LEDAPS

Landsat Ecosystem Disturbance Adaptive Processing System

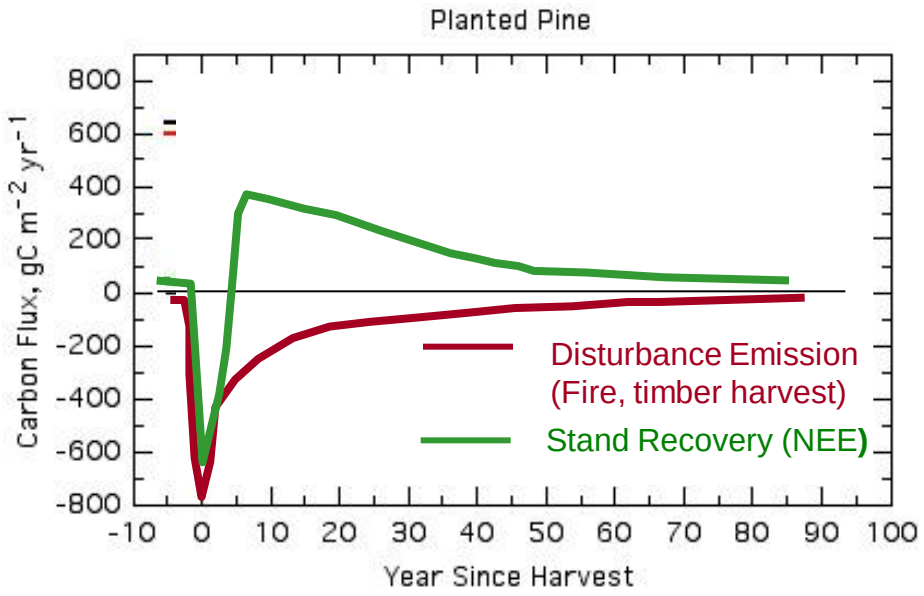
A North-American Forest Disturbance Record from Landsat Imagery

Jeffrey Masek, NASA GSFC
Forrest G. Hall, GSFC & UMBC
Robert Wolfe, GSFC & Raytheon
Warren Cohen, USFS Corvallis
Eric Vermote, GSFC & UMCP
Nazmi Saleous, NASA GSFC

Why Map Disturbance with Landsat?

7km

1985 1988 1999

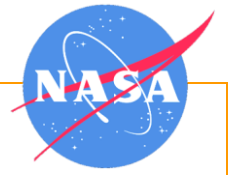


- Disturbances (fire, harvest, insect damage) emit C to atmosphere

- Recovery governs forest age structure and hence net ecosystem exchange (NEE) with atmosphere

- Patch size of many disturbances is small (<100 Ha)

LEDAPS Goals



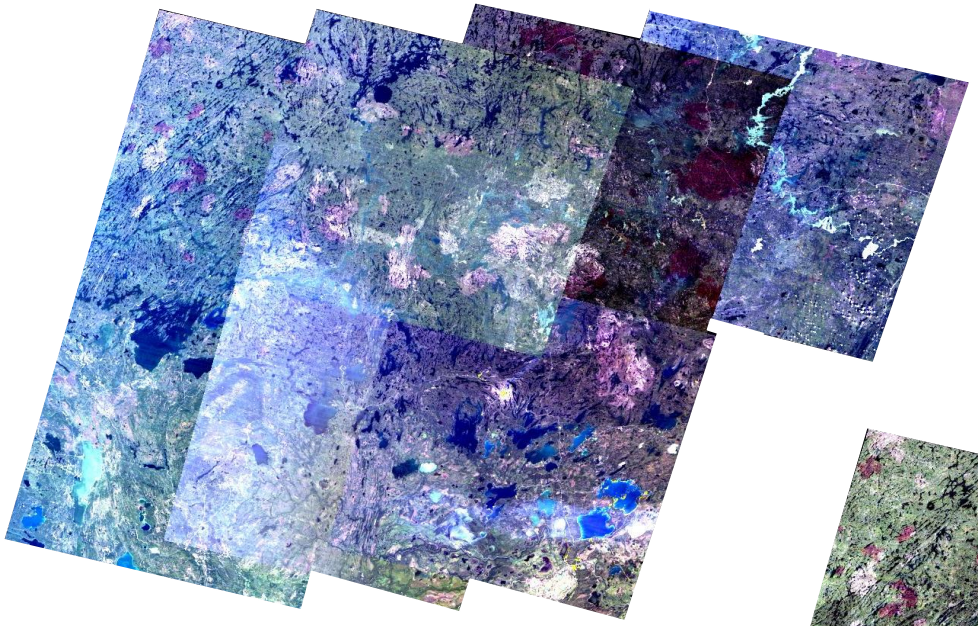
- Generate decadal surface reflectance (SR) product for North America from Landsat GeoCover archive (1975-2000)
  - *apply lessons from MODIS processing*

- Generate **decadal, wall-to-wall** maps of forest disturbance, recovery, and conversion for **North America** from reflectance data set
  - *high-resolution (30m) scene-based products*
  - *coarse-resolution (0.05 deg) modeling products*

- Develop automated approaches to Landsat processing that can be adapted for other community applications
  - *we do this for AVHRR, MODIS, VIIRS… why not Landsat?*

- Work with representatives of USDA Forest Service to evaluate applications utility of SR and disturbance products for carbon management and forest monitoring.

