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# Developing Consistent and Continuous Moderate Resolution Data Products from Landsat and Landsat-like Data


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# Objectives

- Location consistent

  - Data from different sensors can be analyzed in pixel-by-pixel directly

- Temporal consistent and continuous

  - More frequent consistent observations

- Radiometric consistent

  - Data from same or different sensors are comparable in values for short-term or long-term time-series analysis

# I. Location Consistent

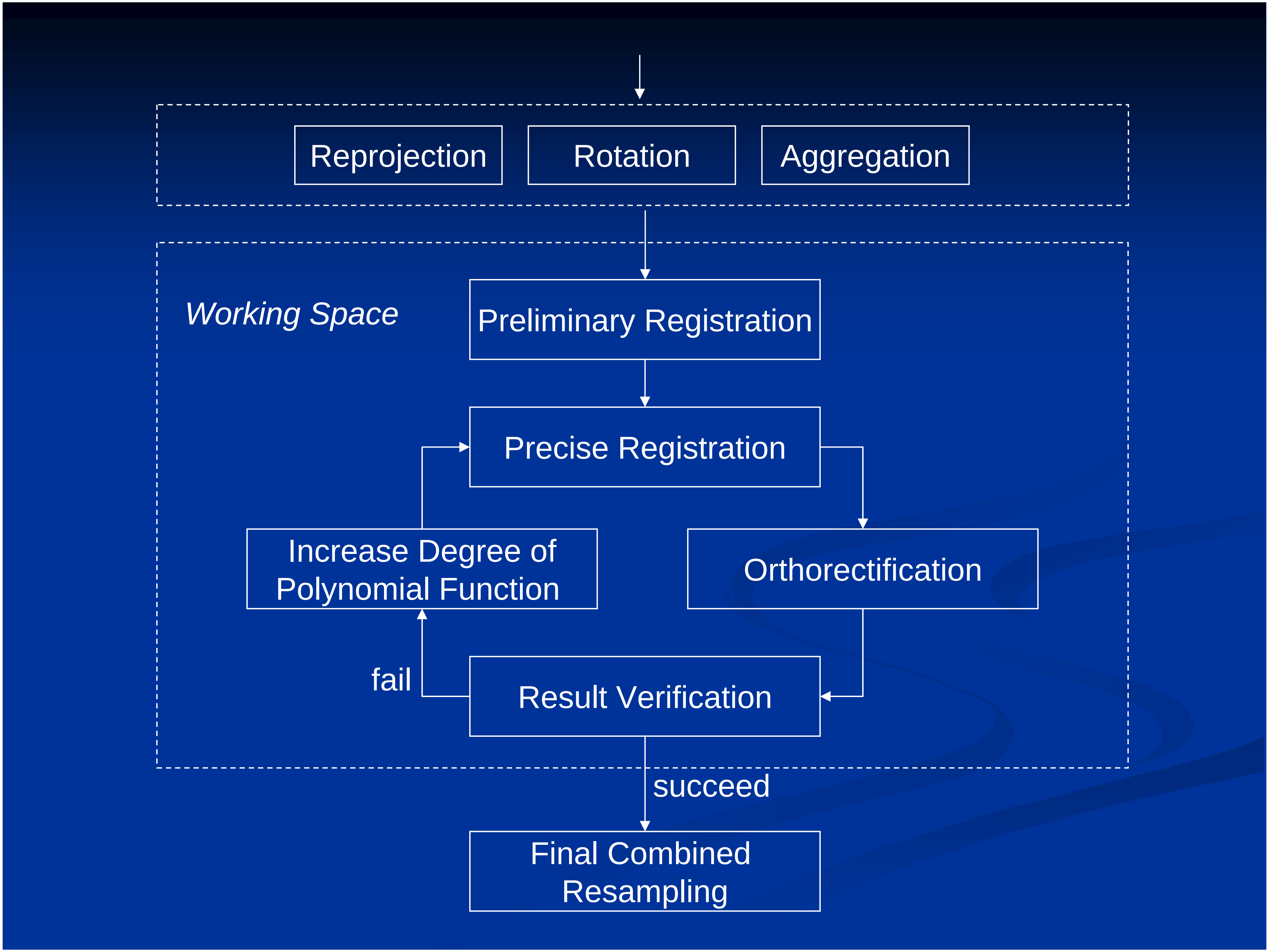
- **Background:**
  - Data from different sources or same source from different processing systems are often found hard to be analyzed in pixel-by-pixel due to the image distortions, different projections, and inaccurate registration etc.
  - Even though some satellite data are precisely registered and orthorectified, mismatches of up to a few pixels are common in those data sources.

- **Objective:**

  Develop an automated registration and orthorectification package for Landsat and Landsat-like data processing.

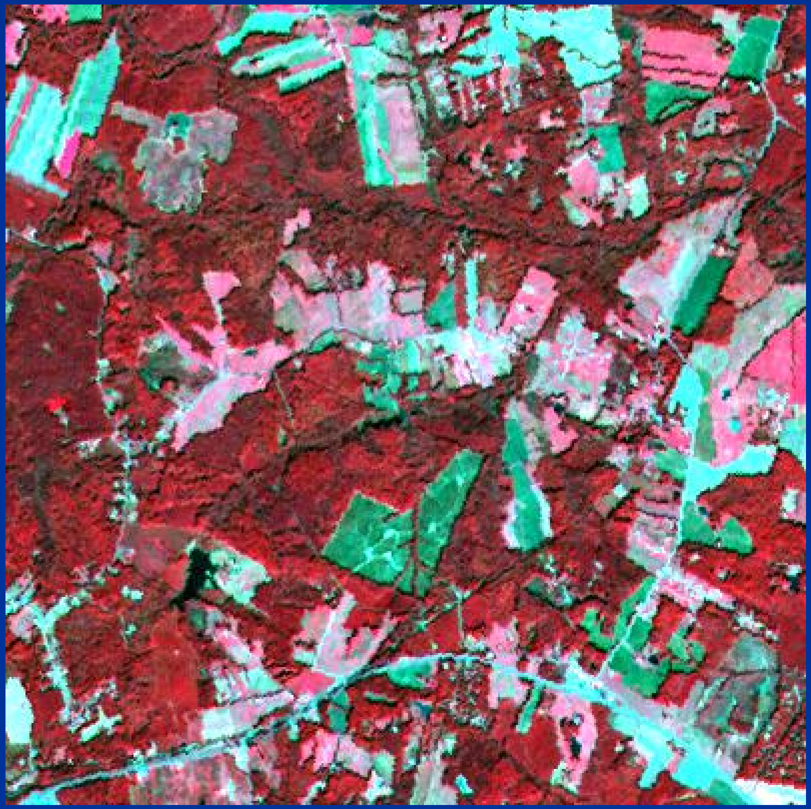
# Automated Registration and Orthorectification Package (AROP)

- The AROP package uses precisely registered and orthorectified Landsat data (e.g., GeoCover or GLS) as the base image to co-register and orthorectify the warp image and thus to make geo-referenced time-series images consistent in the geographic extent, spatial resolution, and projection. It can handle:
  - Three options: (1) automated precise registration; (2) orthorectification; (3) combined processing
  - Different projections between base (reference) and warp images
  - Map rotation (to north up)
  - Different spatial resolution between base and warp
  - Binary or GeoTIFF format inputs
  - Combined resampling processing
  - Pyramid registration: preliminary registration using coarse resolution; precise registration using fine resolution
  - Iterative results verification and processing
- A technical paper (F. Gao, J. Masek and R. Wolfe) submitted in June 2008
- C source code has been released for internal uses and will be released to public once paper is out.


