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Developing Consistent Time Series Landsat Data Products

Feng Gao

Hydrology and Remote Sensing Laboratory
USDA ARS, Beltsville, MD 20705

with contributions from Jeff Masek, Yanmin Shuai, Conghe Song and Landsat Science Team Members

Consistent Requirements

- Location consistent

  - Data from different sensors and/or dates can be analyzed in pixel-by-pixel (sub-pixel accuracy)

- Radiometric consistent

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

- Product consistent

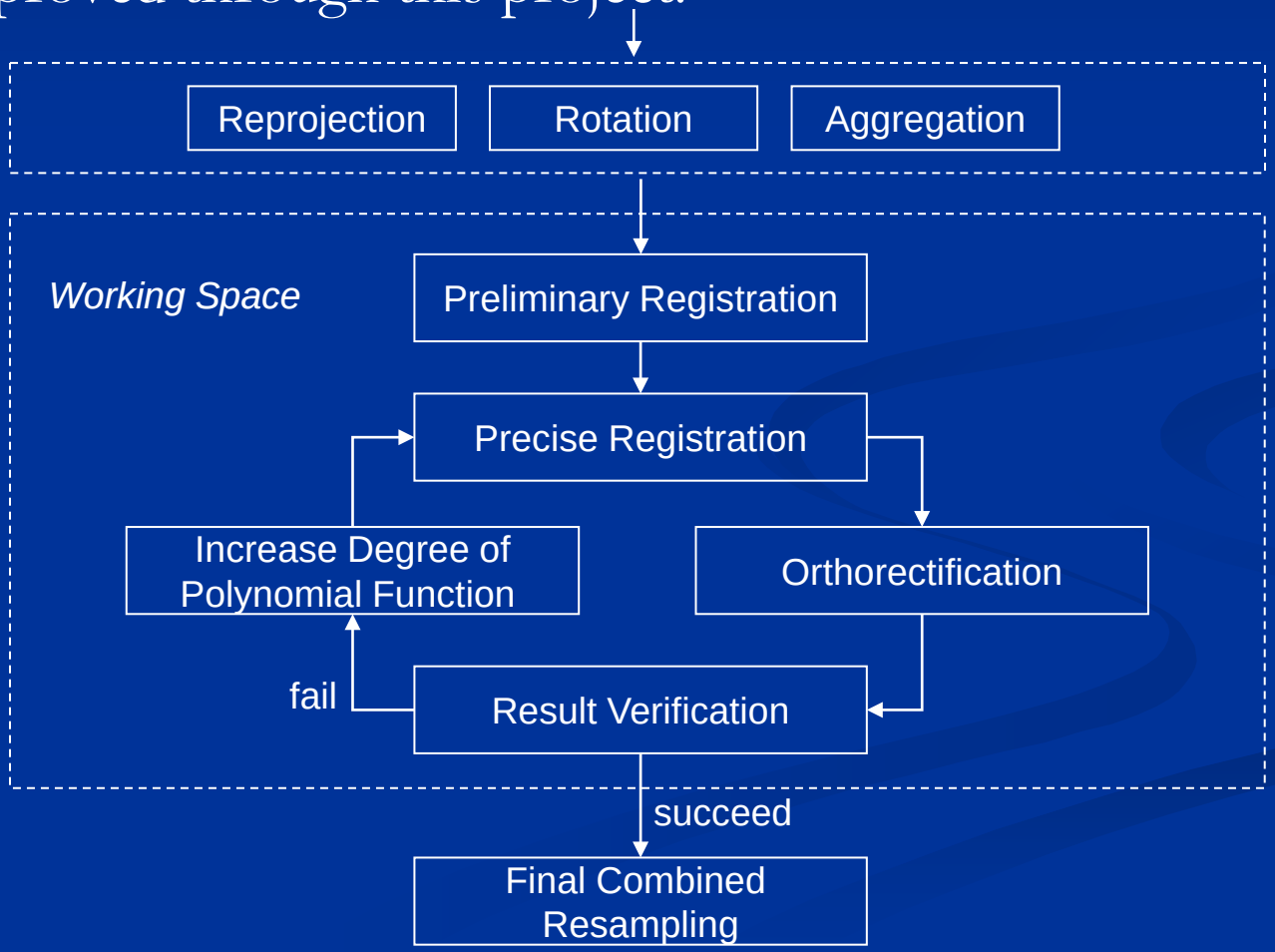
  - Data products are compatible among different sensors and should be agree with existing high quality data products

Examples from Landsat Science Team Project

1. Consistent Pixel Location
   - An automated approach for registration and orthorectification
2. Consistent and Dense Time Series Data
   - 2.1 Physical approach
   - 2.2 Normalization approach
   - 2.3 Data fusion approach for dense time series
3. Consistent High-level Data Products
   - 3.1 Albedo
   - 3.2 Leaf area index
   - 3.3 Impervious surfaces

1. Location Consistent – AROP

Automated Registration and Orthorectification Package (AROP) was initially developed in 2005 and has been continuously improved through this project.

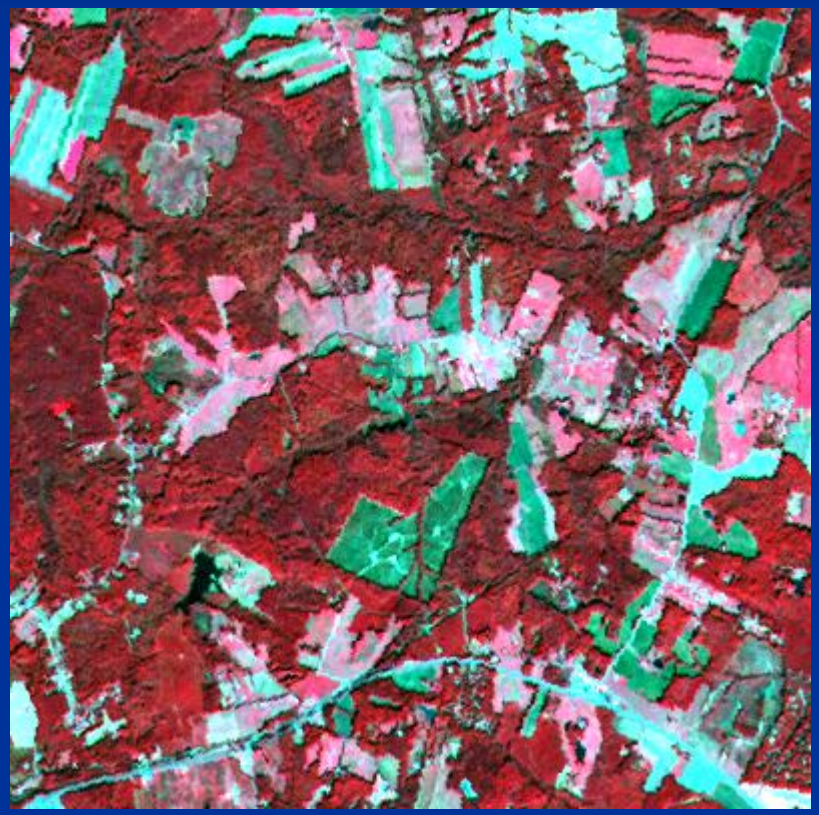


AROP Status

- Has been tested and applied for Landsat data (MSS, TM and ETM+), CBERS, ASTER, AWiFS and HJ-1
- Provides four options: 1) orthorectification; 2) precise registration; 3) combined registration and orthorectification; and 4) verification
- Accepts different projections and spatial resolution
- Combines resampling (projection, rotation, scaling, registration and orthorectification) in one transfer function
- Provides pyramid registration: preliminary registration using coarse resolution; precise registration using fine resolution
- Iterative results verification and processing
- Open C source code
- 20+ active users

Multiple and Single Resampling

Resampled 3 times

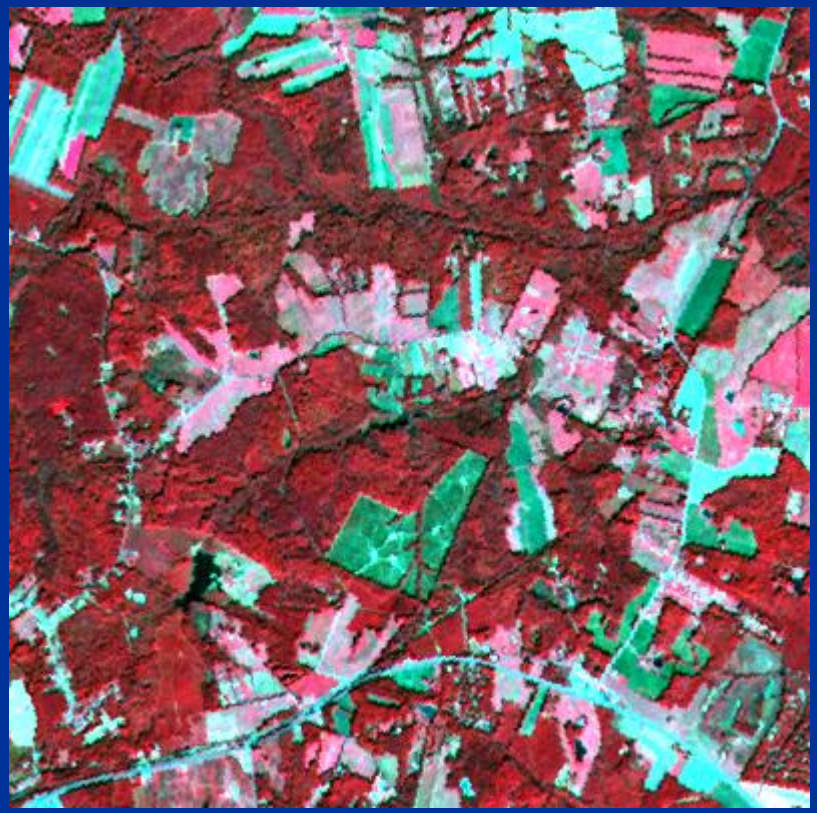


Warp Image
AST_L1B_00310232005160936_*_7406.hdf
October 23, 2005
VNIR Pointing Angle: 5.674
Map Orientation Angle: -9.049154
UTM Zone: 17 N

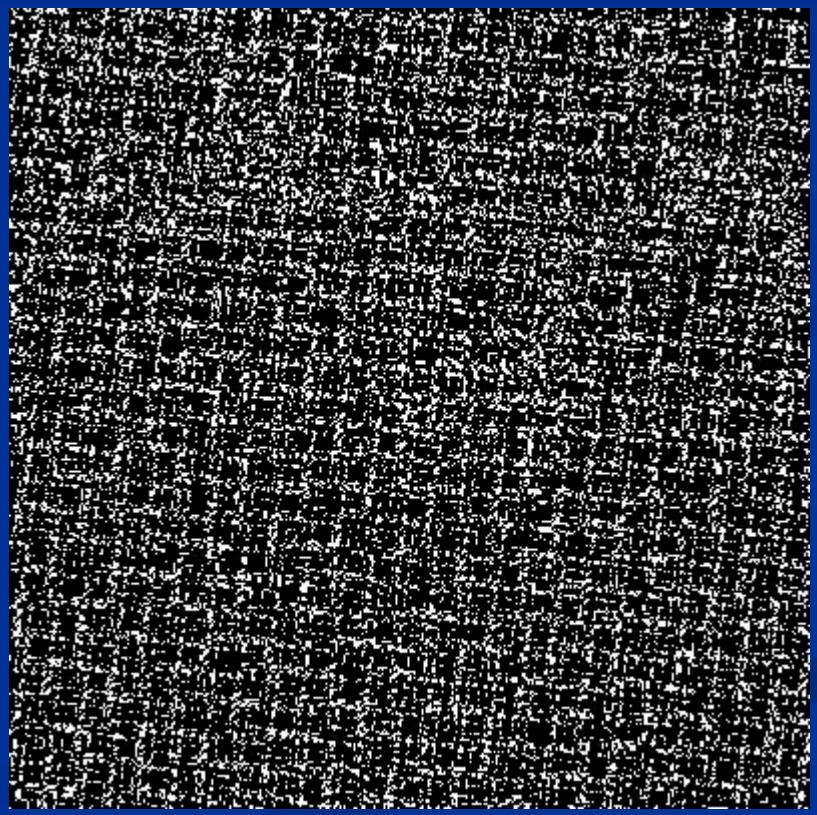
Base Image
GeoCover ETM+
September 30, 1999
UTM Zone: 18 N

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

Combined resampling



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



Minimize resampling procedures!