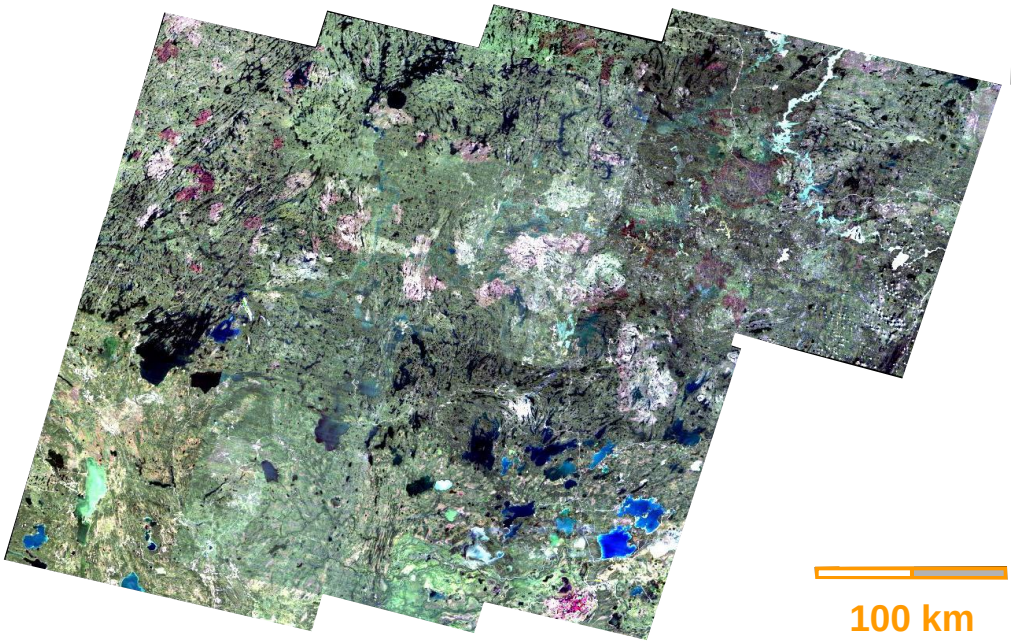
Landsat-5: Atmospheric Correction

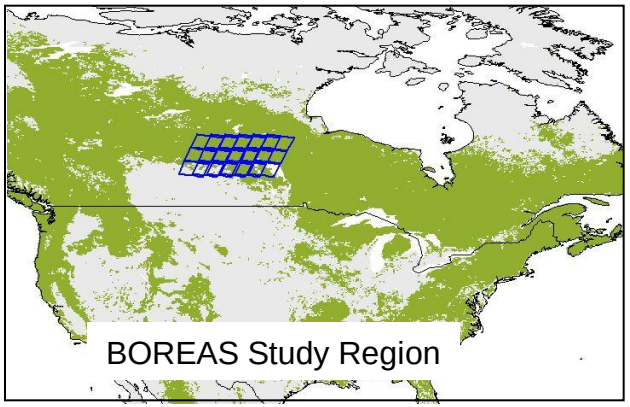


1990's Landsat-5 mosaic

← TOA reflectance

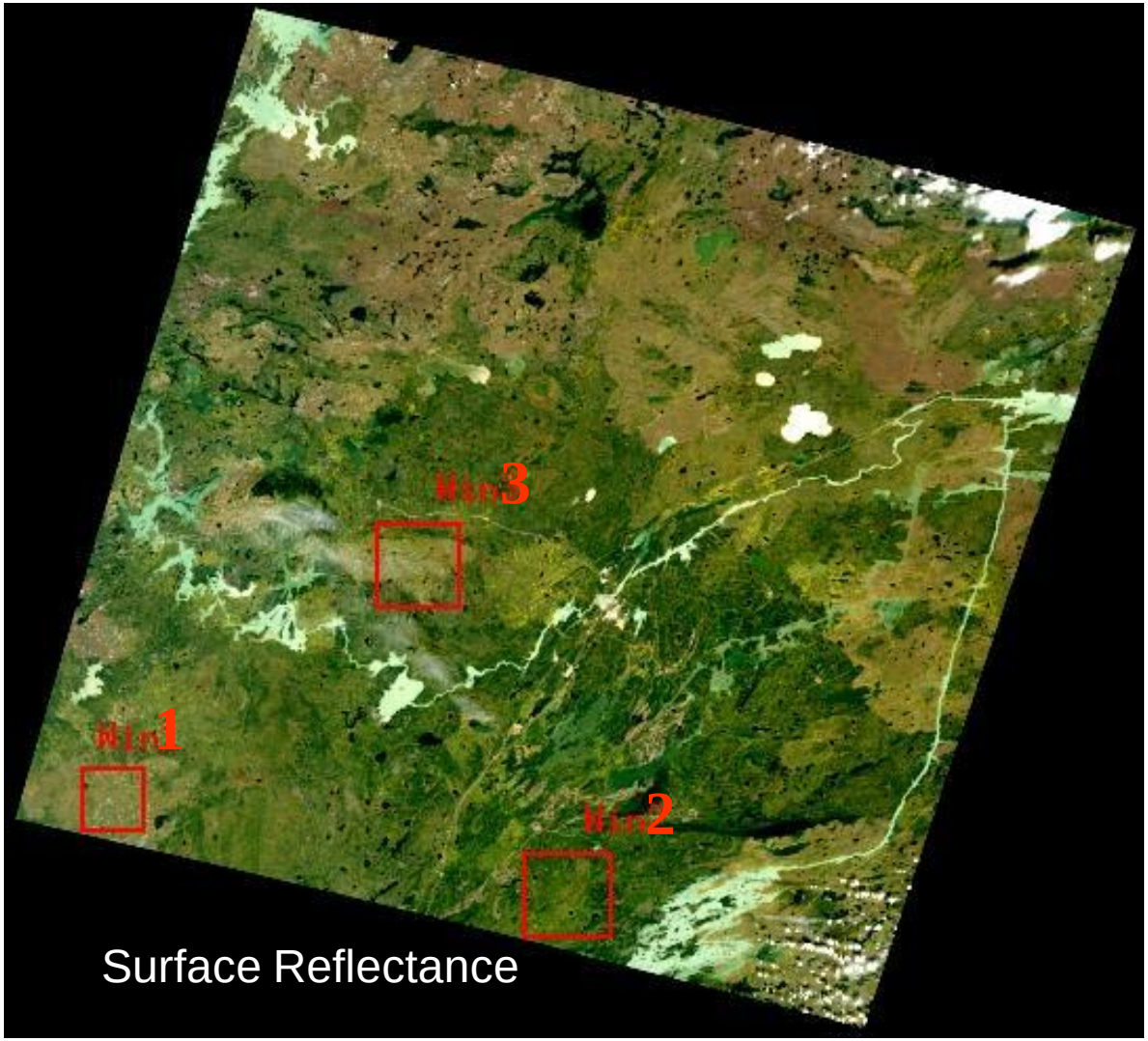
Surface reflectance ↓





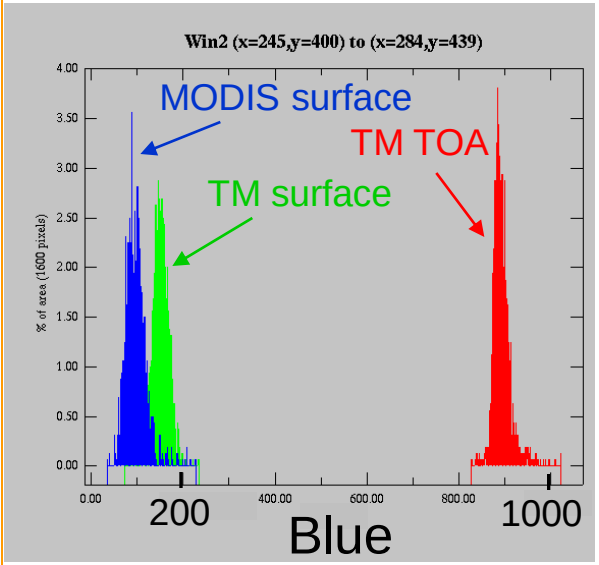
100 km

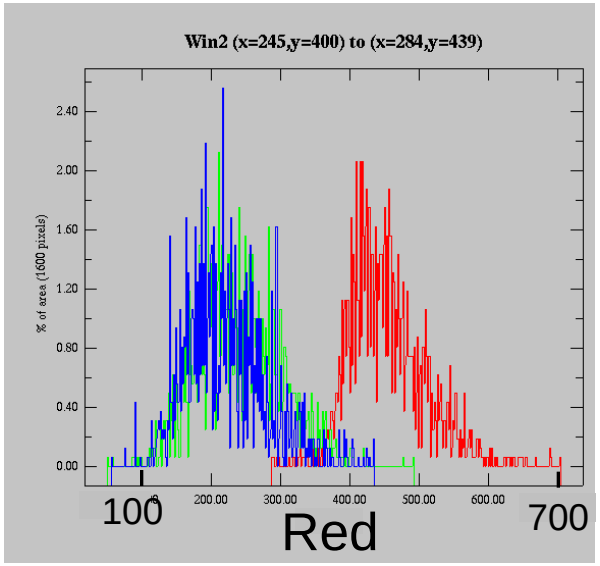
Example: BOREAS SR Validation

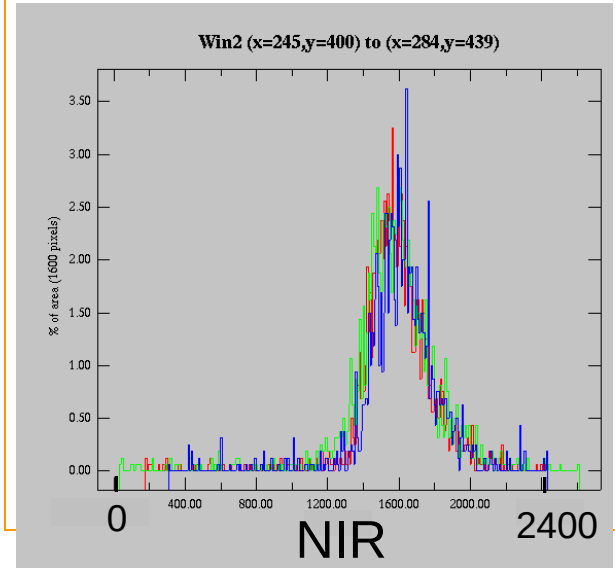


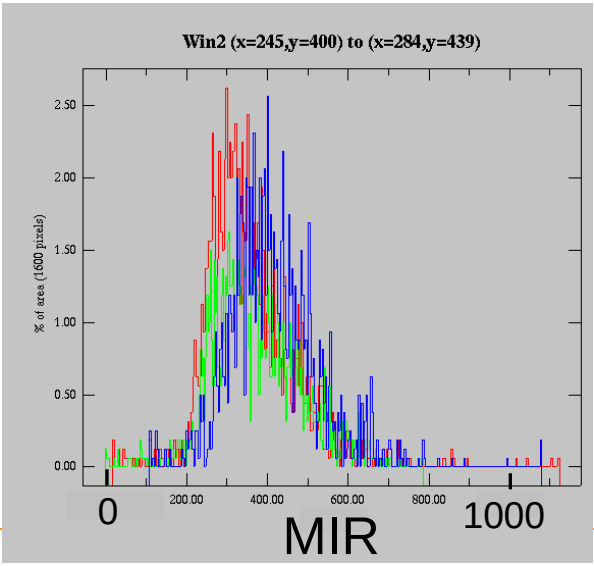
Scene: p033 r021 Date: 09/17/2001 (True Color)

Window 2 MODIS Comparison









For typical vegetated target, when compared to MODIS:

< 0.5% abs error VIS
< 3% abs error NIR

Units:
Reflectance
(x 10000)

Forest Disturbance Mapping

Initial Goal: stand-clearing disturbances (harvest, fire) and secular changes in forest cover

Two approaches to mapping disturbance:

1. **"Disturbance Index"**: semi-empirical spectral index developed by Sean Healey and Warren Cohen, USDA Forest Service.