Reprojection
Rotation
Aggregation
Working Space
Preliminary Registration
Precise Registration
Increase Degree of Polynomial Function
Orthorectification
fail
Result Verification
succeed
Final Combined Resampling

# Differences Between Multiple and Single Resampling

Resampled 3 times in v2.1

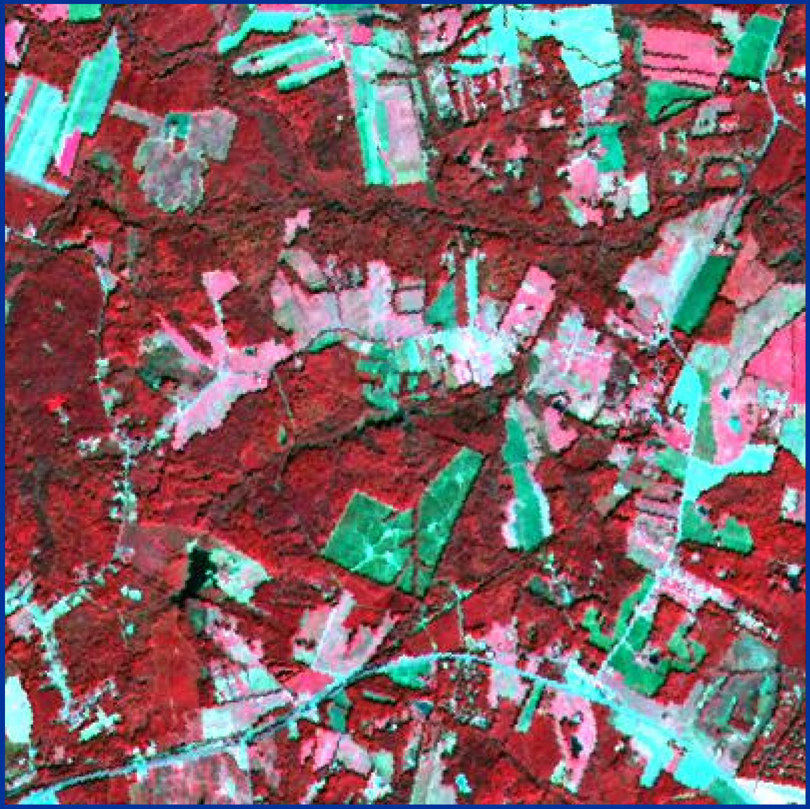


Warp Image
AST_L1B_00310232005160936_*_7406.hdf
October 23, 2005
VNIR Pointing Angle: 5.674
Map Orientation Angle: -9.049154
UTM Zone: 17 N

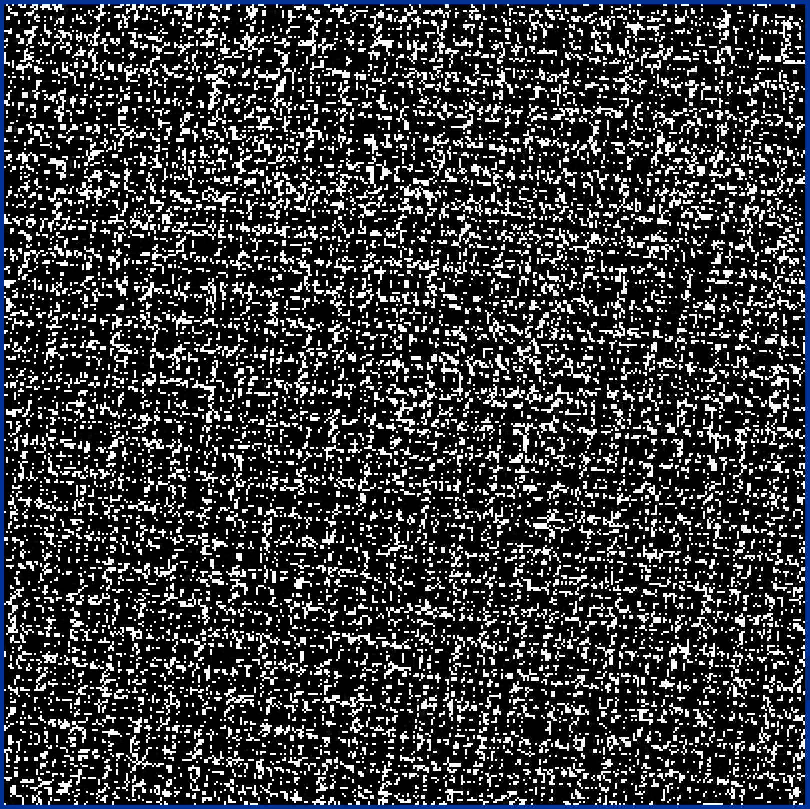
Base Image
GeoCover ETM+
September 30, 1999
UTM Zone: 18 N

Resampled three times:
(rotation, reprojection, ortho and registration)
Resolution: 15m

Resamples once in v2.2



Difference between v2.1 and v2.2
(1 time vs. 3 times resampling)
(NIR band, 15m resolution)



# II. Temporal Continuous

- **Background:**
  - The 16-day revisit cycle of Landsat has limited its use for studying global biophysical processes (16-day, 30m)
  - At the same time, MODIS scans whole Earth once or twice each day. However, the coarse resolution limit its ability in heterogeneous landscapes (daily, 250m & 500m)
- **Objective:**

  To combine the spatial resolution of Landsat with the temporal temporal frequency of coarse-resolution sensors, such as MODIS.

# Spatial and Temporal Adaptive Reflectance Fusion Model

- Objectives:

  Fuse high-frequency temporal information from MODIS and high spatial resolution information from Landsat to produce "daily" Landsat-like surface reflectance

| | | | | |
|---|---|---|---|---|
| MODIS SR | 1 | 2 | 3 | 4 |
| Landsat SR | 1 | ? | ? | 4 |

- Input:

  MODIS and Landsat surface reflectance pair at $t_k$

  MODIS surface reflectance $M(x_i,y_j,t_0)$ at prediction date

- Predict:

  Landsat surface reflectance $L(x_i,y_j,t_0)$ at prediction date

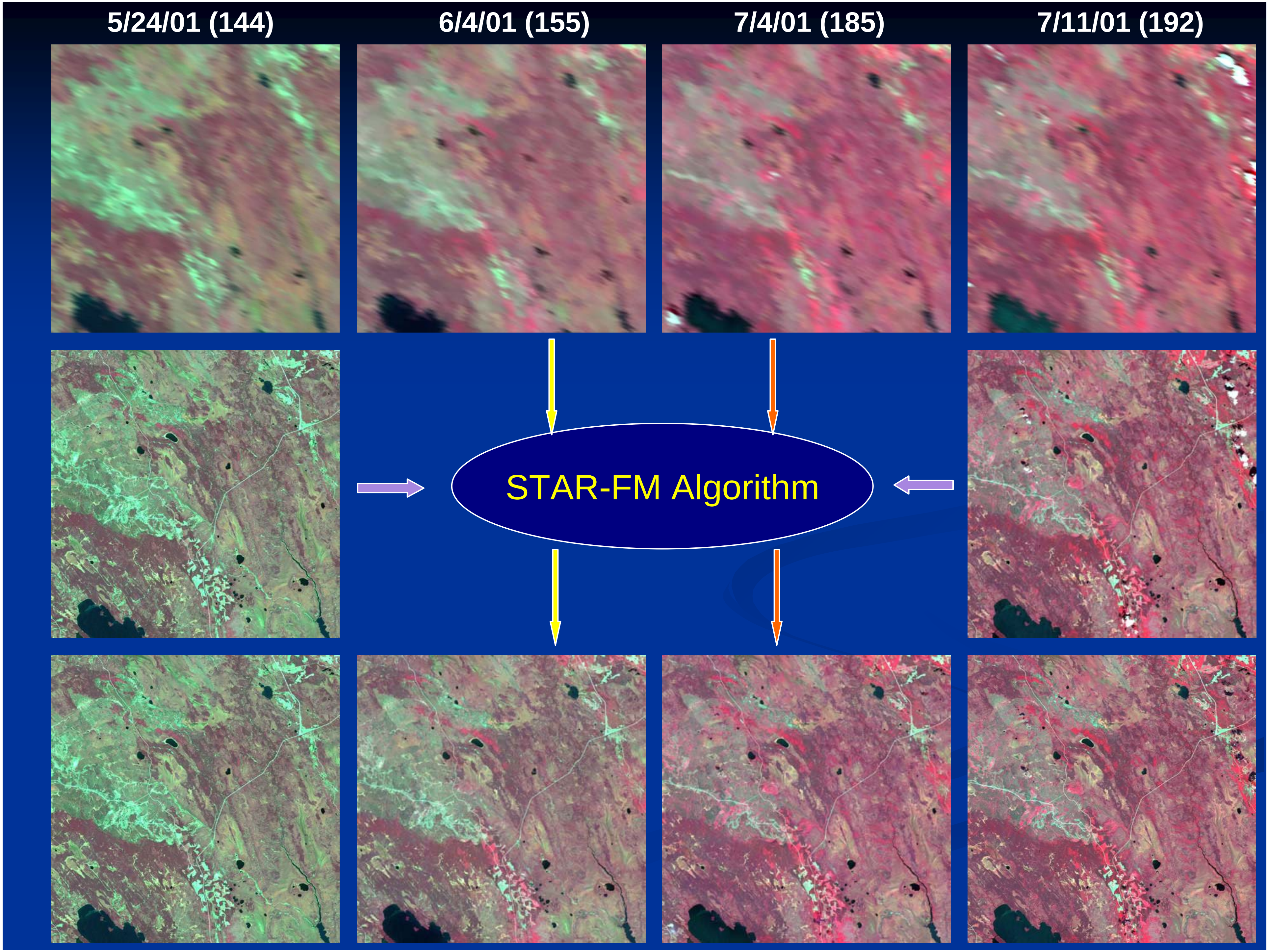
Gao, F., J. Masek, M. Schwaller and H. Forrest, On the Blending of the Landsat and MODIS Surface Reflectance: Predict Daily Landsat Surface Reflectance, IEEE Transactions on Geoscience and Remote Sensing, vol. 44, no. 8, pp. 2207-2218, 2006

# STAR-FM Code Released !

- C source code (Linux) and examples were released in February 2008
- Based on the 2006 IEEE TGRS paper (Gao and Masek et al.) with improvements in:
  - Quality flag – stores number of high quality samples used in the prediction for each pixel.
  - Backup algorithm – use a look-up-table that stores the best predictions from whole image and replaces poor prediction.
- Collaborated with several research groups
  - LC-ComPS (surface reflectance)
  - Michael Wulder (top-of-atmosphere reflectance)
  - Randolph Wynne (NDVI)
  - Martha Anderson (surface temperature)
  - Requests from China, India, Germany, and Brazil

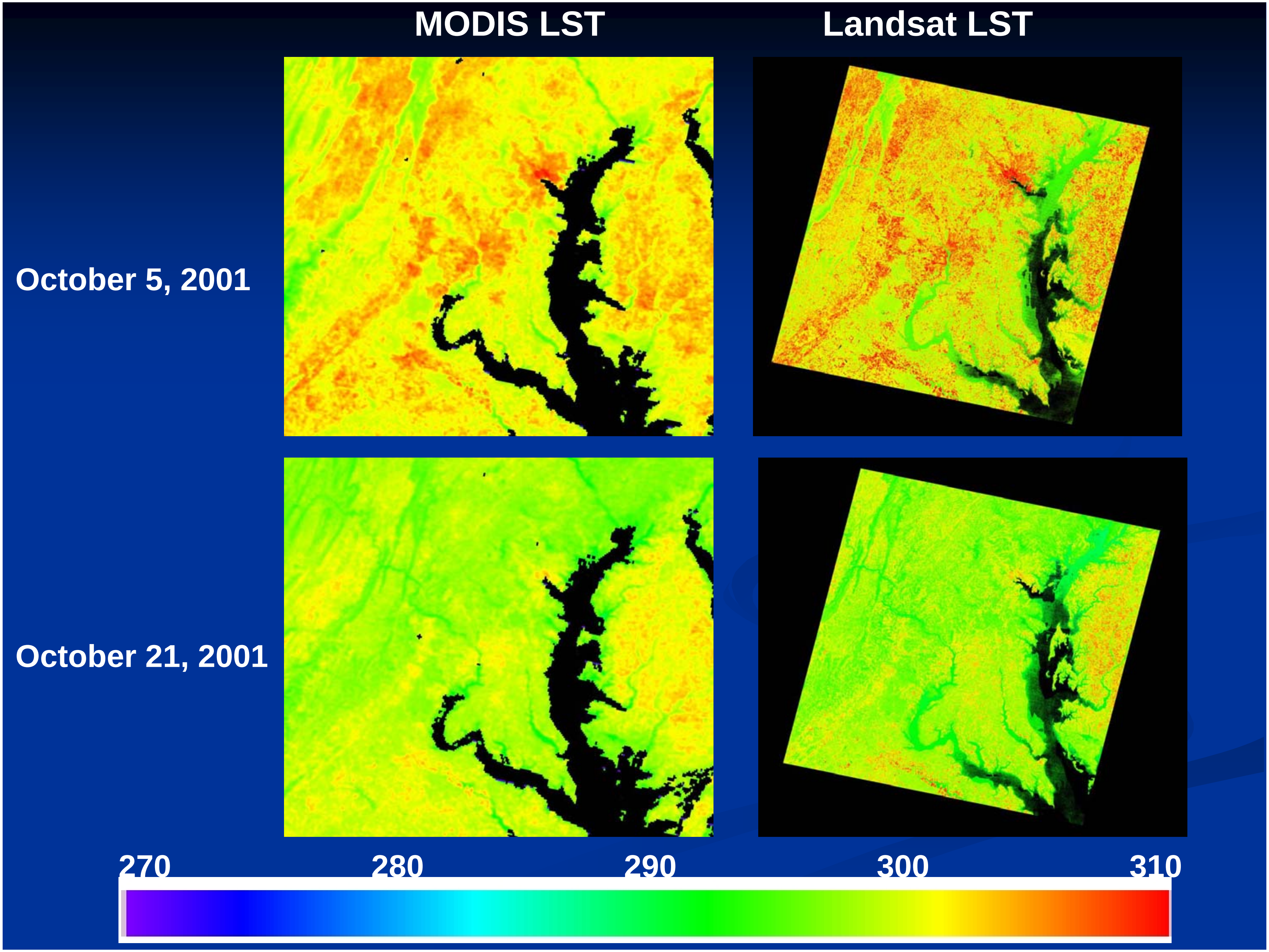
# Example I: STAR-FM for LC-ComPS

- LC-ComPS: Land Cover Change Community-based Processing and Analysis System, a NASA ACCESS project (GSFC & UMD, PI: Jeff Masek)
- One of goal is to use MODIS 8-day (Collection 5) Nadir BRDF-adjusted Reflectance (NBAR) product and Landsat LEDAPS surface reflectance as inputs to produce 8-day temporal continuous fused surface reflectance at Landsat resolution.
- Automatic processing: users can run STAR-FM by choosing either Internet GUI or Linux command line.