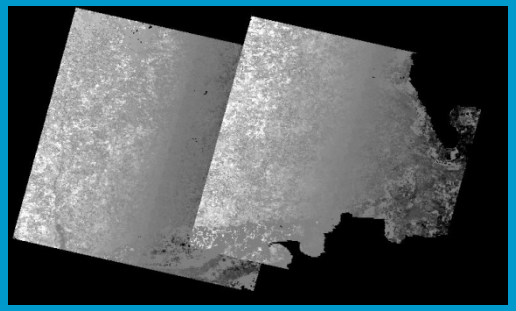
2. Radiometric Consistent

2.1 Physical approach

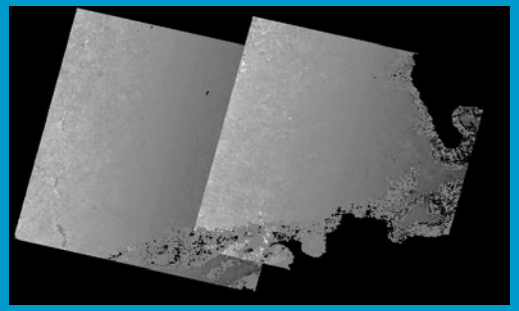
- Ledaps standalone version
  - Tested on TM and ETM+
  - 12 version releases
  - about 100 users

- BRDF effects
  - View angle effect (within-scene)
  - Day of year effect (season/location)
  - Mean local time drift effect

Relative Difference of Reflectance Comparing to Nadir View



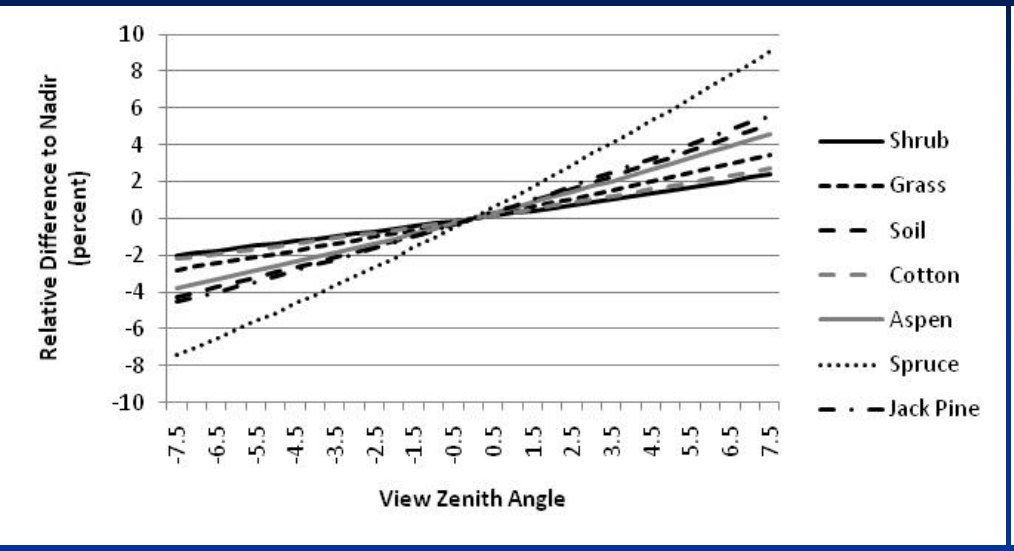
Red band

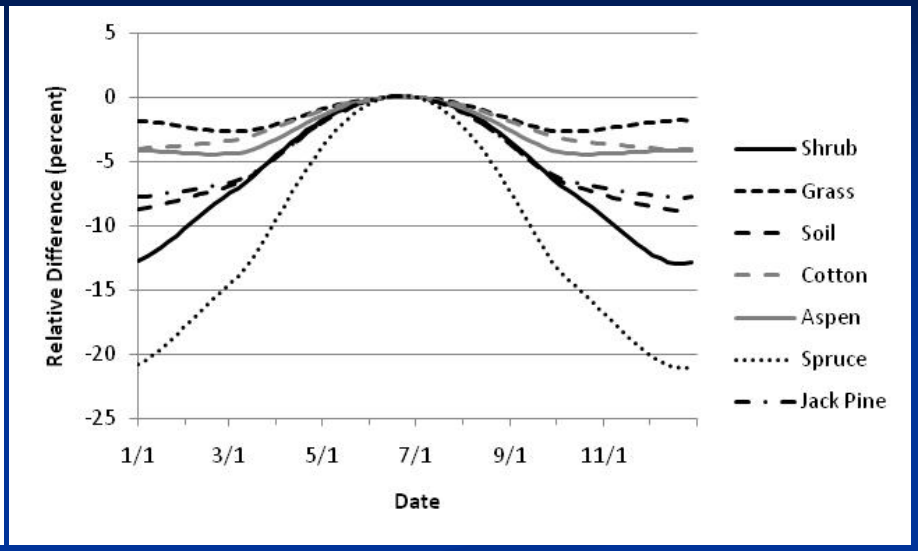


NIR band

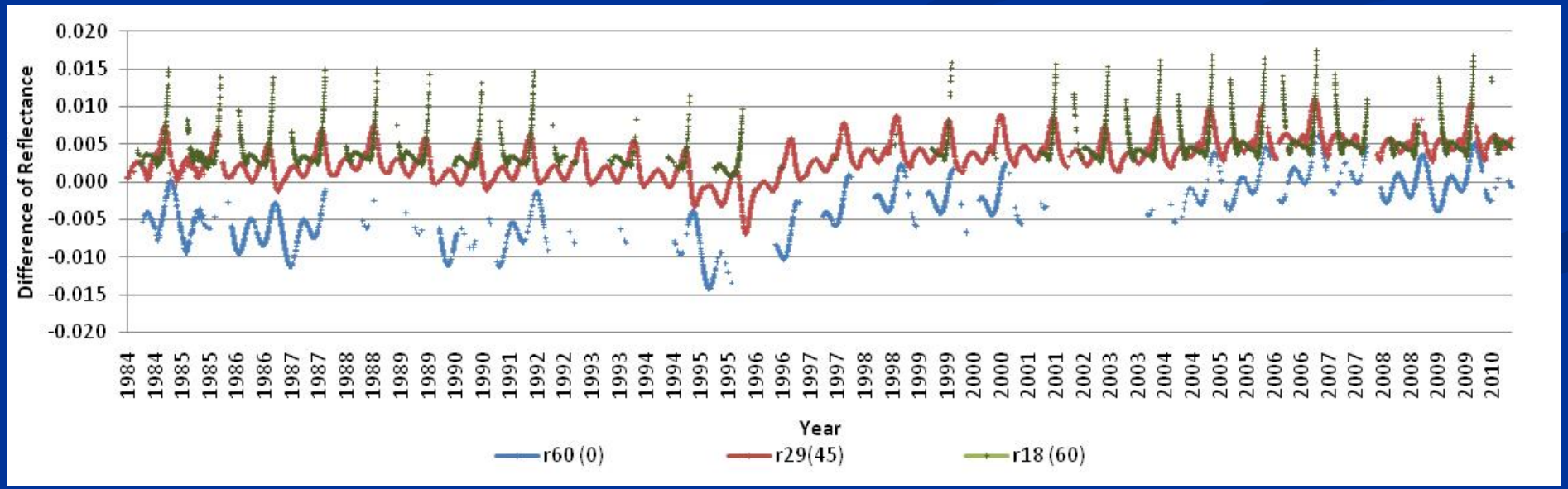
-10 0 10

Three Types of Angular Effect





(NIR band)



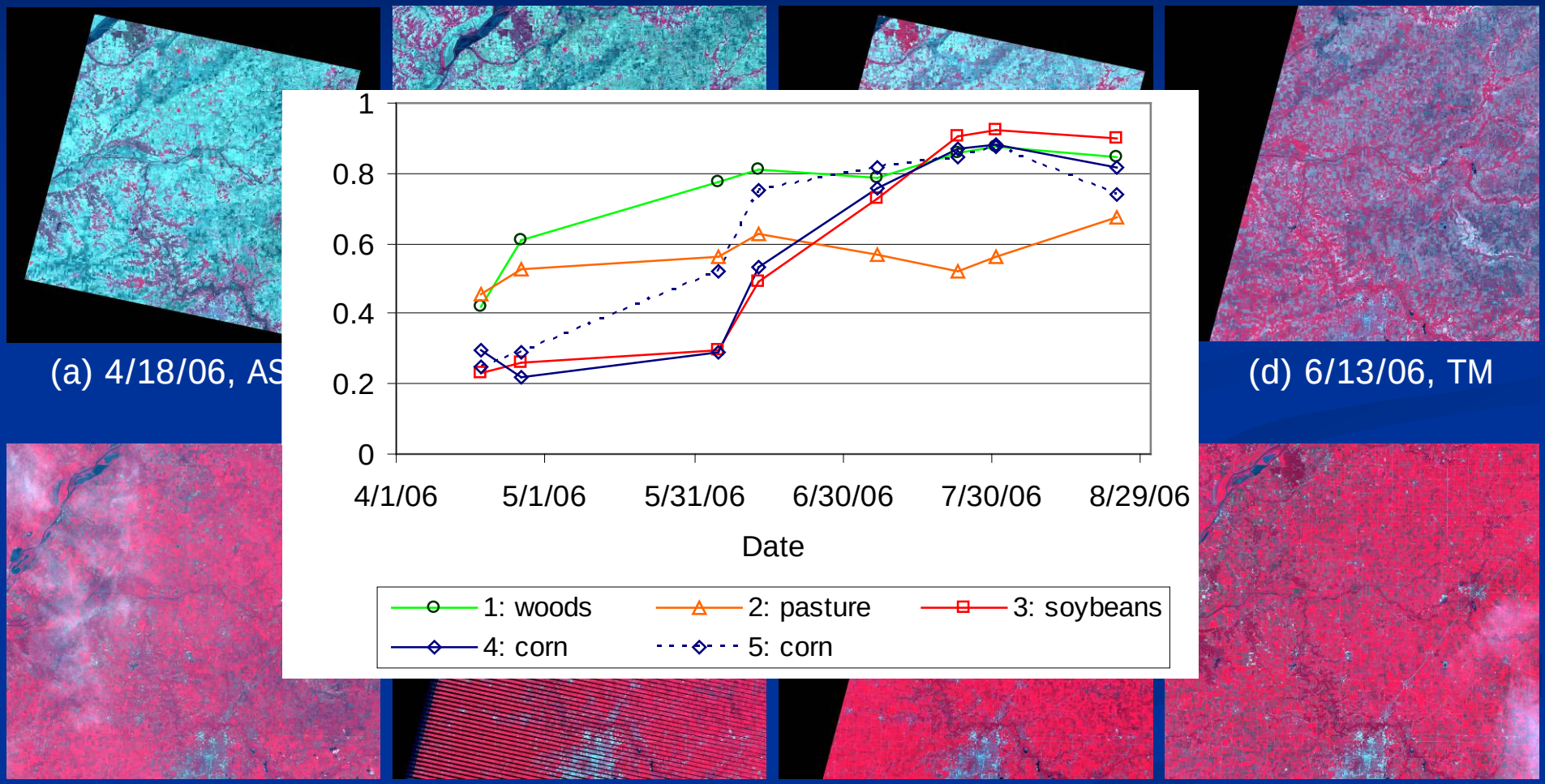
Landsat BRDF Effects Summary

- The view angle effect are normally in the range of +-6% for red and +-5% for NIR band relatively. The averaged angular effects at the edge of a Landsat scene are about +-5% for red and +-3% for NIR relatively.
- The day of year effect are less than 13% for both red and NIR bands relatively except spruce comparing to the reflectance from the middle day of year
- The overall angular effect caused by Landsat-5 drift from 1984 to 2010 are about 5.8% for red and 5.5% for NIR band with the exception of spruce.
- BRDF correction for Landsat data may be needed for time-series analysis esp. when Landsat data are acquired from the different day of the year.
- BRDF effects need to be examined for a large area application.