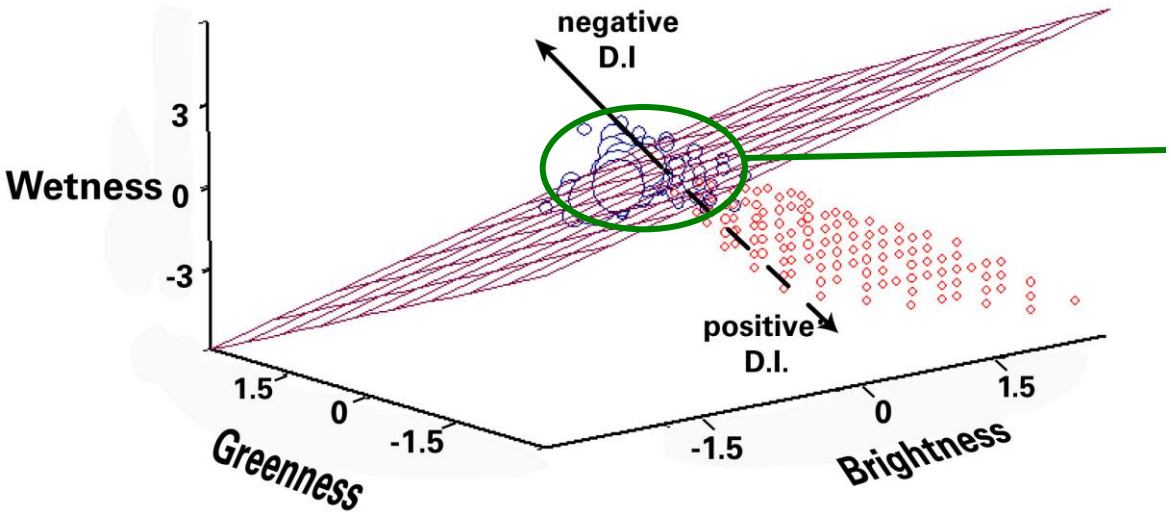
2. Matching **spectral trajectories** from canopy reflectance models to retrieve physical canopy parameters (D. Peddle/F. Hall/F. Huemmrich)

Tasseled Cap Disturbance Index

Disturbance Index is a simplified approach for mapping areas of decreased canopy cover and shadow using the Landsat Tasseled Cap Transform

$DI = Brightness_{norm} - (Greenness_{norm} + Wetness_{norm})$

Disturbance (and Regrowth) are detected as strong decadal increases (decreases) in the DI