5/24/01 (144)
6/4/01 (155)
7/4/01 (185)
7/11/01 (192)
STAR-FM Algorithm

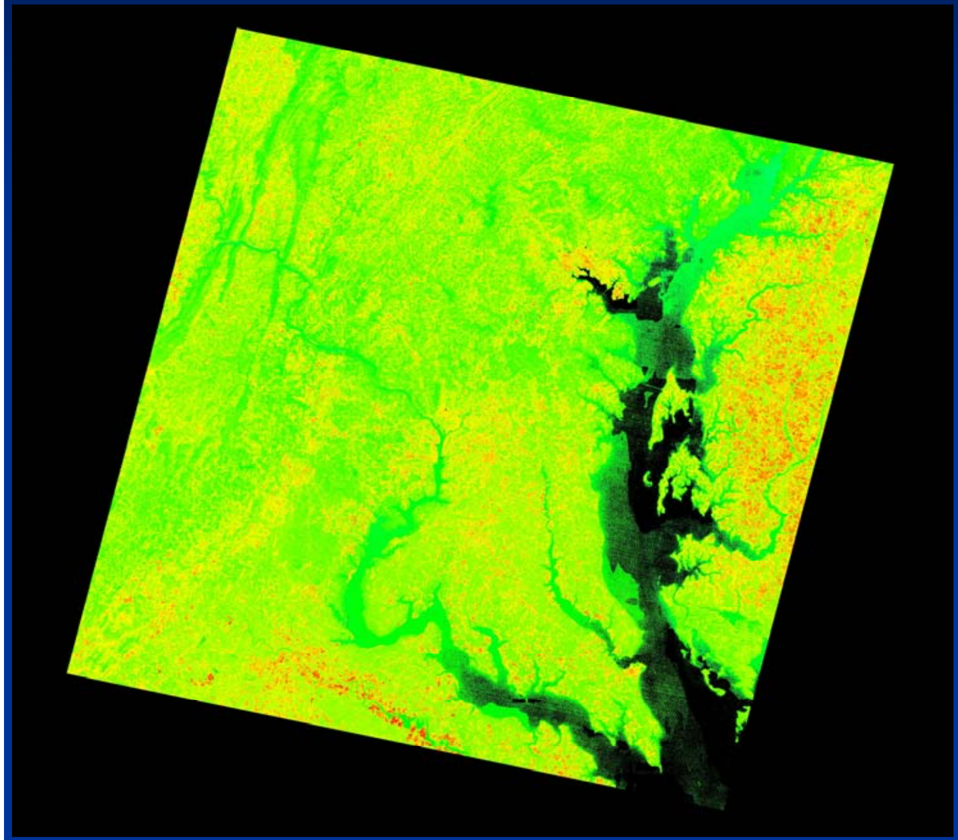
# Example II: STAR-FM for Surface Temperature

- Collaborated with Dr. Martha Anderson
- Used daily MODIS LST and Landsat LST
- We found clear scenes worked well
- Needs consistent surface temperature product between two sensors (also true for VI and TOA reflectance)
- Difference in acquisition time may cause some variations