2.2 Normalization Approach

- Combine observations from multiple Landsat and Landsat-like data in a consistent way for time series analysis
- Normalize the scene differences (seasonal pheonology variation) for large area applications

Combining Data from Multiple Sensors for Vegetation Monitoring



(a) 4/18/06, AS

(d) 6/13/06, TM

(e) 7/7/06, AWiFS

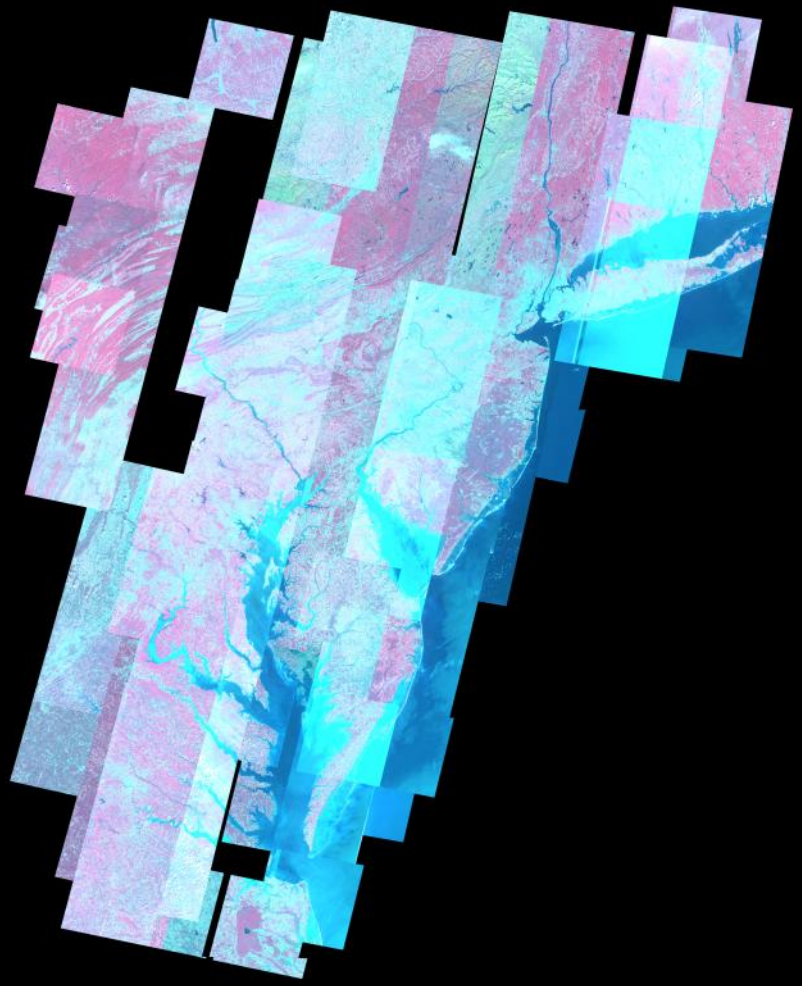
(f) 7/23/06, ETM+

(g) 7/31/06, TM

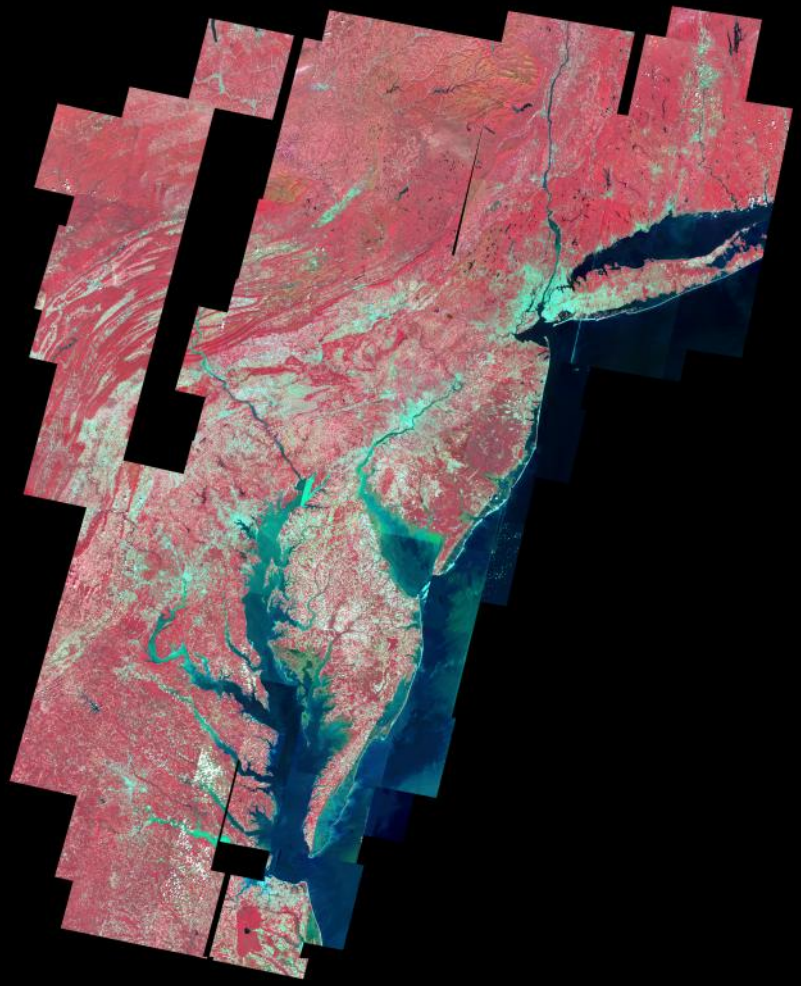
(h) 8/24/06, AWiFS

Combining Scenes from Different Dates

- Chesapeake Bay ASTER Example

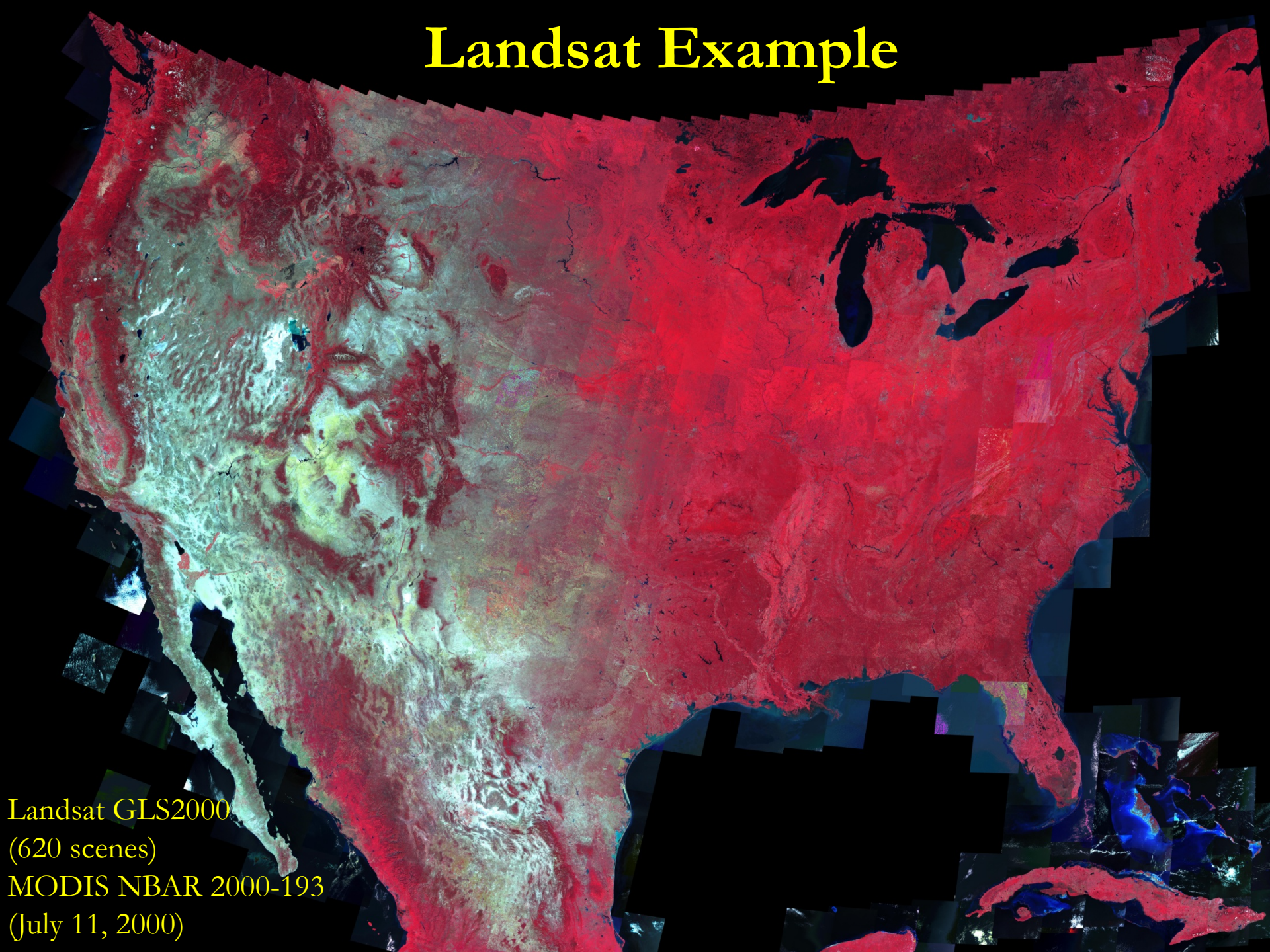


ASTER TOA mosaic (195 scenes)
~2004

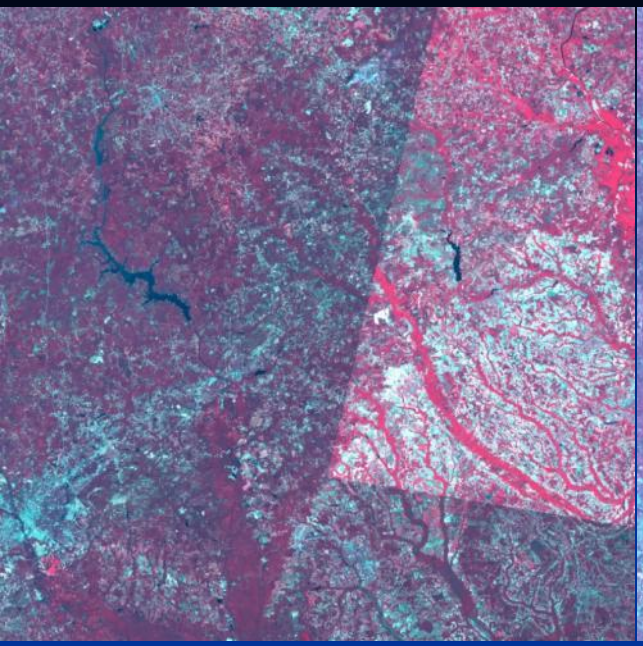


Normalized ASTER SR mosaic (195 scenes)
Used MODIS NBAR data on 2004-265
(September 21, 2004)