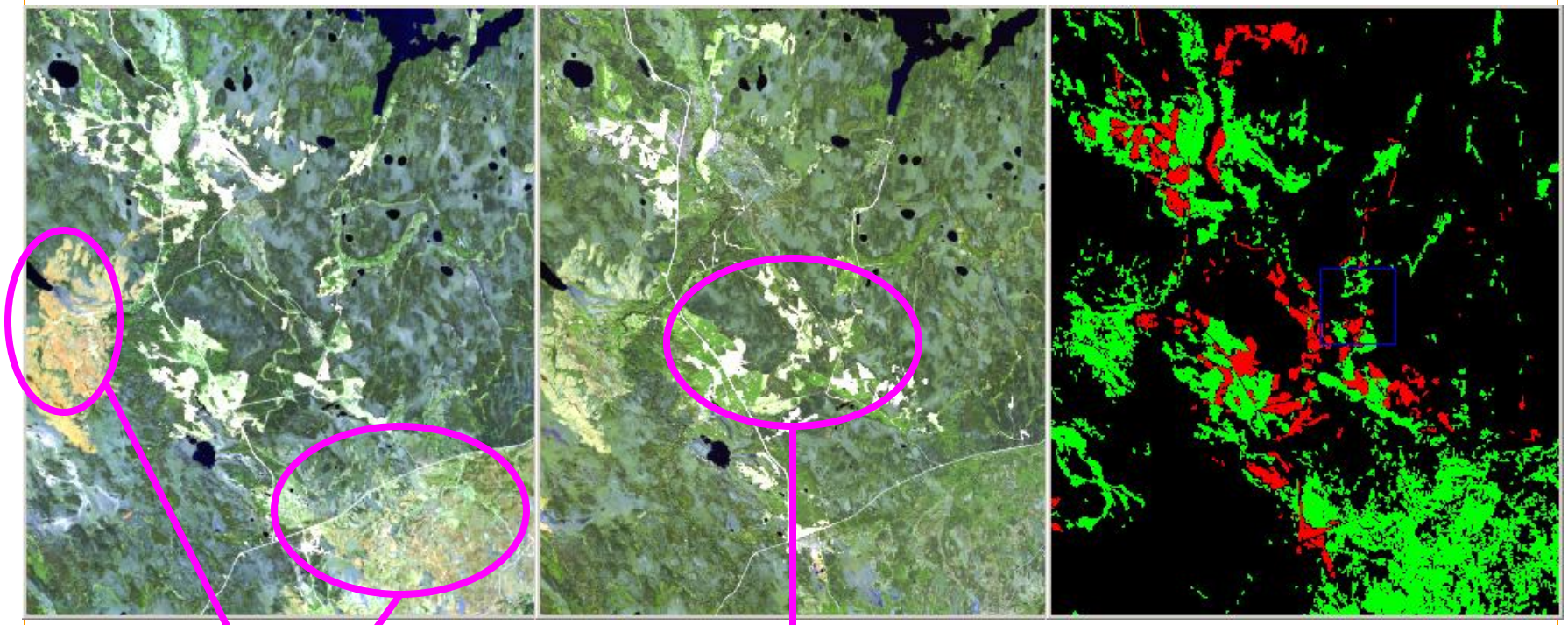


Mature forest class

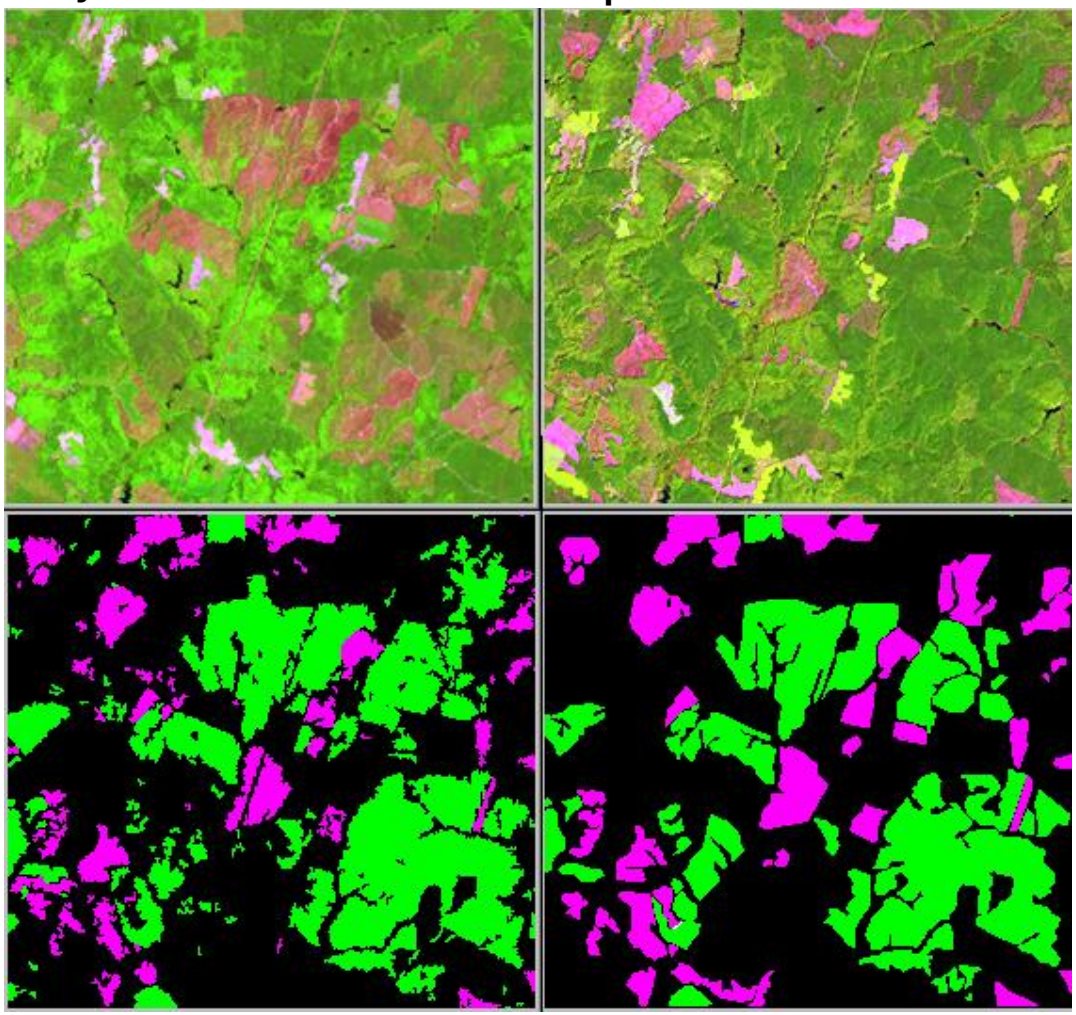
Disturbance Index Example - Boreal

Path 37 Row 22 – Central Saskatchewan

August 1987 August 2001 Disturbance /Recovery



Disturbance Index Example - Virginia



Rapid rotation planted pine + mixed hardwoods

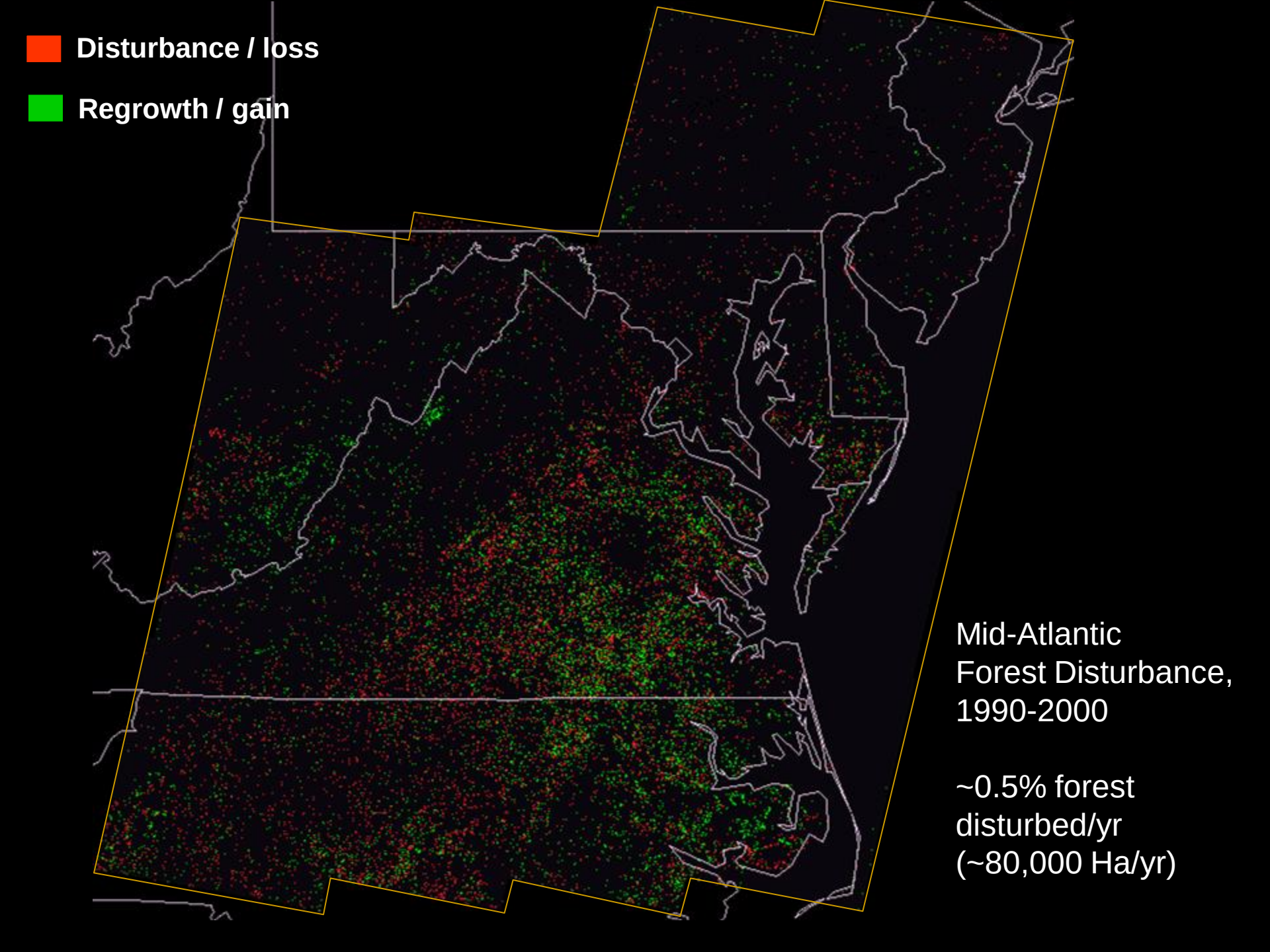
- Overall accuracy: 87%
- Omission error: 18%
- Commission error: 20%

Some tendency to undercount disturbance, overcount regrowth

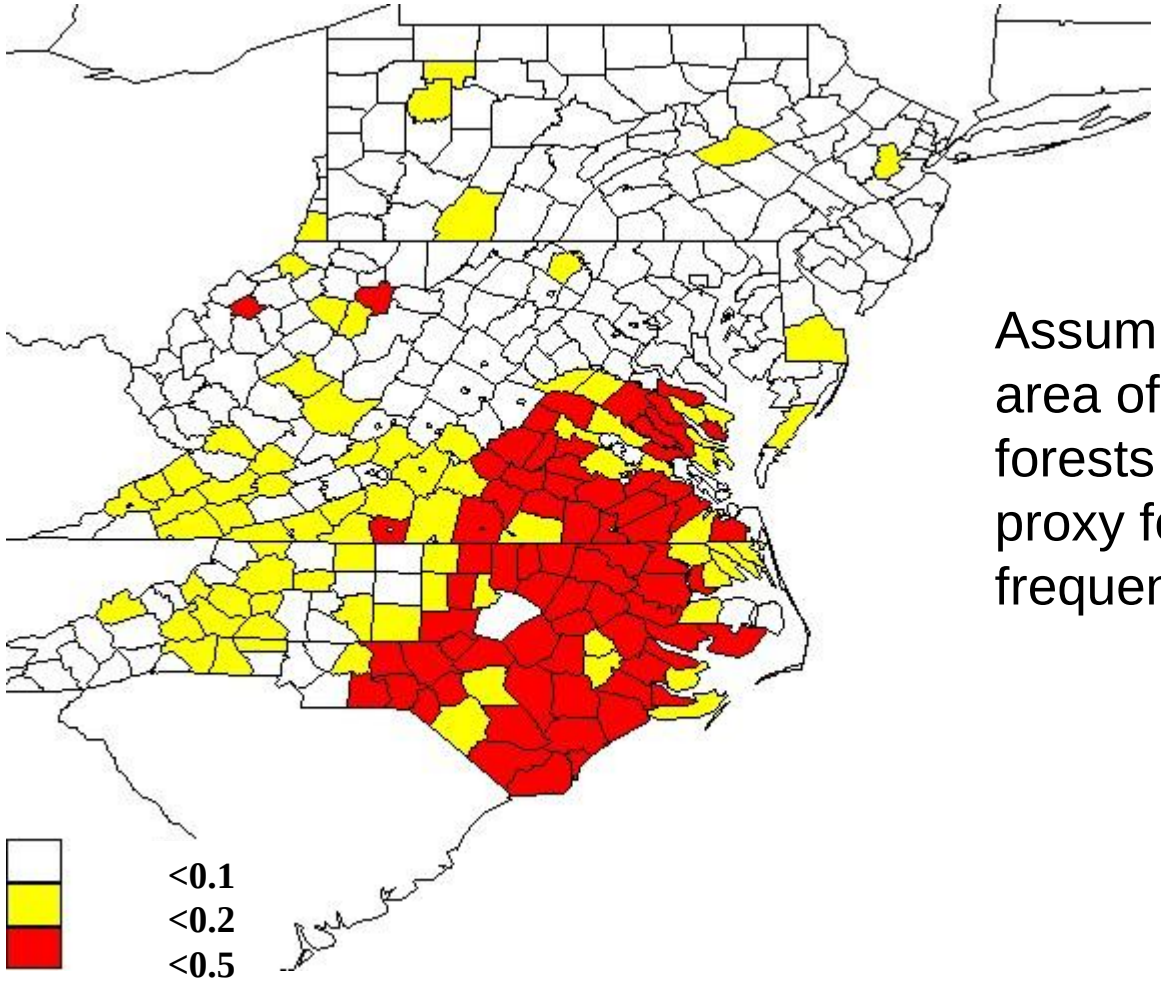
Disturbance

Regrowth

4 km


Disturbance / loss
Regrowth / gain
Mid-Atlantic
Forest Disturbance,
1990-2000
~0.5% forest
disturbed/yr
(~80,000 Ha/yr)

