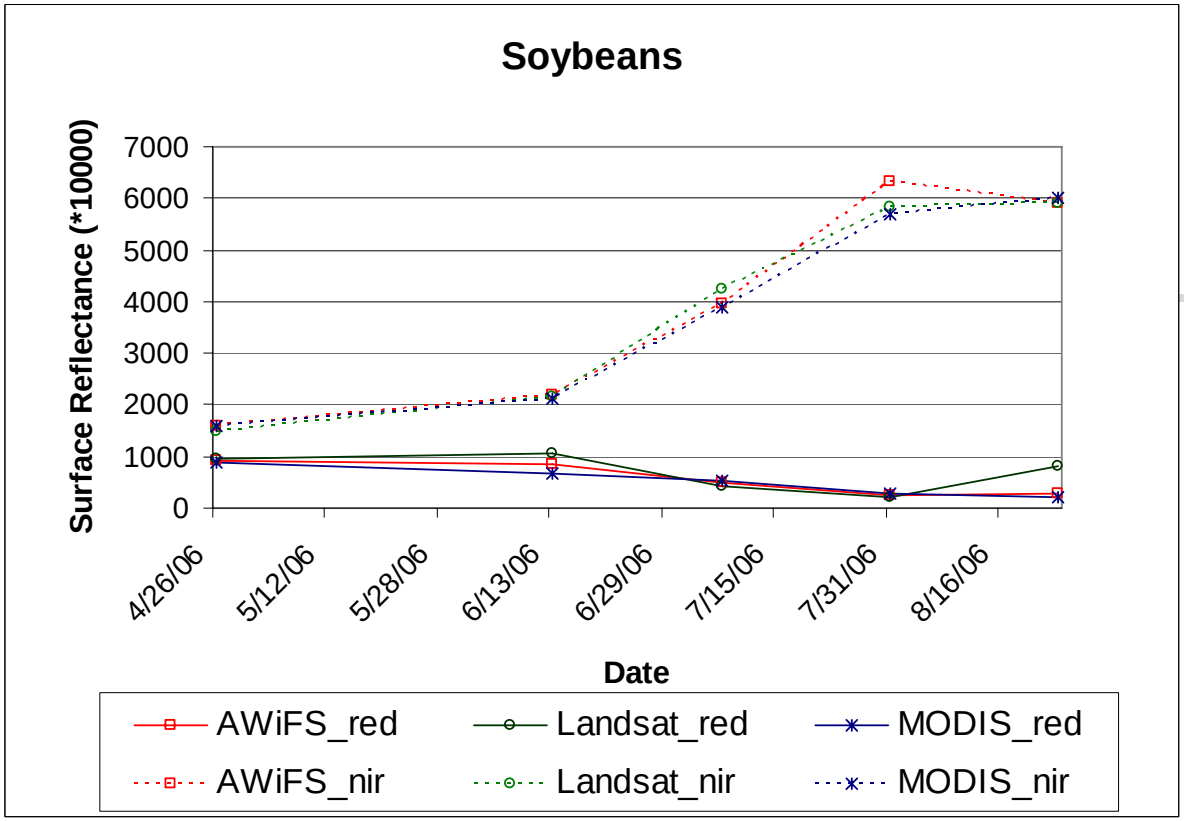


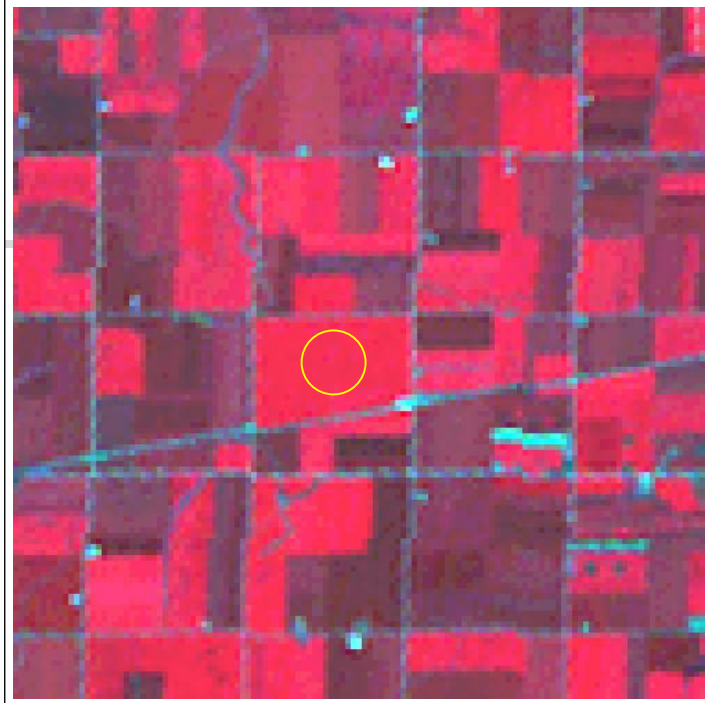
	4/26/06	6/13/06	7/7/06	8/24/06
AWiFS_NDVI	0.646	0.902	0.804	0.869
Landsat_NDVI	0.600	0.877	0.885	0.902
MODIS_NDVI	0.658	0.818	0.813	0.849





	4/26/06	6/13/06	7/7/06	7/31/06	8/24/06
AWiFS_NDVI	0.324	0.721	0.841	0.876	0.831
Landsat_NDVI	0.249	0.687	0.926	0.885	0.770
MODIS_NDVI	0.287	0.705	0.828	0.874	0.864





	4/26/06	6/13/06	7/7/06	7/31/06	8/24/06
AWiFS_NDVI	0.268	0.441	0.772	0.926	0.906
Landsat_NDVI	0.213	0.335	0.824	0.931	0.754
MODIS_NDVI	0.277	0.526	0.762	0.910	0.927