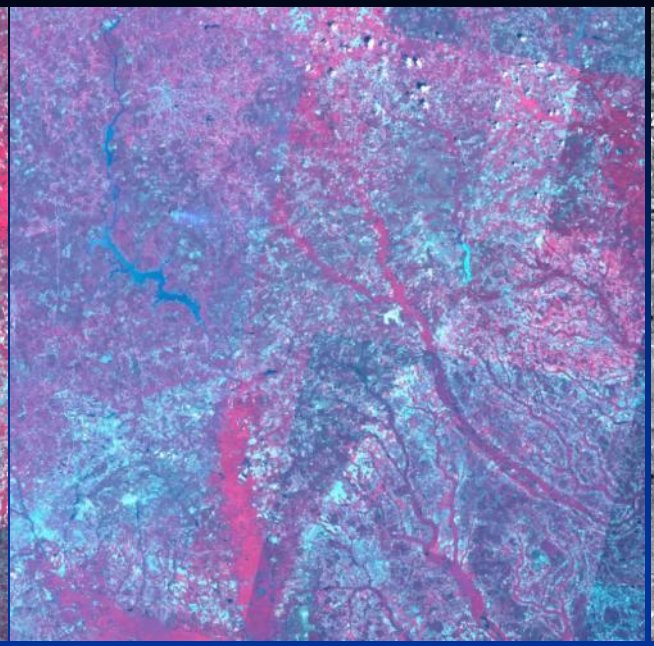
Landsat Example



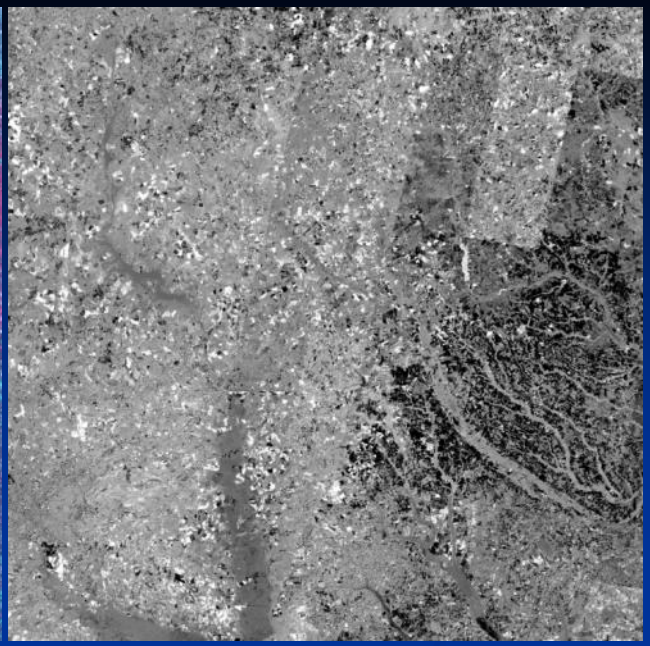
Landsat GLS2000
(620 scenes)
MODIS NBAR 2000-193
(July 11, 2000)



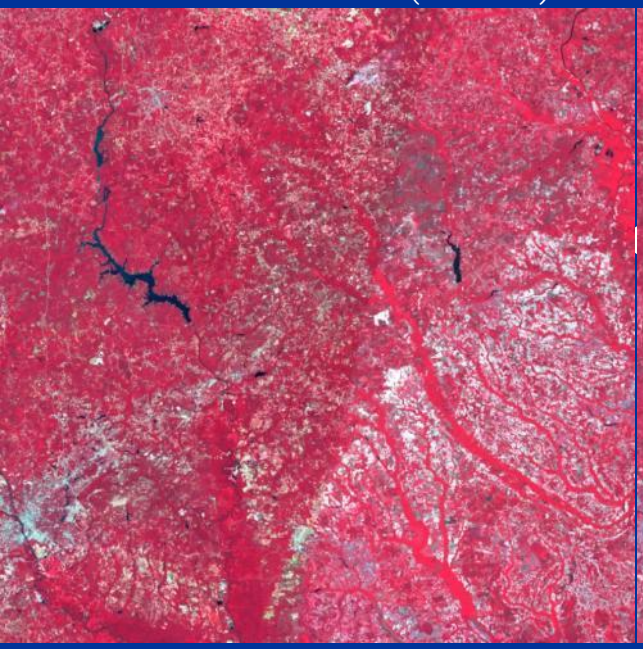
Landsat SR (~2000)



ASTER TOA (~2005)

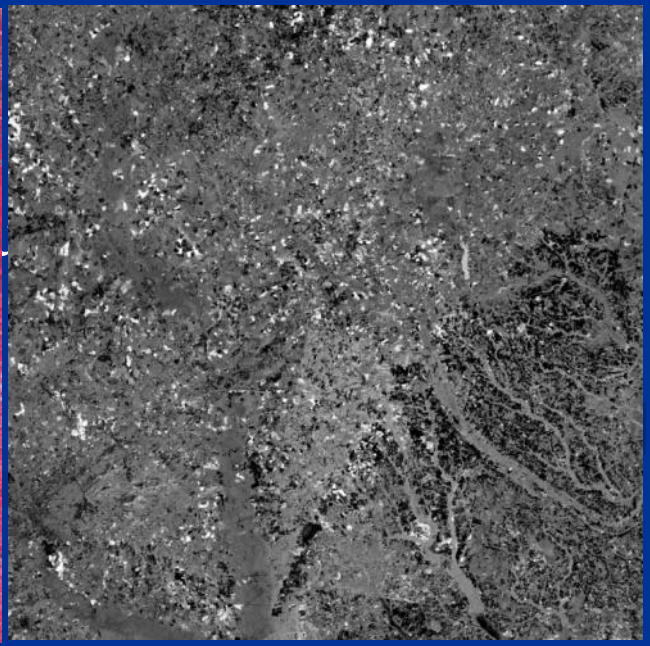


ΔDI



Normalized Landsat (2000-193)

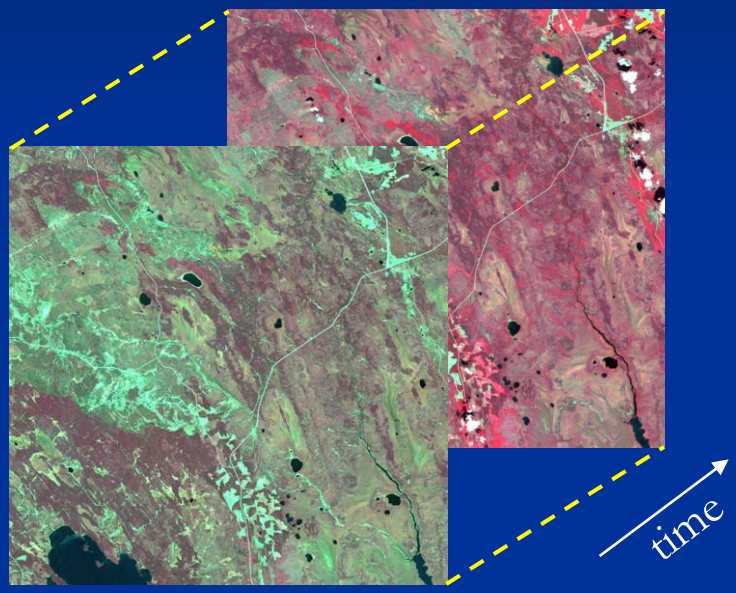
Normalized ASTER (2005-193)



ΔDI from Norm. Data

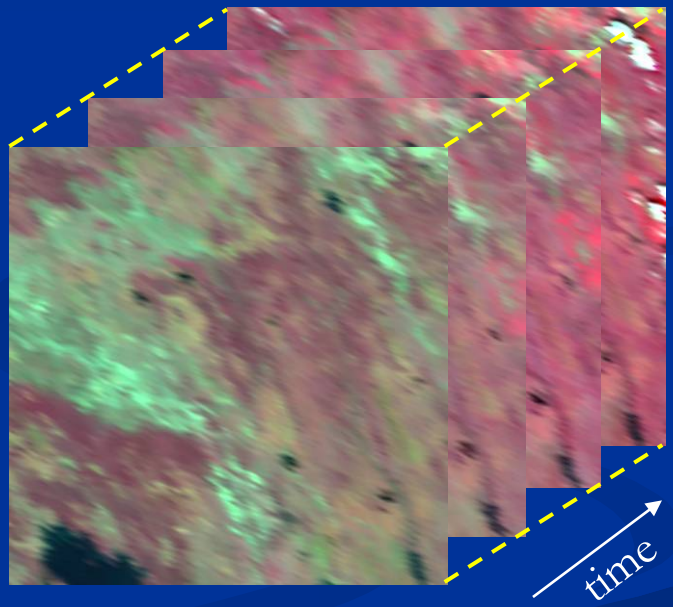
2.3 Landsat Dense Time Series form Data Fusion Approach

Landsat



- Landsat
  - 30m spatial resolution
  - 16-day revisit cycle

MODIS



- MODIS
  - one or two revisit per day
  - 250m & 500m spatial resolution

Objective - combine the spatial resolution of Landsat with the temporal frequency of coarse-resolution MODIS.

StarFM Status

- standalone C version
- open source in Linux system
- available from the LEDAPS website
- 10+ users
- 20+ citations in refereed journals since 2008
- Model improvements are still ongoing
  - STARRCH (Hilker and Wulder etc., RSE 2009)
  - ESTARFM (Zhu and Chen etc., RSE 2010)
  - More coming …

StarFM Application Examples

- Forest monitoring and disturbance mapping, 2009a, 2009b, 2010, RSE

  (T. Hilker, M. Wulder etc., Canadian Forest Service)

- Improving wildland fire severity mapping , 2009

  (F. Gao-ERT, J. Morisette-USGS, R. Wolfe-NASA)

- "A data-model fusion approach for upscaling gross ecosystem productivity to the landscape scale based on remote sensing and flux footprint modeling," 2010, Biogeosciences

  (B. Chen etc., Chinese Academy of Sciences)

StarFM Application Examples (cont.)

- "Improved classification of conservation tillage adoption using high temporal and synthetic satellite imagery," 2011, RSE
  (Jennifer Watts etc., University of Montana)

- "Mapping daily evapotranspiration at field to global scales using geostationary and polar orbiting satellite imagery, " 2010, HESSD
  (Martha Anderson etc., USDA ARS)

- "An evaluation of data fusion products for the analysis of dryland forest phenology," 2011, RSE, in review.
  (Walker, J.J., etc., Virginia Tech.)