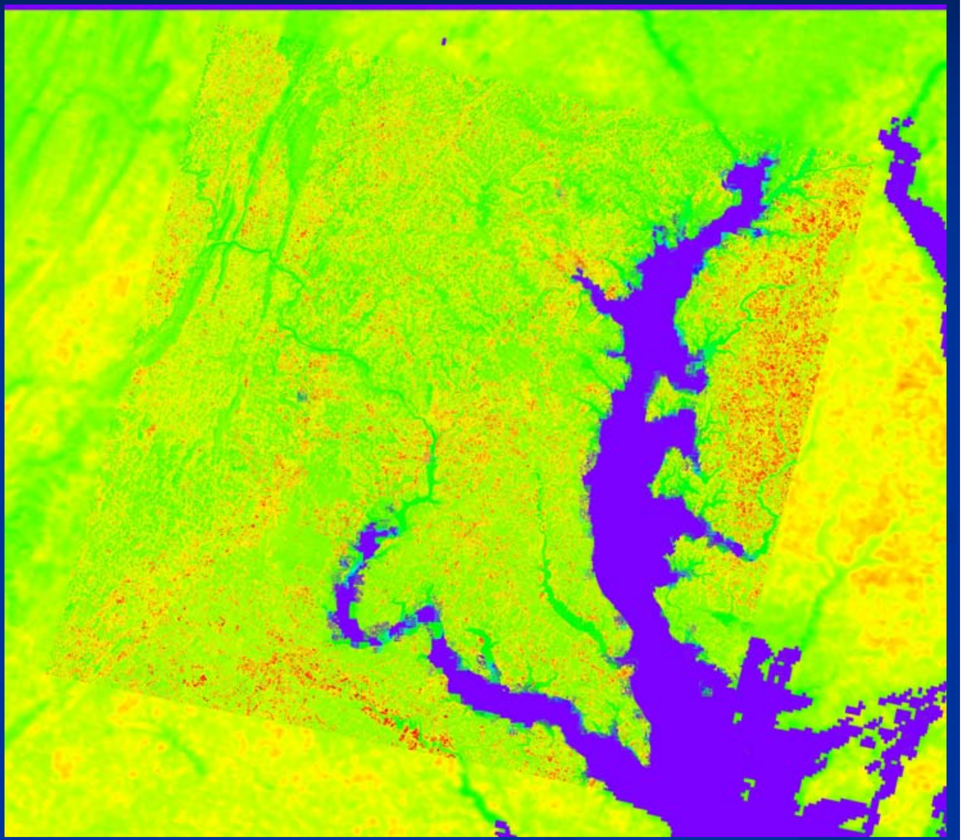

MODIS LST
Landsat LST
October 5, 2001
October 21, 2001
270
280
290
300
310

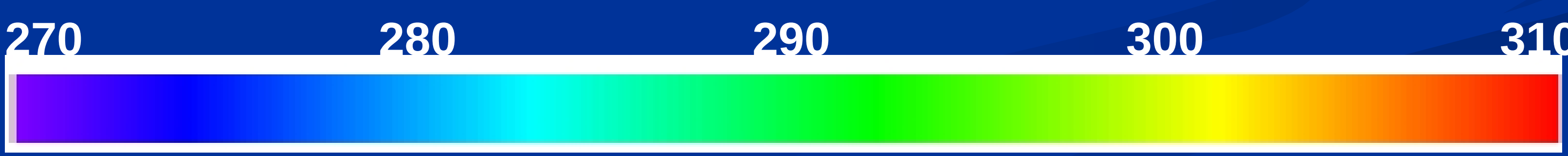
# October 21, 2001

**Actual Landsat LST**



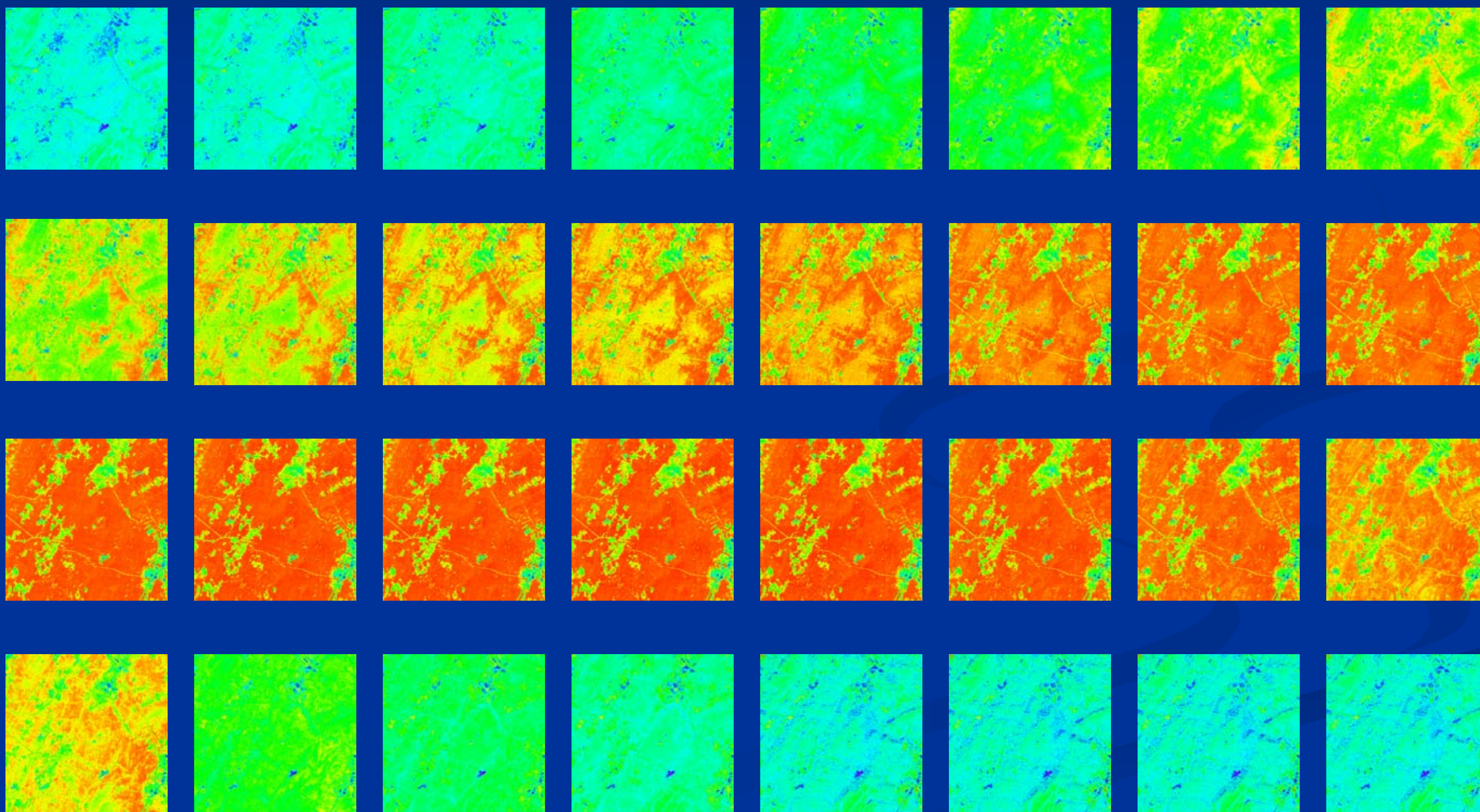
**Predicted LST using October 5, 2001**






y=1.04*x+-11.30; r2= 0.602; ave_abs_diff=1.39; ave_diff=-0.64

# Temporal Continuous Using Timesat Fitting (cont.)



# III. Radiometric Consistent

- Background:
  - Required for long term climate/environment data record
  - Required for time-series analysis
  - Required for large area (multiple scenes) processing

- Objective:

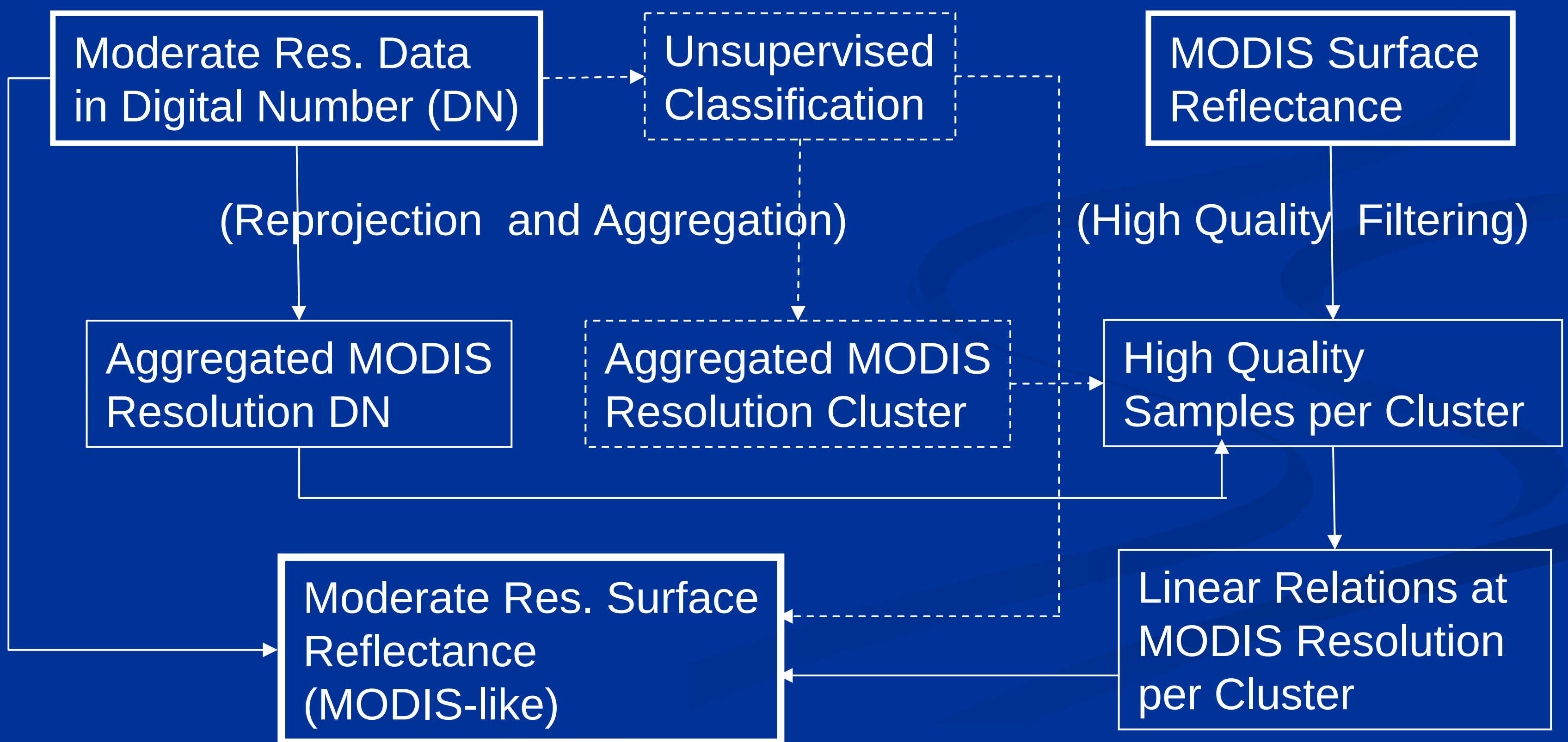
  Produce consistent moderate resolution data product using existed consistent data product as a reference

- Applications:

  We tested the idea using MODIS products as references and applied to
  - Surface reflectance
  - Leaf area index
  - Land cover

# Approach

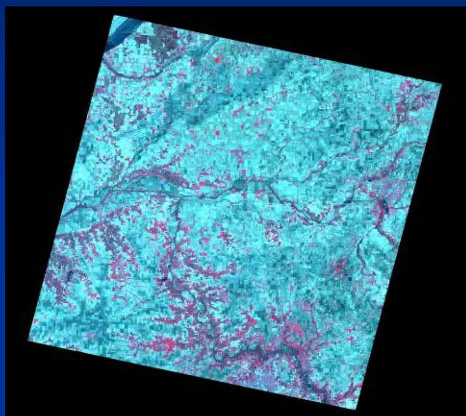
This approach converts sensor digital number (DN) to surface reflectance directly using MODIS products as reference data sets.