Forest Service FIA Comparison



% county area < 20yr

Assumption: Fractional area of very young forests can act as a proxy for disturbance frequency

Disturbance Validation

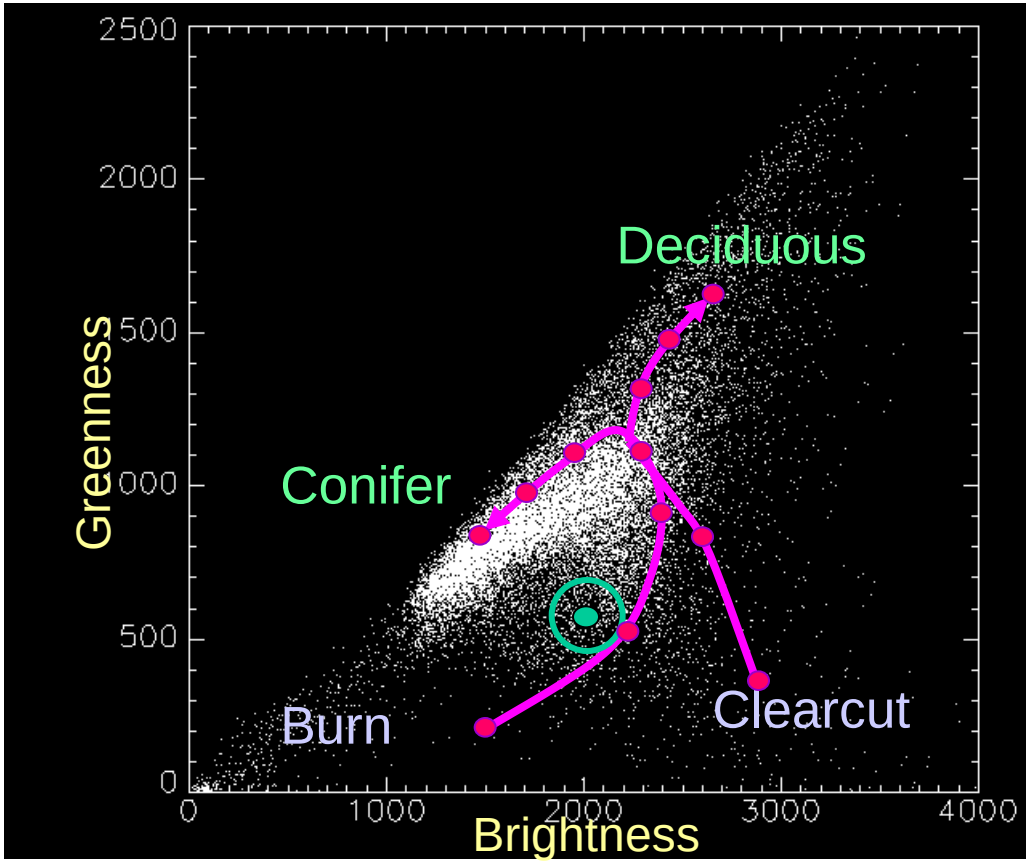
- Visual interpretation of image pairs, time series
- Comparison with FIA / CanFI statistics
- Comparison with high-resolution air photo archives
- Known land-use histories (LTERs, Research Forests)

Canopy Reflectance Modeling Approach

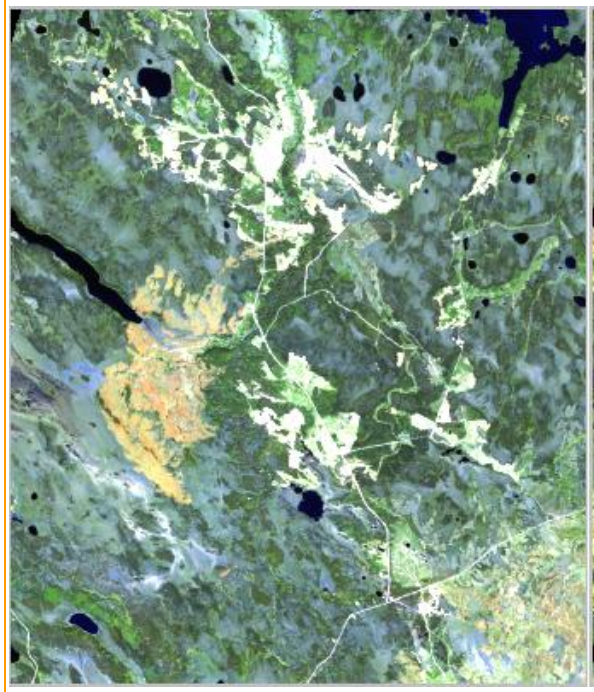
Use canopy reflectance model to predict spectral trajectories for different stand types, background conditions, and illumination conditions

Use Landsat reflectances to find position along 'best fit' trajectory and retrieve model canopy parameters

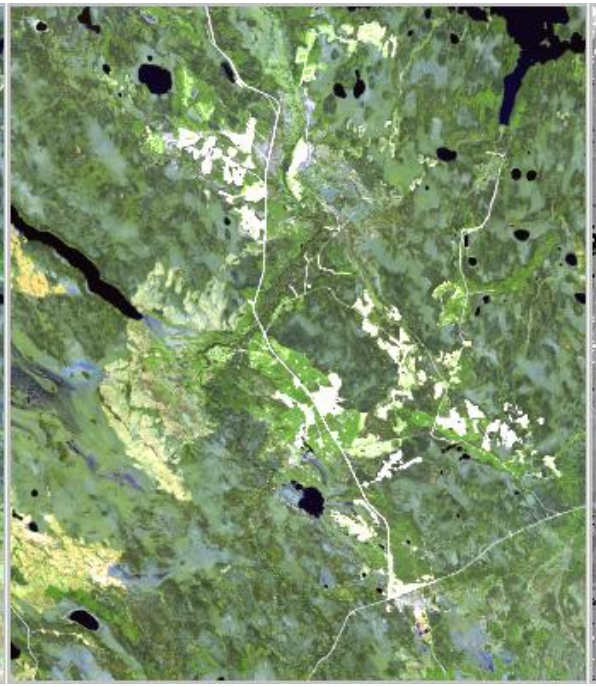
Better approach for partial harvest, thinning, other non-stand clearing changes