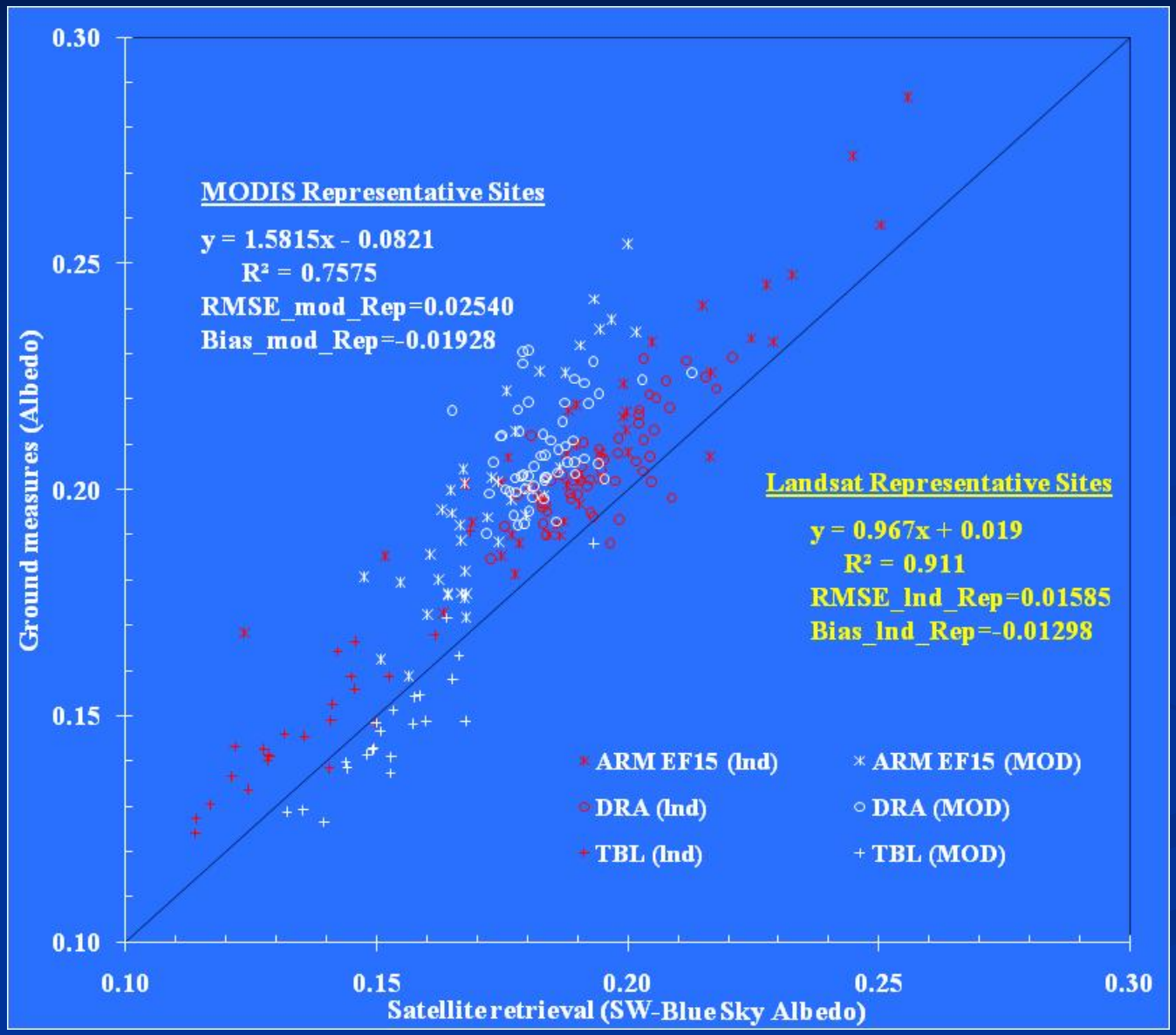
- Crop type classification and condition monitoring
  (onging work with USDA NASS)

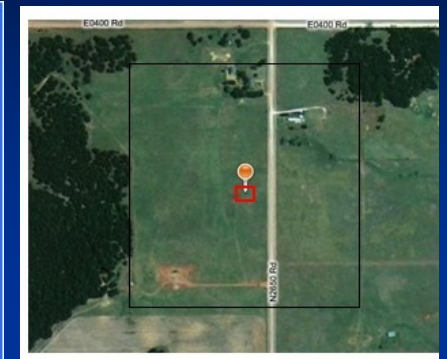
3. Consistent High-level Data Products

3. 1 Albedo

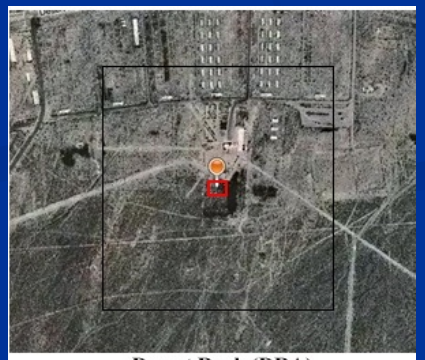
- Extract MODIS BRDF parameters from "pure" homogeneous pixels
-Apply magnitude inversion approach to Landsat surface reflectance
-Initial validation shows better quality on heterogeneous areas
-NASA Terra project (PI: Jeff Masek) looks at albedo changes at Landsat spatial scale due to forest disturbances

Validation on Homogeneous Sites





ARM Extended Facility #15 (EF15)



Desert Rock (DRA)

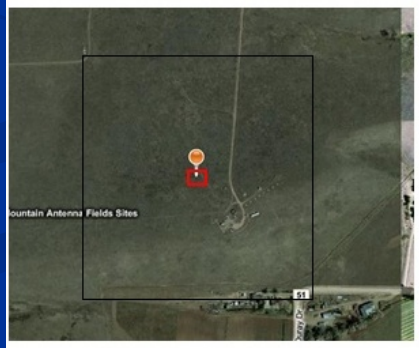
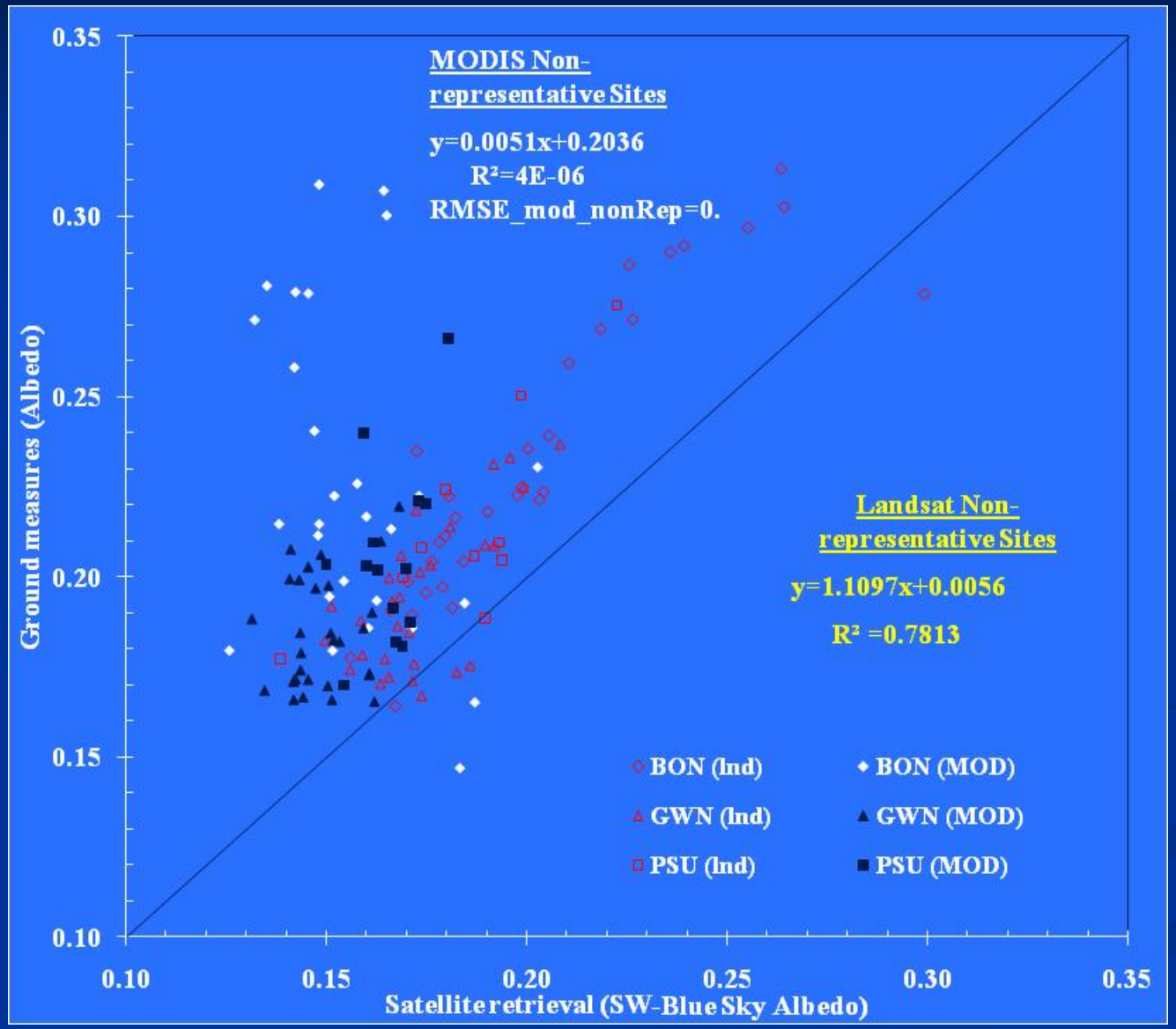
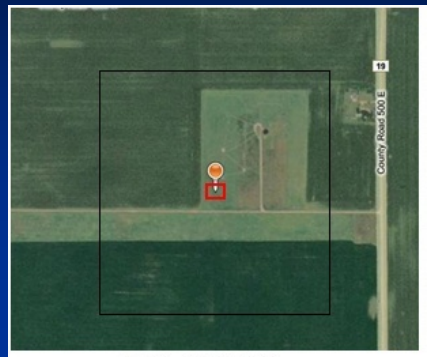


Table Mountain (TBL)

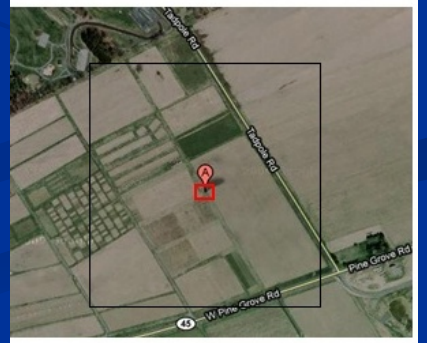
Validation on Heterogeneous Sites





Bondville (BON)

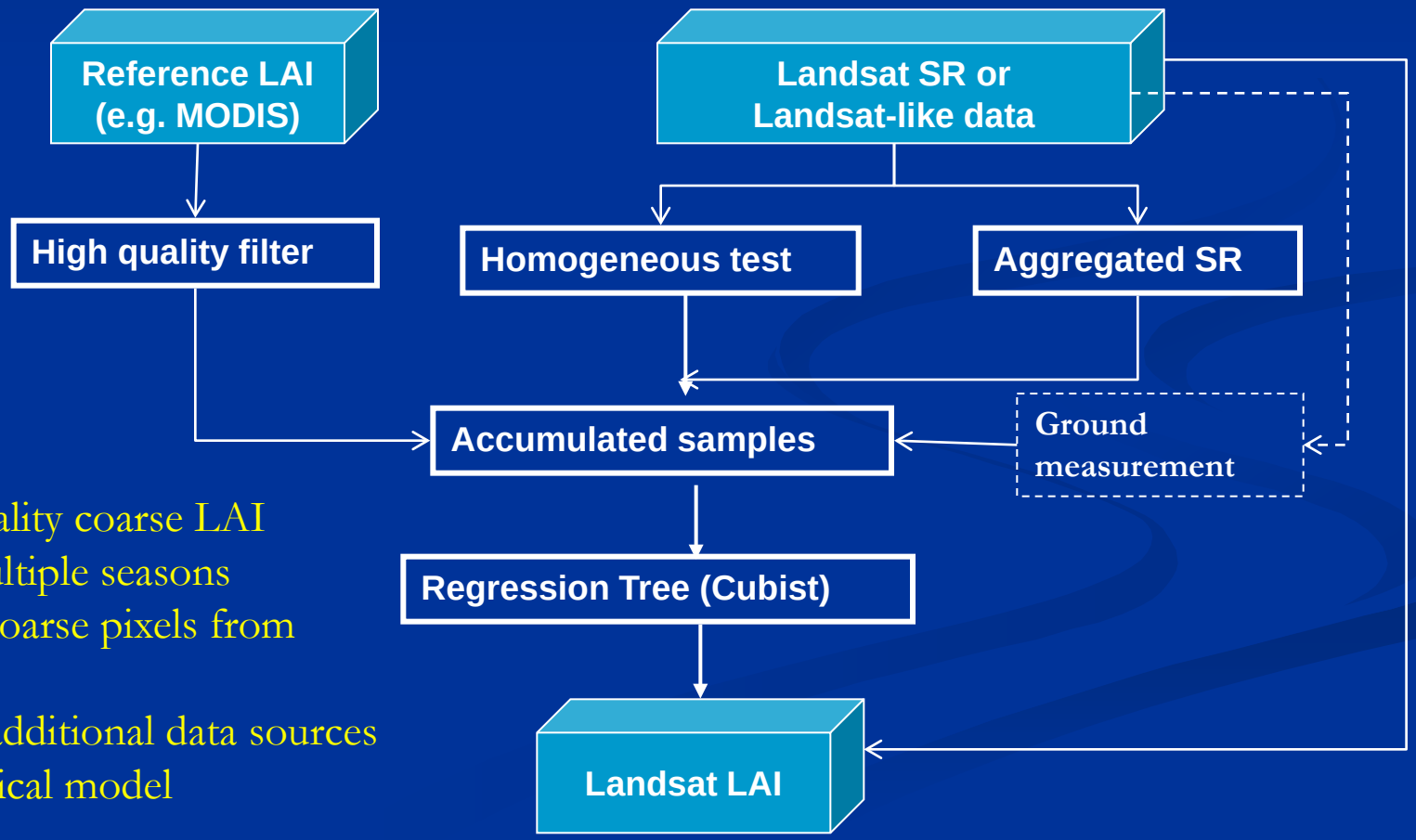
Goodwin Creek (GWN)