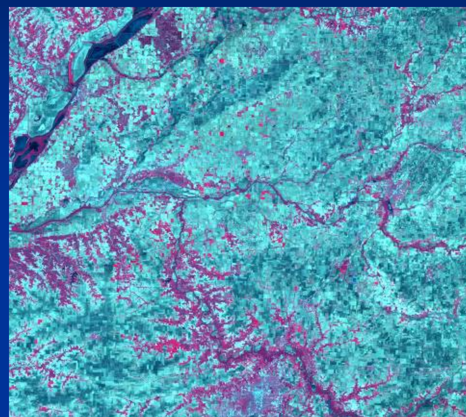
# Application I: Combining Data from Different Sensors

- A more robust land monitoring system would combine observations from multiple, international sensors – this will offer more frequent observations
- Consistent data set should be processed in surface reflectance. However, even with perfect calibration and atmospheric correction, direct comparison of surface reflectance from different sensors are still limited by viewing and illumination geometries, spectral band response function and geolocation accuracy and resampling approaches.
- We correct moderate resolution satellite data (DN) to a consistent data stream (SR) using standard surface reflectance as a reference data set.

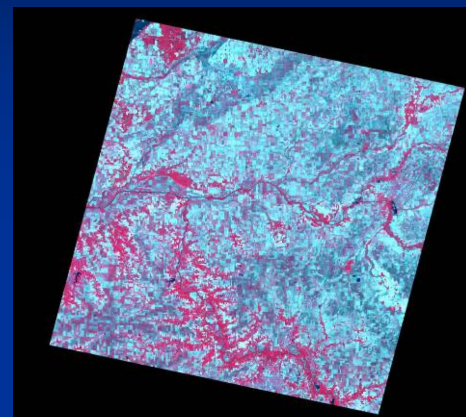
# Combining Data from Different Sensors for Vegetation Monitoring