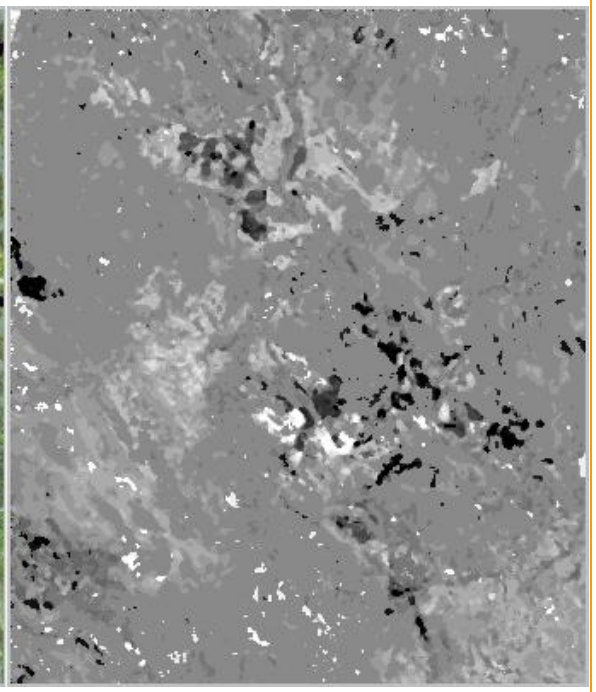
Spectral Trajectory Matching Example



August 1987



August 2001

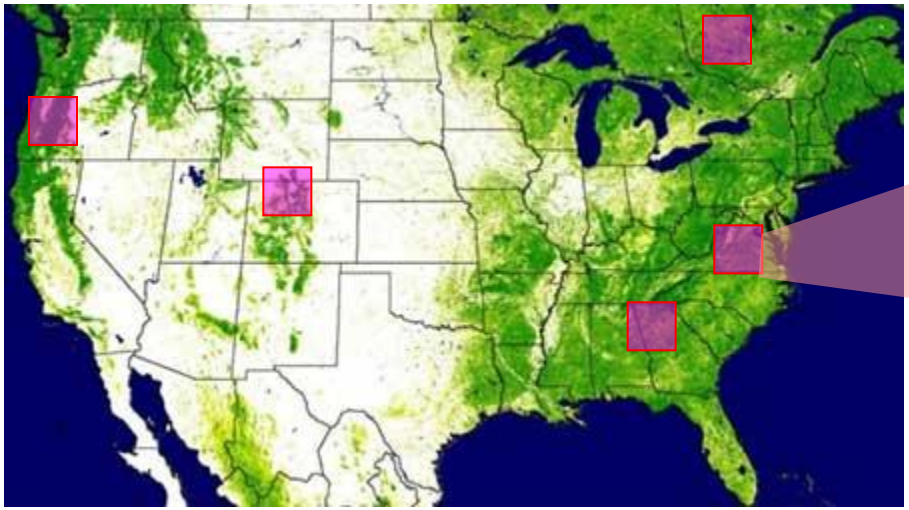


Δ Canopy Cover

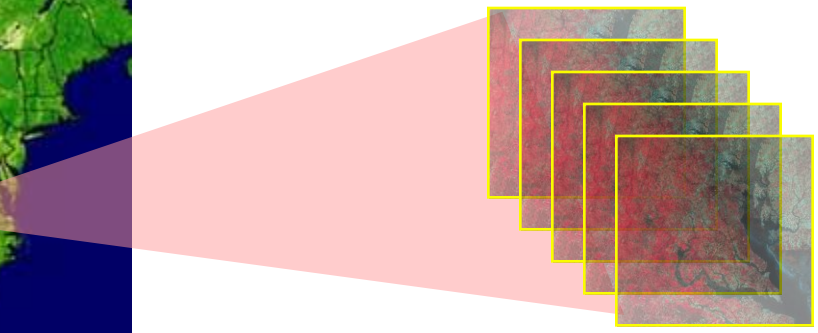
-100%

+80%

“Three-Dimensional” Disturbance Mapping



Decadal, wall-to-wall mapping



~20 “dense” time series
(1 image every 2-3 years)

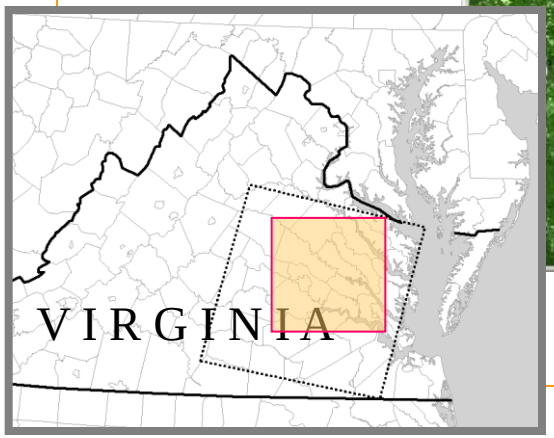
- **LEDAPS wall-to-wall survey gives spatial patterns and mean frequency of stand-clearing disturbance events**

- **Dense time series gives detailed disturbance history, separates secular change from disturbance, provides validation for LEDAPS product** (*collaboration with S. Goward project*)