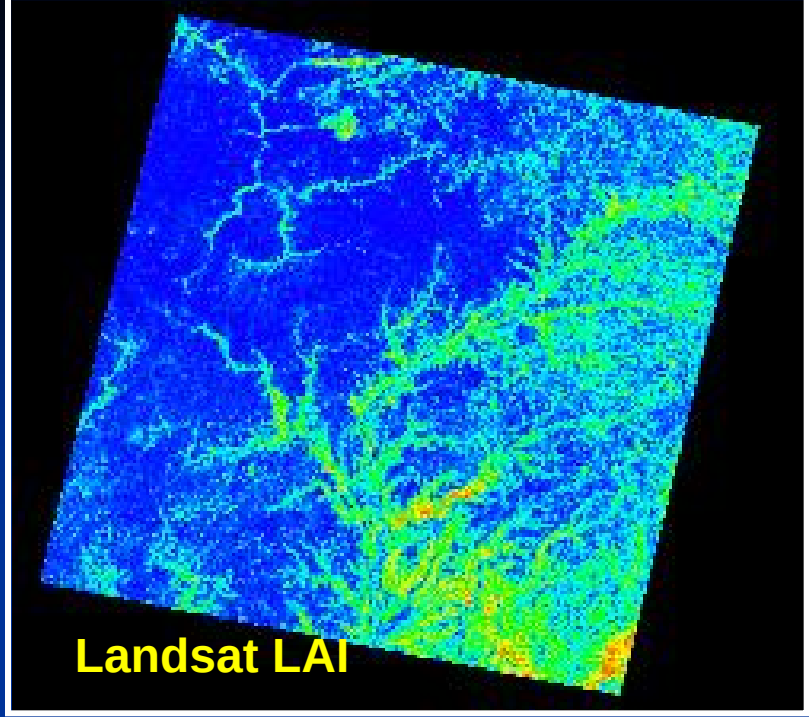
Penn State University (PSU)

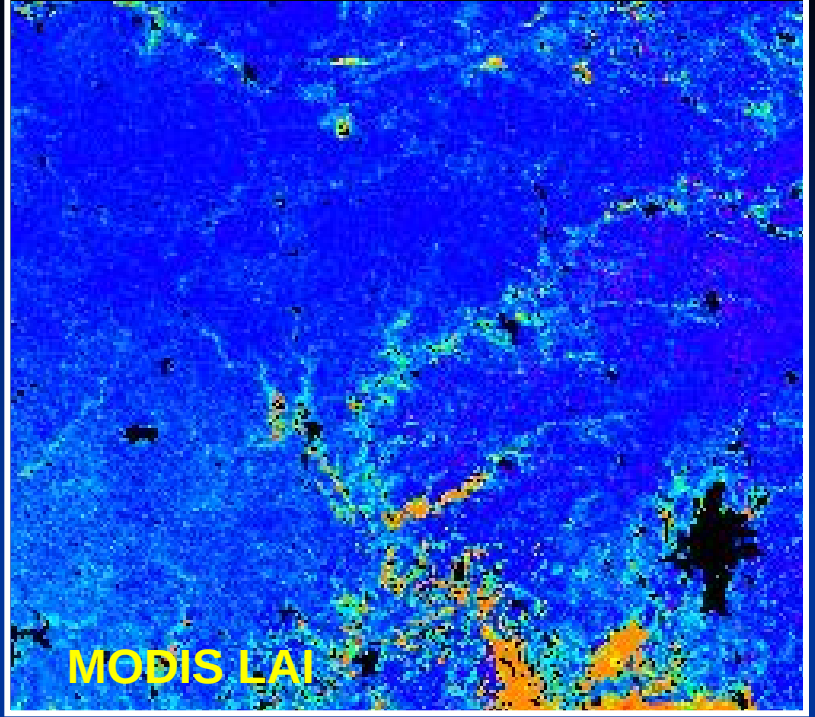
3.2 Leaf Area Index

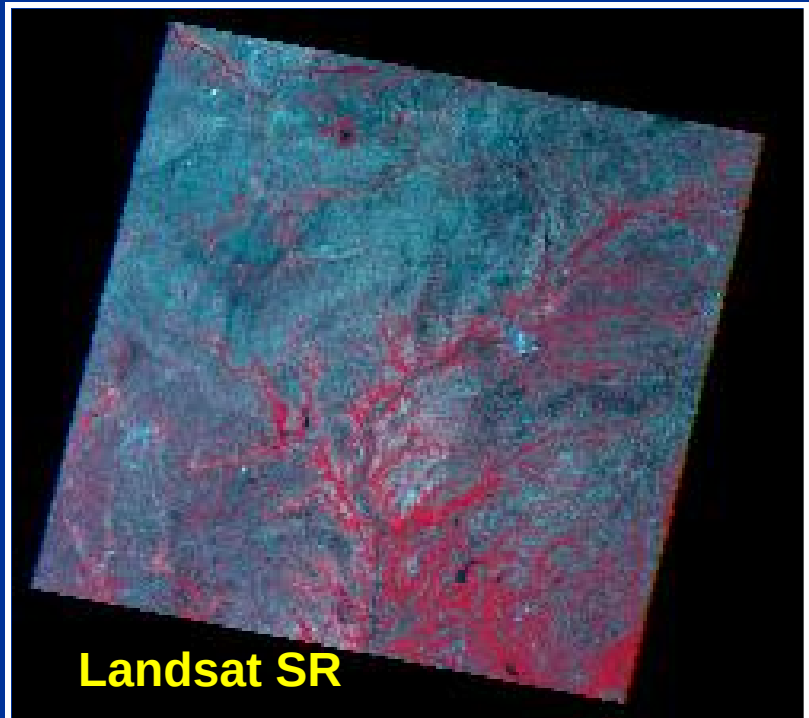
An empirical approach was tested that uses same period high quality coarse resolution LAI data and ground measurements to calculate LAI at Landsat spatial resolution



- High quality coarse LAI from multiple seasons
- "pure" coarse pixels from Landsat
- Accept additional data sources in empirical model