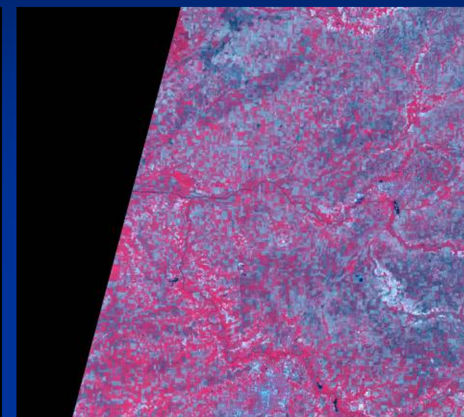
(a) 4/18/06, ASTER



(b) 4/26/06, AWiFS

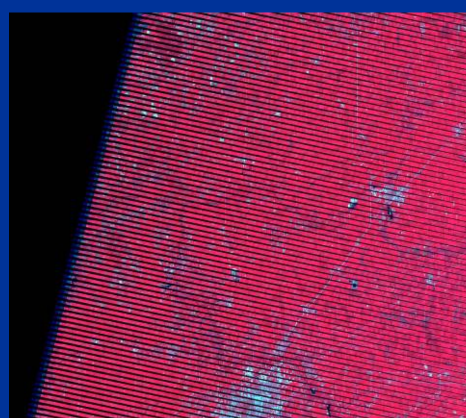


(c) 6/5/06, ASTER



(d) 6/13/06, TM

(e) 7/7/06, AWiFS



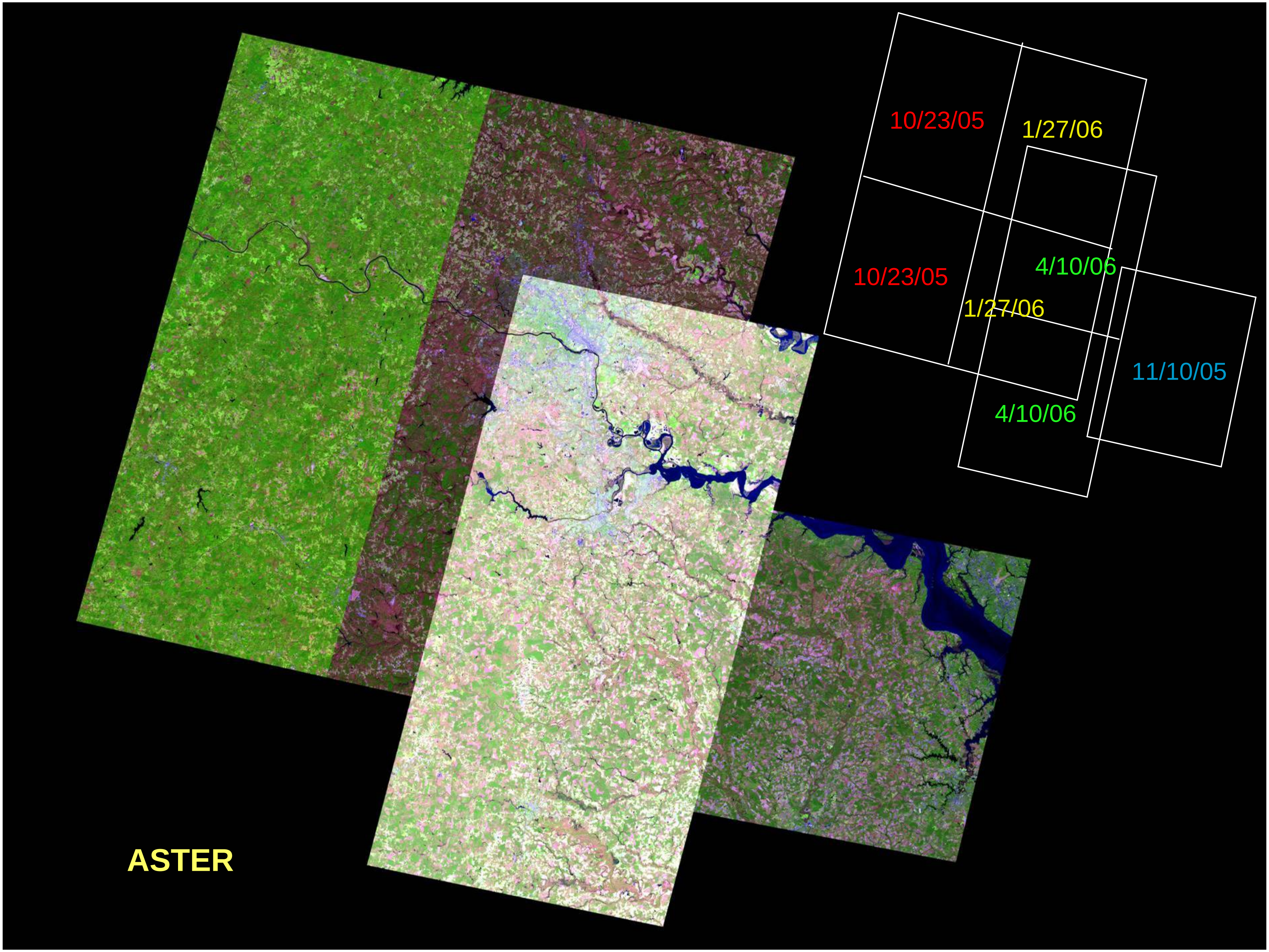
(f) 7/23/06, ETM+

(g) 7/31/06, TM

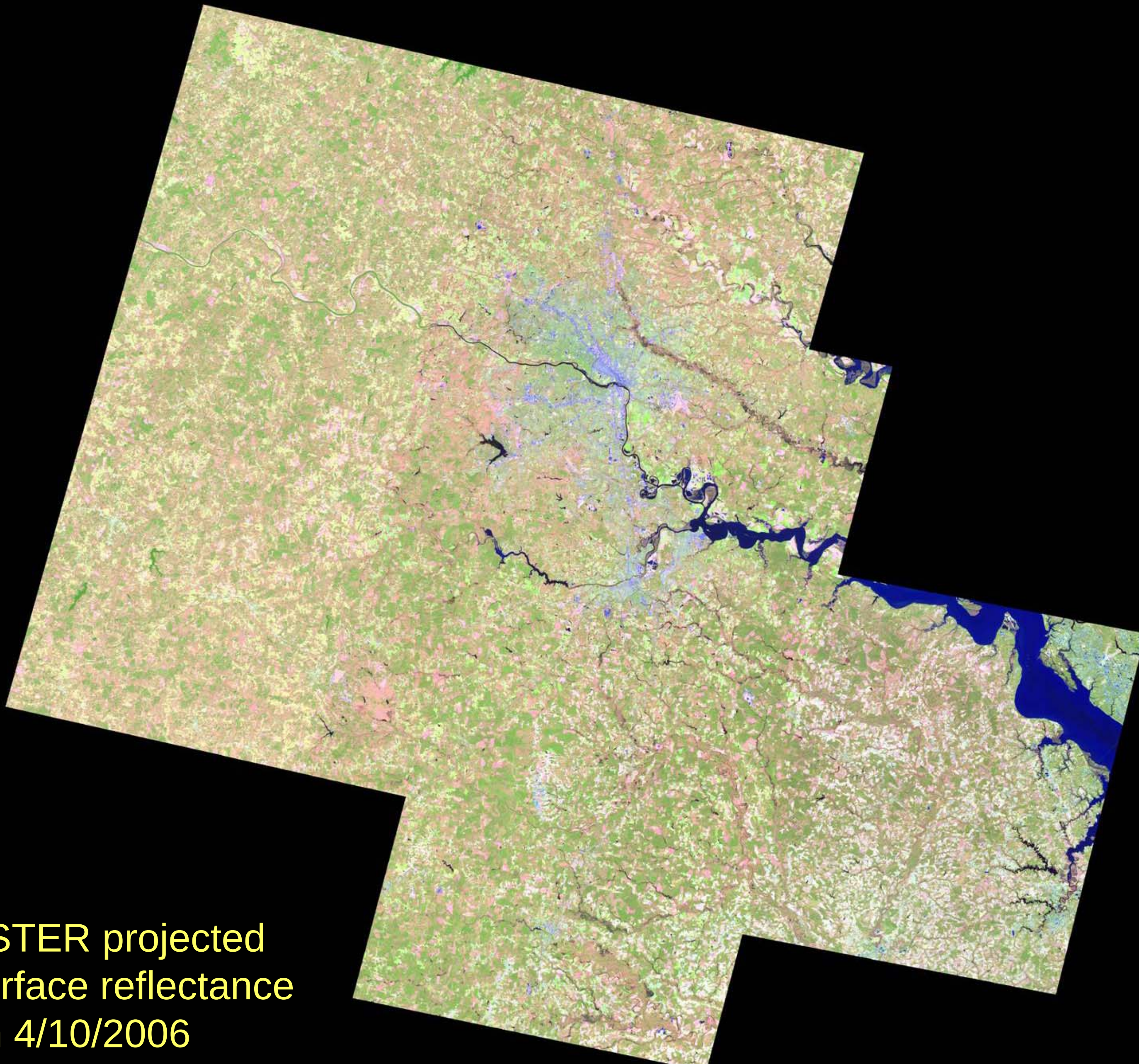
(h) 8/24/06, AWiFS

# Application II: Combing ASTER Data from Different Acquisition Dates

- ASTER limitations:
  - Small scene coverage: 9 ASTER scenes make one Landsat scene
  - No blue band: AOT can't be retrieved from ASTER data itself
- Normalization approach
  - Phenology can be adjusted to one reference date
  - Digital number can be converted to a consistent surface reflectance