Disturbance History Example: Virginia

RGB (753) image, Eastern Virginia

Oct 5, 2001



Disturbance History Example: Virginia

Clearing Epoch

1985-88

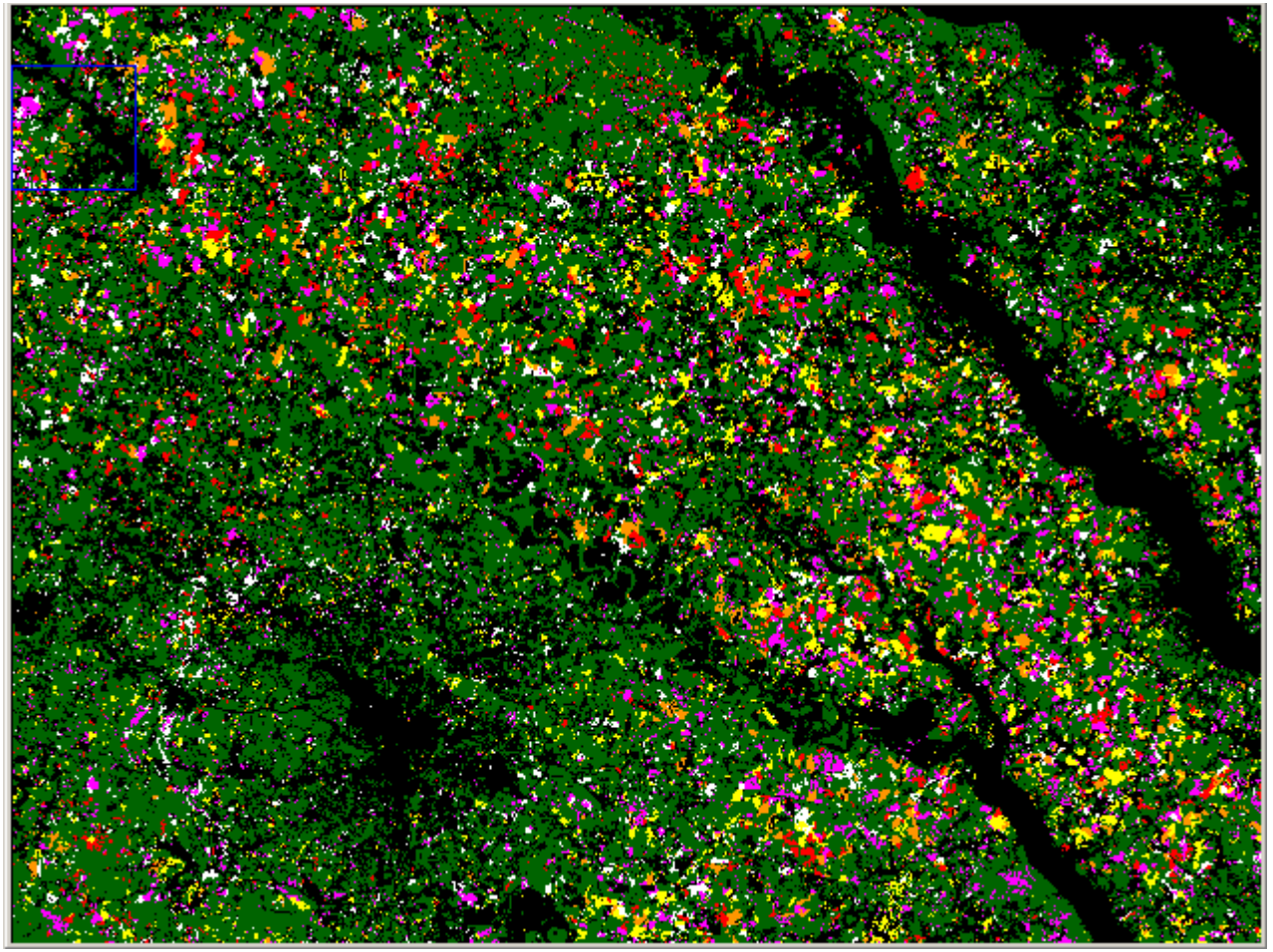
1988-91

1991-95

1995-99

1999-01

Undisturbed Forest

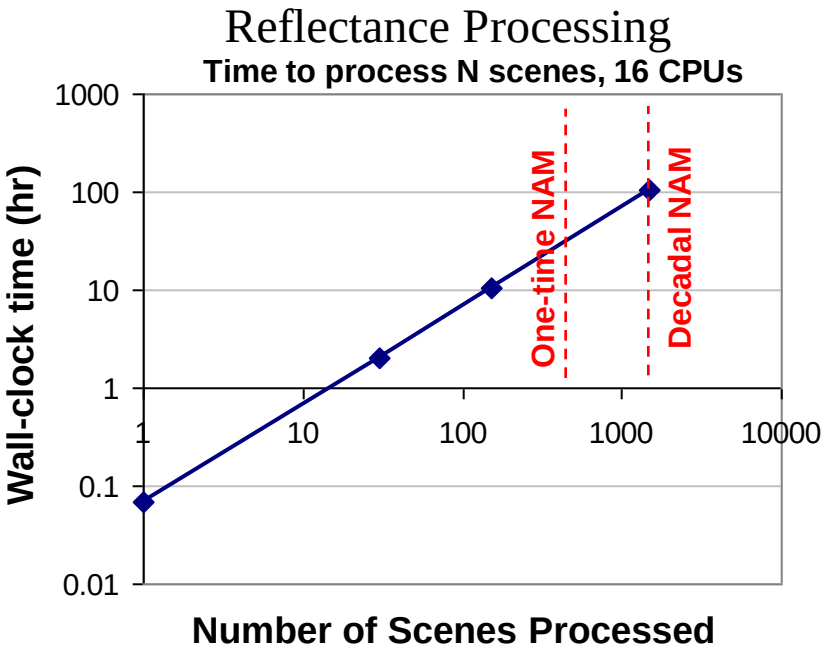


Processing System

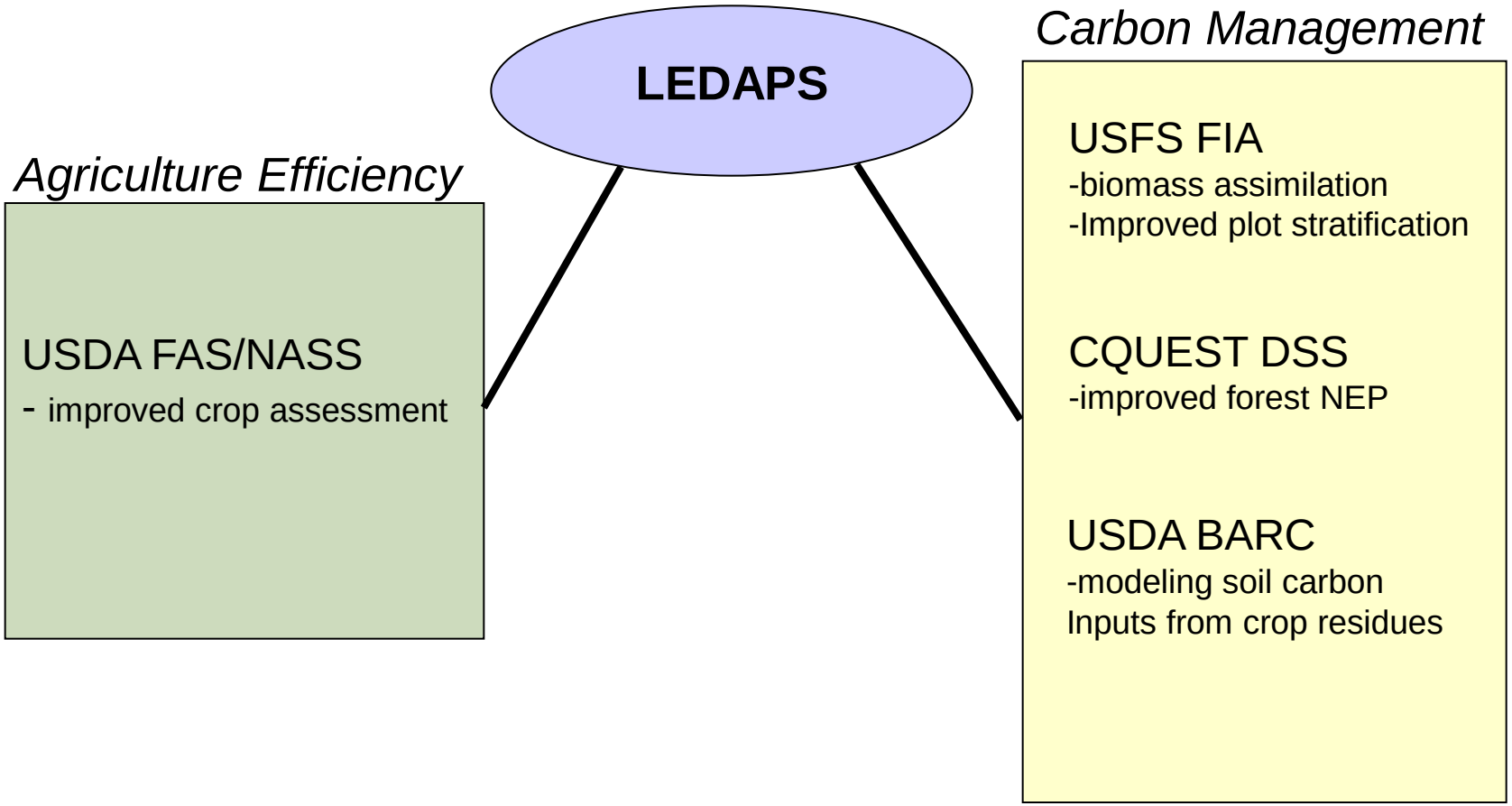
Project requires repeated, automated processing of ~1800 scenes (~0.5 TB).

Re-uses MODIS MODAPS software/hardware architecture, using parallel processing across multiple Linux CPUs.

Should be possible to process continental reflectance data set within 4-5 days using current 16-CPU cluster



Applications Partners



Project Status and Schedule

- Project duration 2004 - 2007.

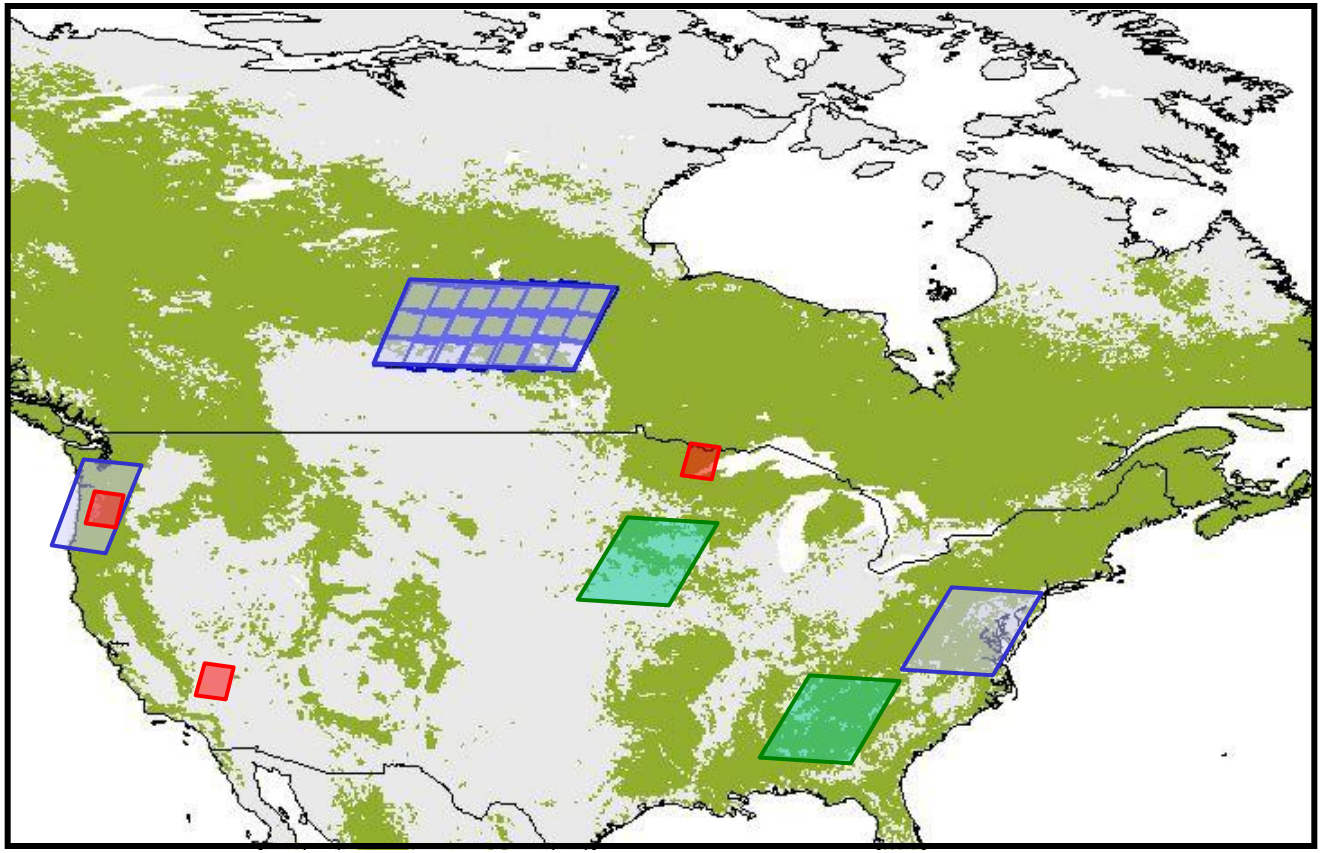
- “Beta” Landsat-7 Reflectance products now available