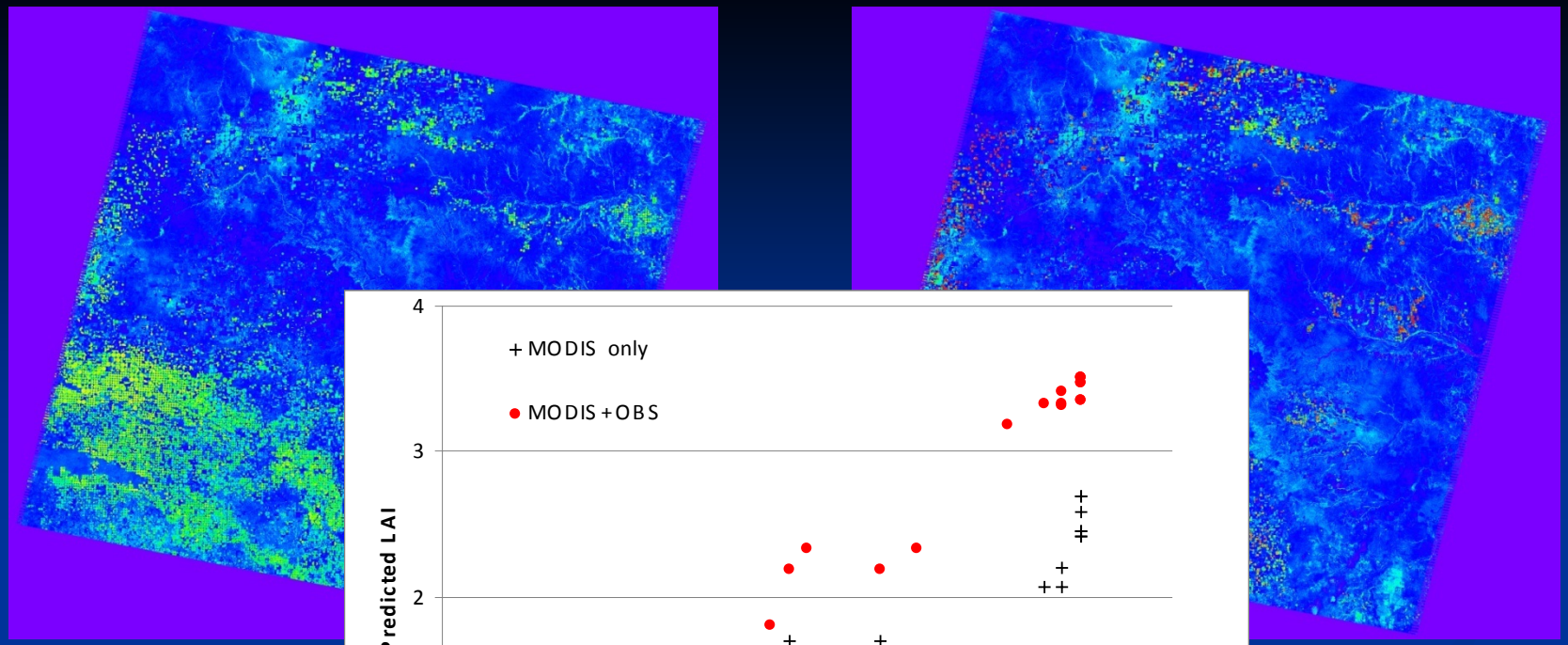

Landsat LAI


MODIS LAI


Landsat SR

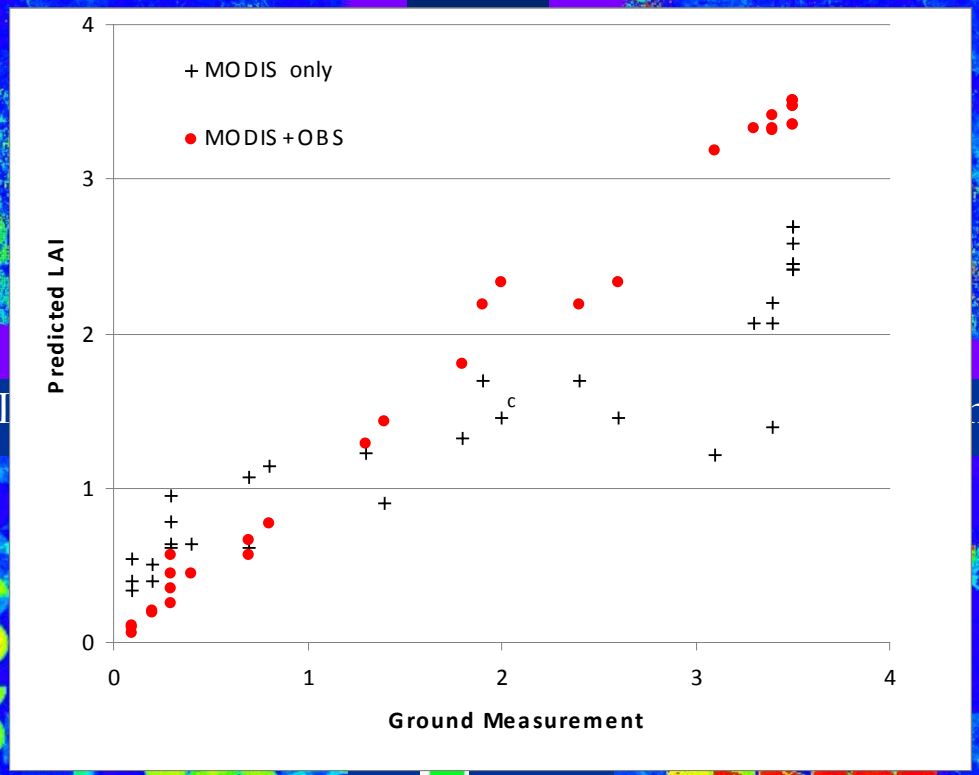
MODIS SR

185 km

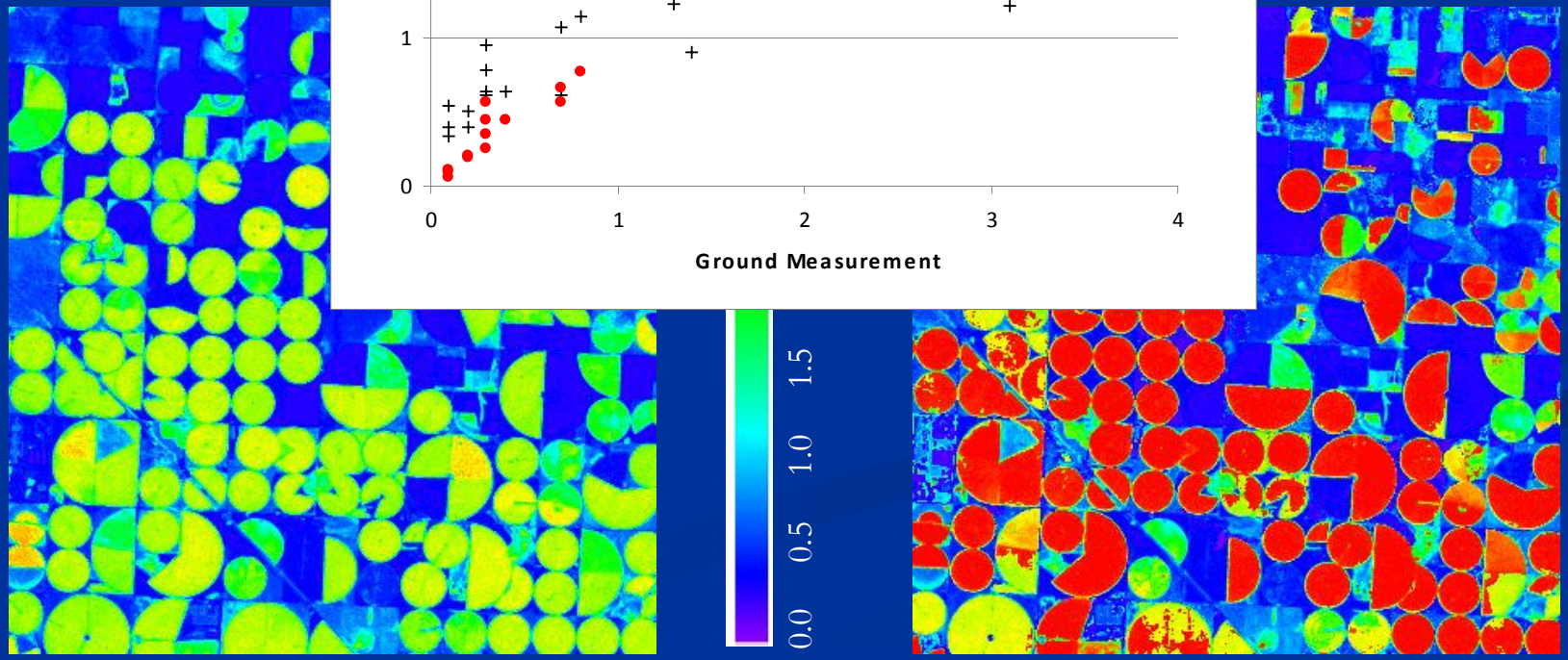


MODIS I

nts improve LAI



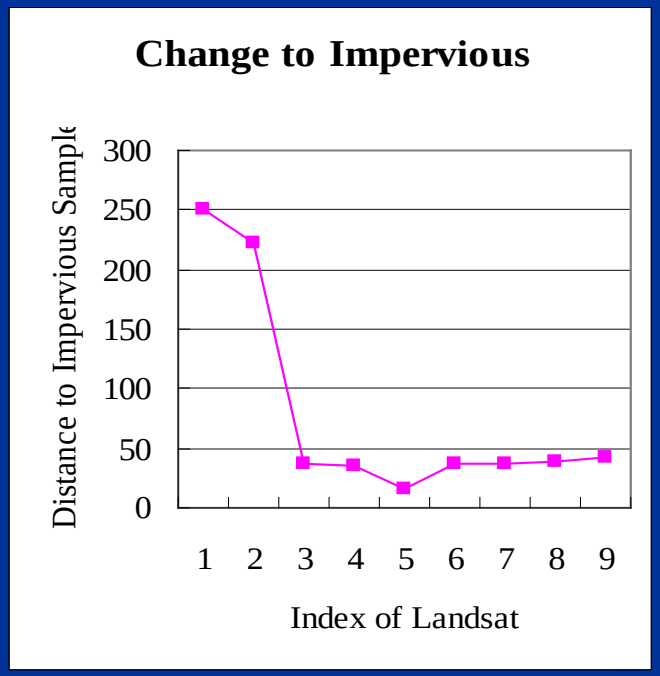
12 km

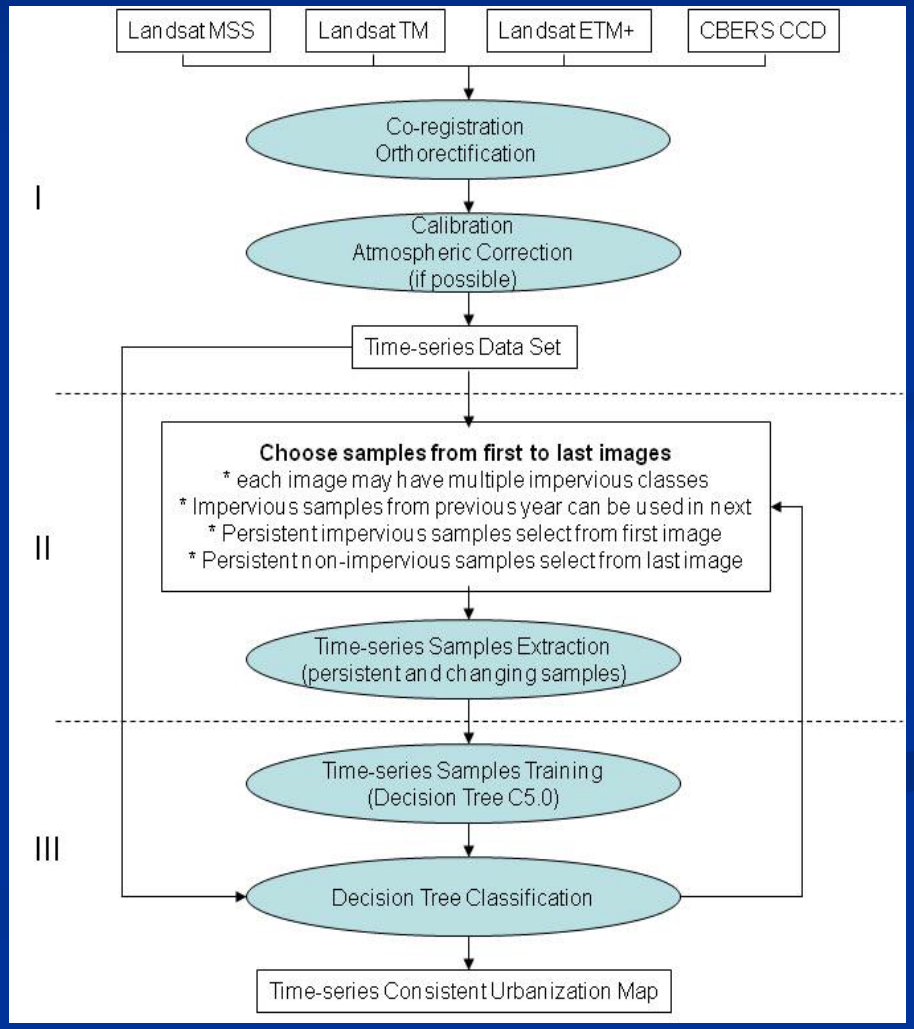


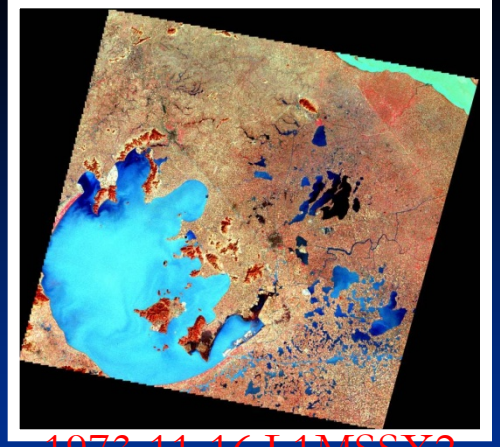
3.3 Impervious Surface

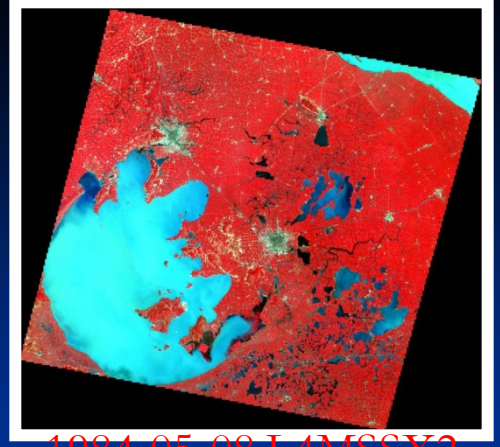
An effective approach was developed to detect impervious surfaces expansion

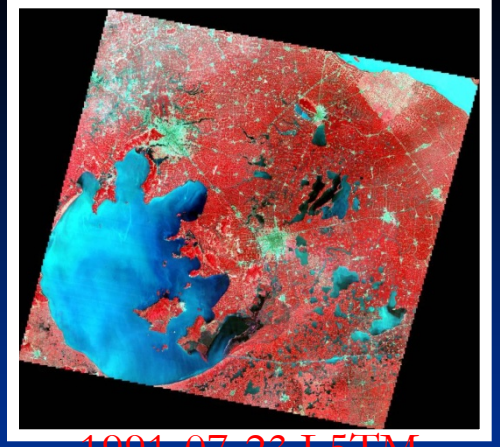
- use image stack as an integrative whole
- noise filter (accept low quality images)
- accept images in different forms (DN, TOA or surface reflectance)
- change results are consistent