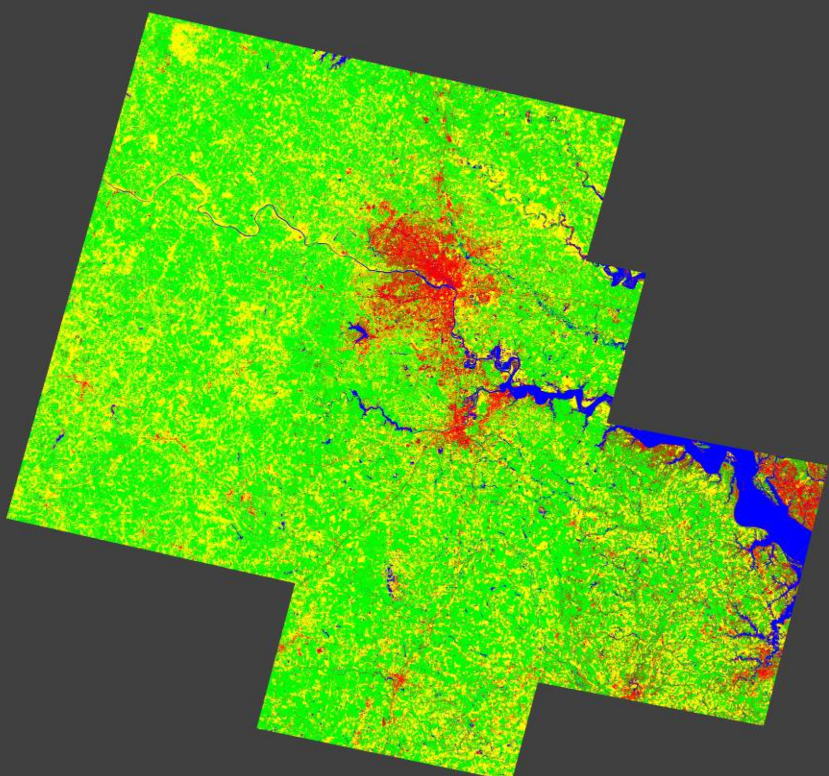


10/23/05
1/27/06
10/23/05
4/10/06
1/27/06
11/10/05
4/10/06
ASTER

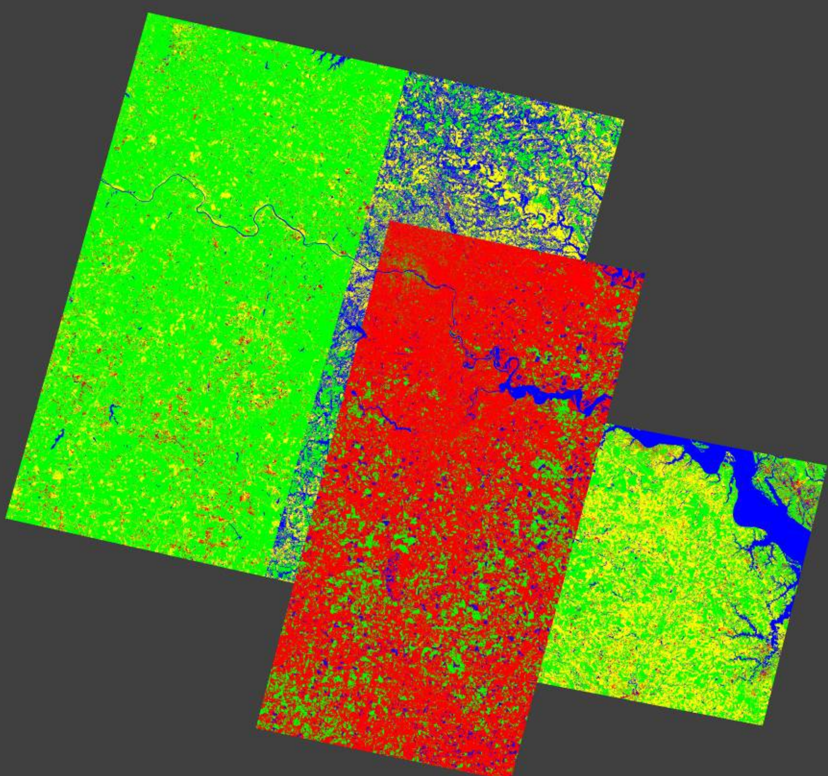


ASTER projected surface reflectance on 4/10/2006

# Supervised Classification Using Same Training Samples



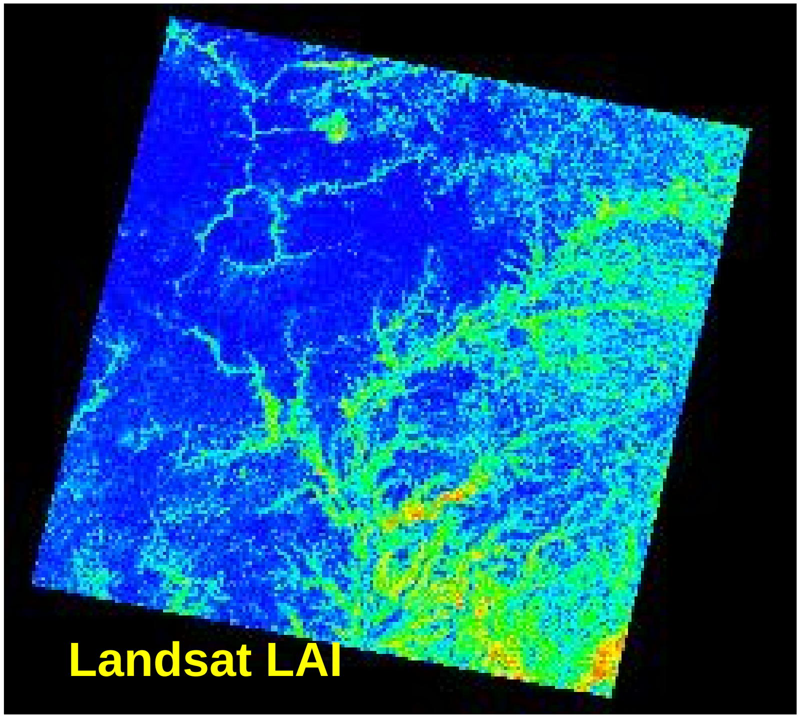
From adjusted ASTER SR

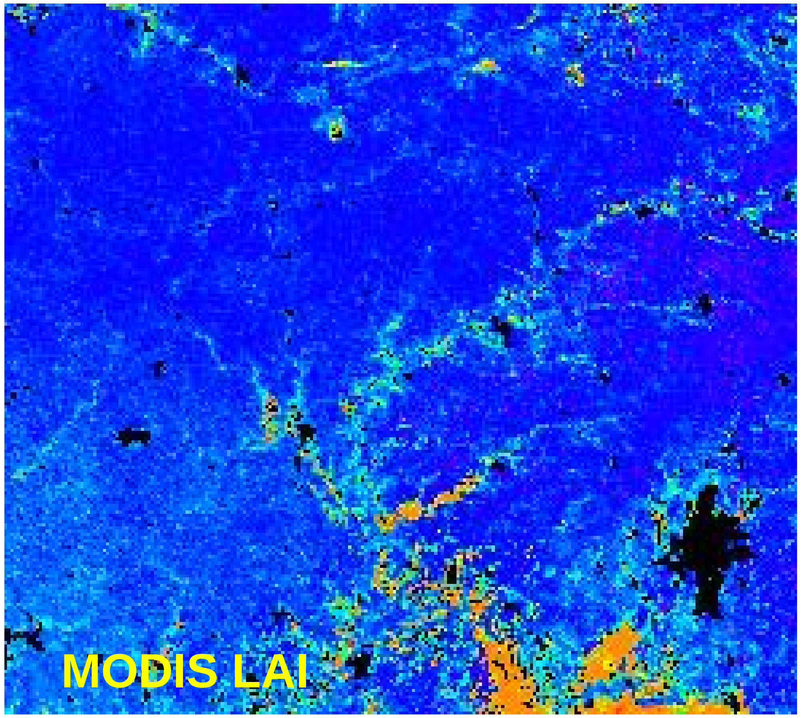


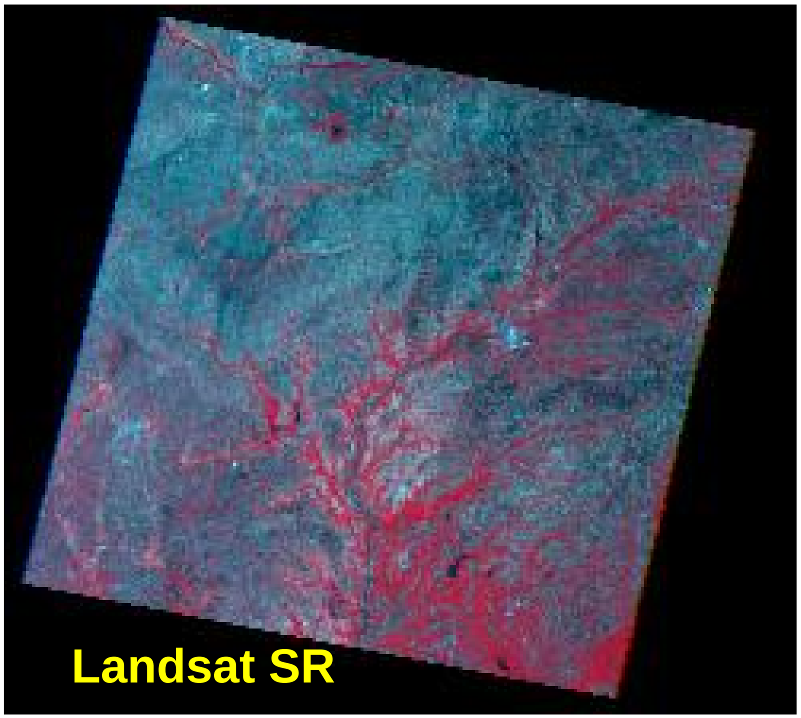
From Original ASTER DN

# Application III. Retrieve LAI

- Use MODIS LAI product as a reference
- Build nonlinear relationship between Landsat DN and MODIS LAI for each spectral cluster based on the homogeneous pixels (at MODIS spatial resolution)
- Apply cluster-based nonlinear relationship to original Landsat DN value for the specific cluster type and retrieve Landsat LAI (at Landsat spatial resolution)


Landsat LAI


MODIS LAI


Landsat SR


MODIS SR

# Summary and Future Plans

- Until now (August 2006 – July 2008)
  - Year 1 tasks (preprocessing): mostly done
  - Year 2 tasks (MSS): partially done
  - Year 3 tasks (STAR-FM): mostly done
- Documentation and coding
  - The automated registration and orthorectification package (AROP) has been submitted
  - The normalization approach on surface reflectance has been submitted and is now under revision
  - AROP code and STAR-FM code have been released
- Year 3 plan
  - Develop algorithm for MSS data processing (Year 2 tasks)
  - Needs more inter-comparisons and validations
  - Collaborate with users on algorithm improvement