- Continental L5 and L7 Reflectance products and “Beta” Disturbance Products available February 2005

- Continental Disturbance Maps available late 2005

- 2006 – 2007 Tasks:
  - *Product validation and reprocessing*
  - *Application of canopy reflectance models for direct estimation of vegetation structure and re-growth state*
  - *Integration with Biochemical models for improved NEP estimation*
  - *Coordination with US Forest Service FIA program*

Initial (Beta) Reflectance Products

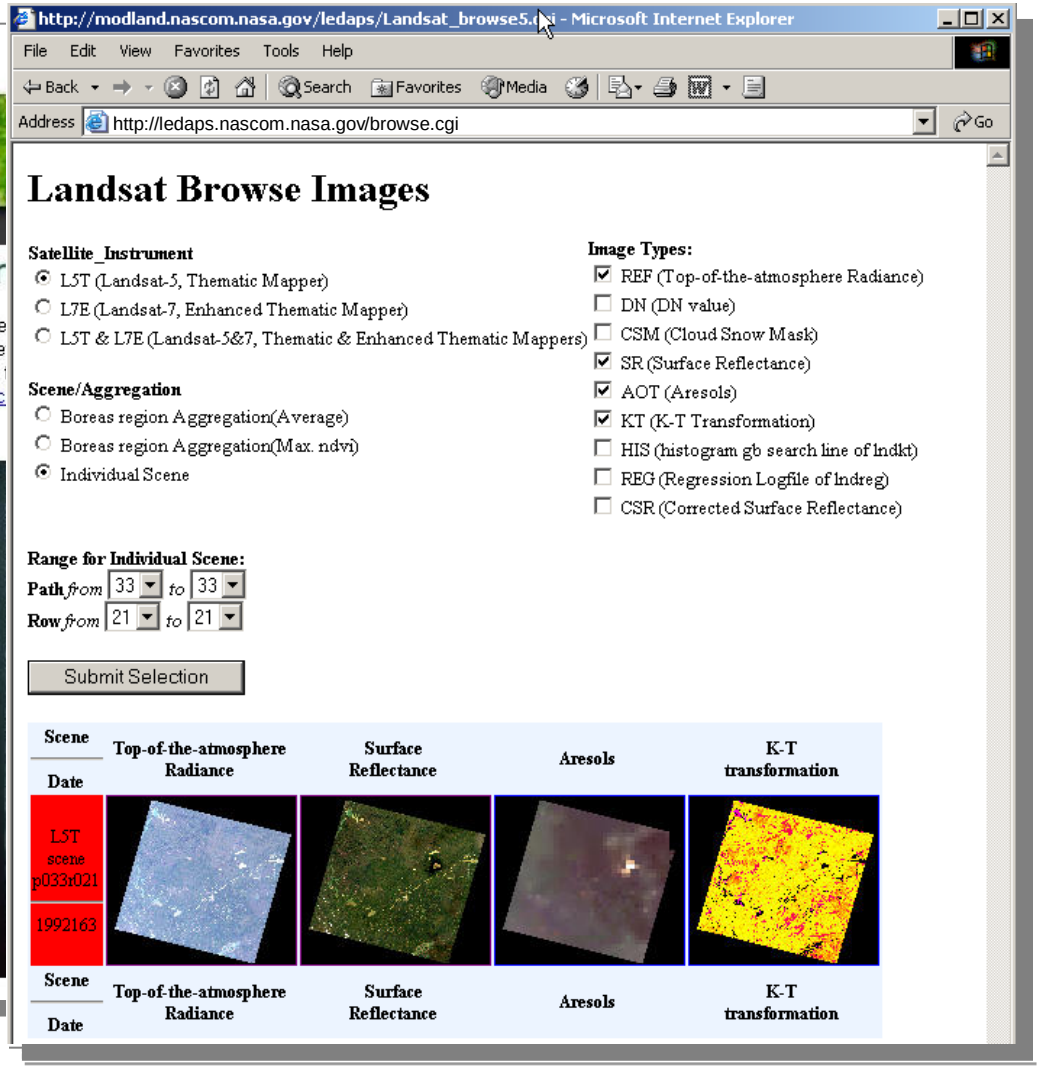


SR Validation

Collaborators

Large-Area/Disturbance

LEDAPS Web Page



http://ledaps.nascom.nasa.gov/ledaps/ledaps.html

Conclusions

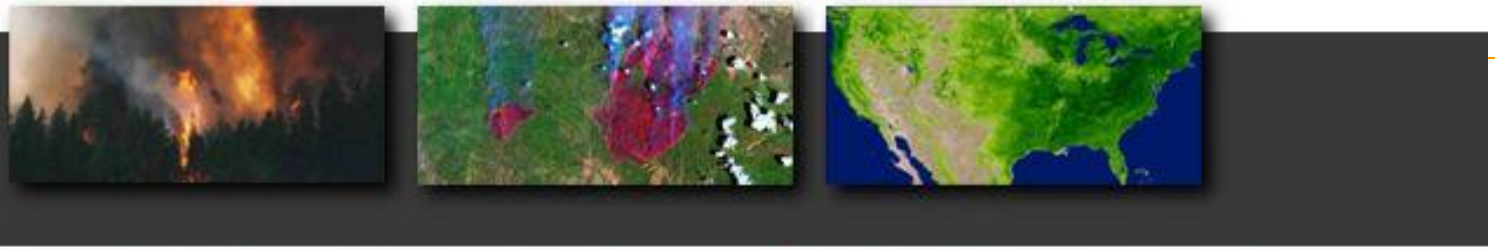
North American data sets of Landsat surface reflectance and forest disturbance are forthcoming

- *need community input for product definitions, validation*
- *collaboration with carbon/ecosystems modeling community to assess product utility and impact*

Processing approaches originally developed for MODIS / AVHRR systems can be adapted to Landsat

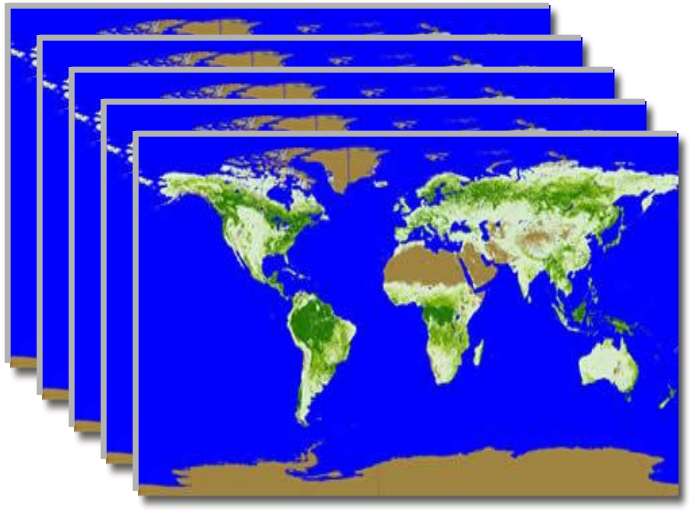
- *faster, more cost effective analyses*
- *enable adjustments to products (re-processing)*
- *does not obviate requirement for manual analysis (validation)*

LEDAPS



Landsat Ecosystem Disturbance Adaptive Processing System

Thank you!



LEDAPS Processing Overview