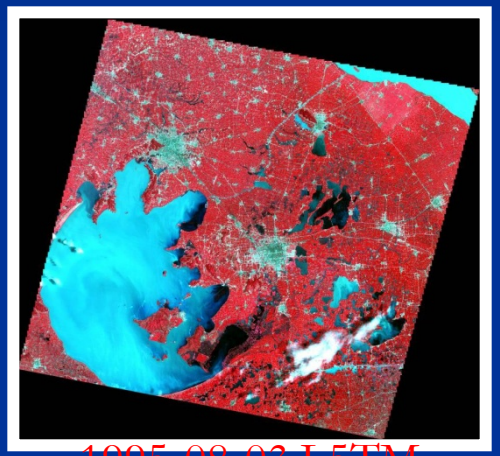


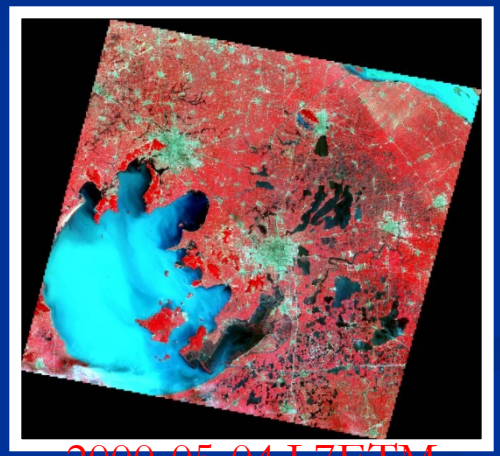


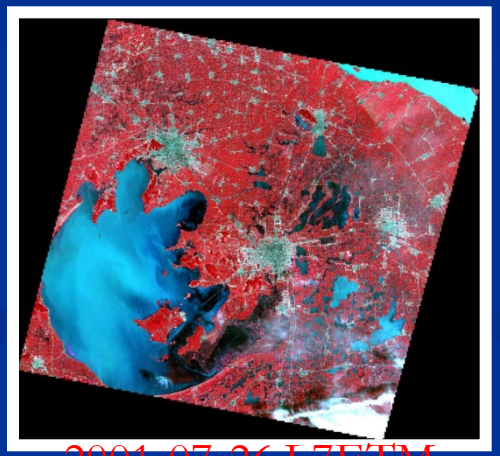

1973-11-16.L1MSSX2

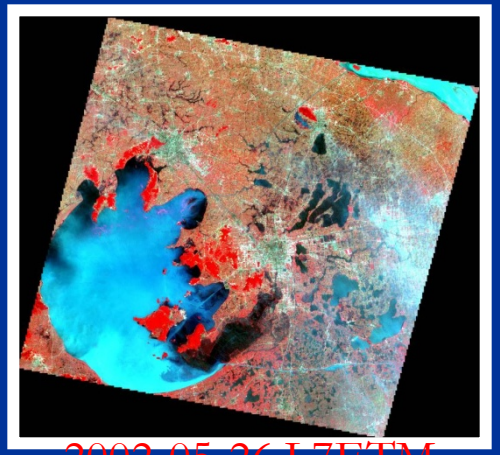

1984-05-08.L4MSSX2

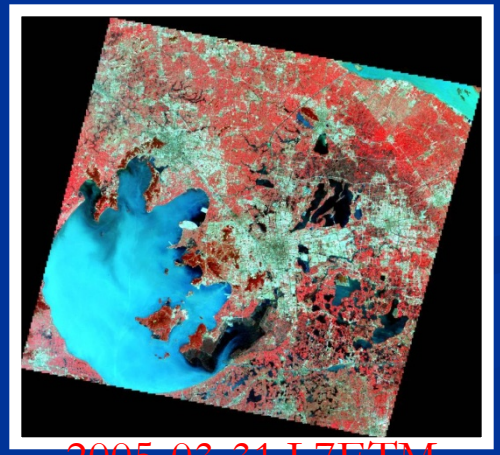

1991-07-23.L5TM

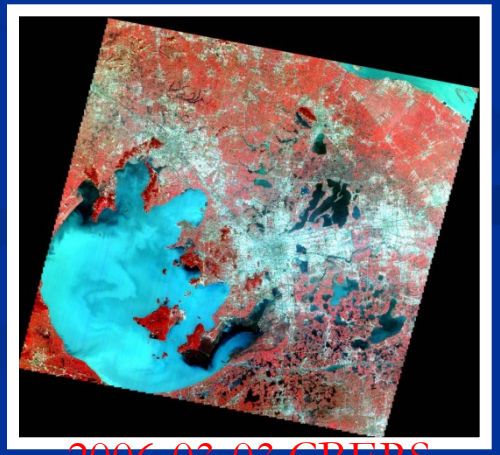

1995-08-03.L5TM

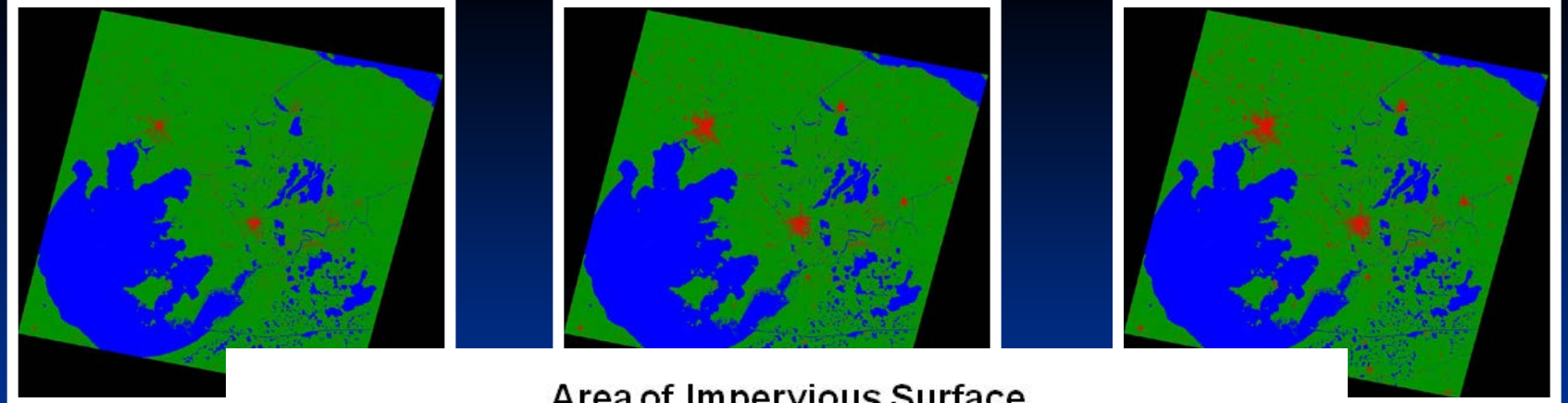

2000-05-04.L7ETM


2001-07-26.L7ETM

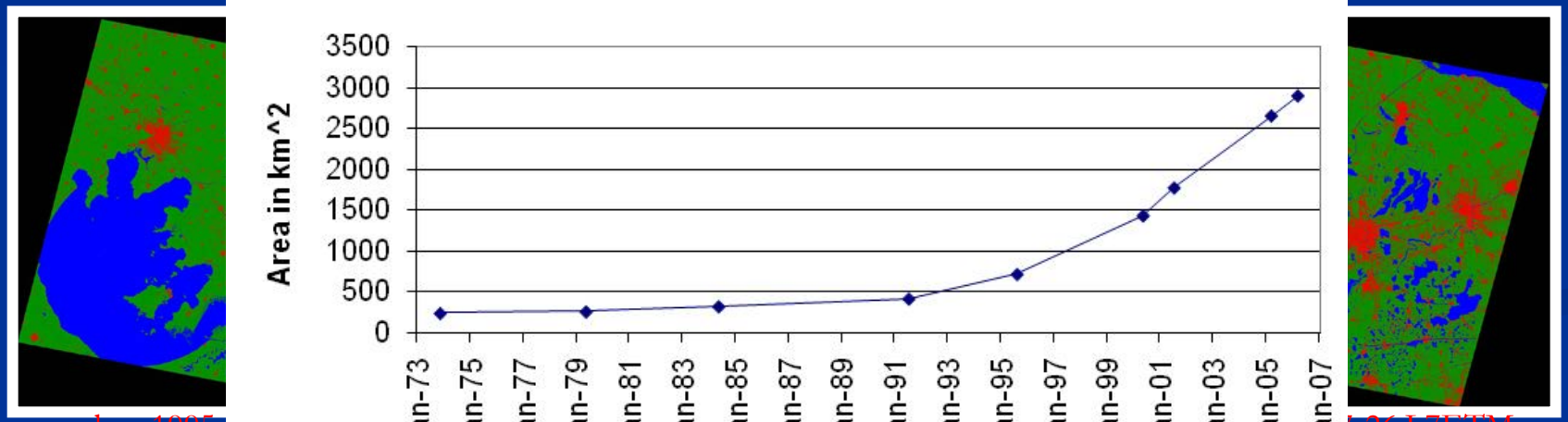

2002-05-26.L7ETM


2005-03-31.L7ETM

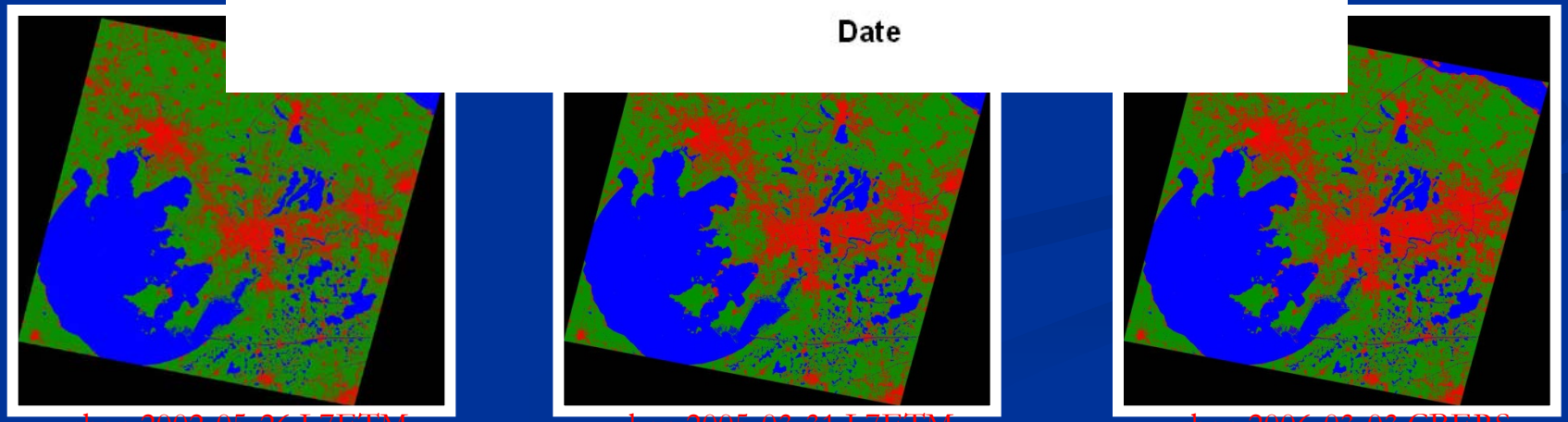

2006-03-03.CBERS



urban.1973- 7-23.L5TM



urban.1995- -26.L7ETM



urban.2002-05-26.L7ETM urban.2005-03-31.L7ETM urban.2006-03-03.CBERS

Summary

In 2006, we proposed to study in four aspects

- International Landsat-like data
- MSS data
- Landsat fused/simulated data
- Land cover change detection using multiple sensor data

Now,

- AROP package has been used for orthorectification and registration process on Landsat (MSS, TM and ETM+), ASTER, AWiFS, CBERS and HY-1
- STARFM approach has been extended and applied to build/simulate dense Landsat time series for various applications
- Normalization approach has been used to combine multiple sensor data for change detection and phenology detection
- A consistent impervious extension mapping approach has been tested and applied to Landsat MSS, TM, ETM+ and CBERS data
- An empirical reference-based approach has been tested to generate compatible Landsat data products from MODIS data products