

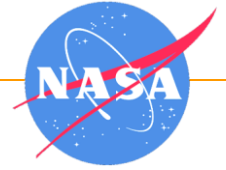


Landsat Ecosystem Disturbance Adaptive Processing System

## **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?



1985

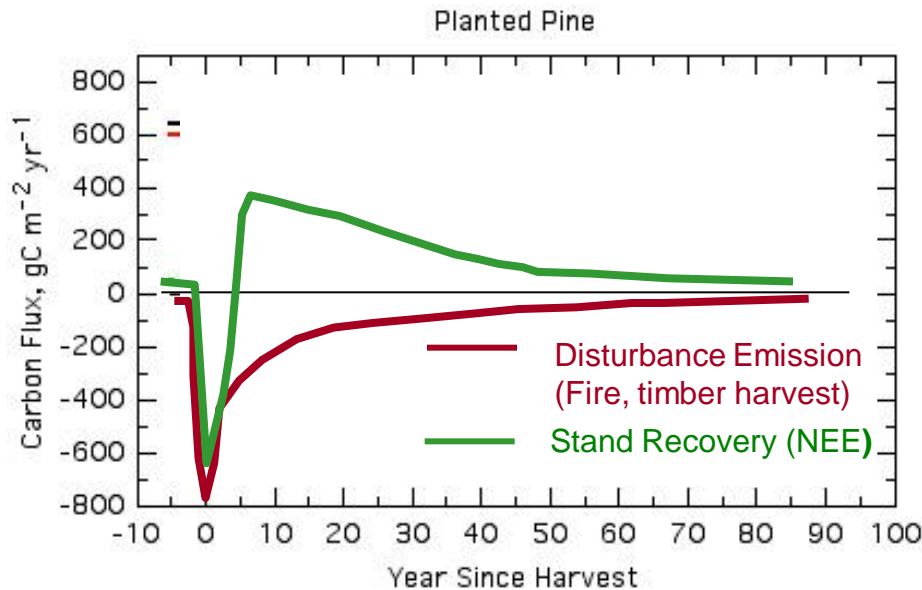


1988



1999

7km

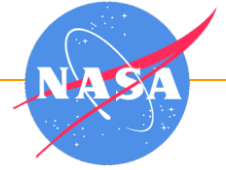


- Disturbances (fire, harvest, insect damage) emit C to atmosphere

- 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.

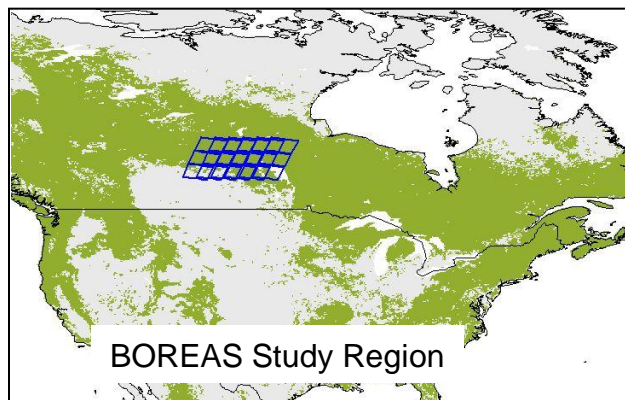
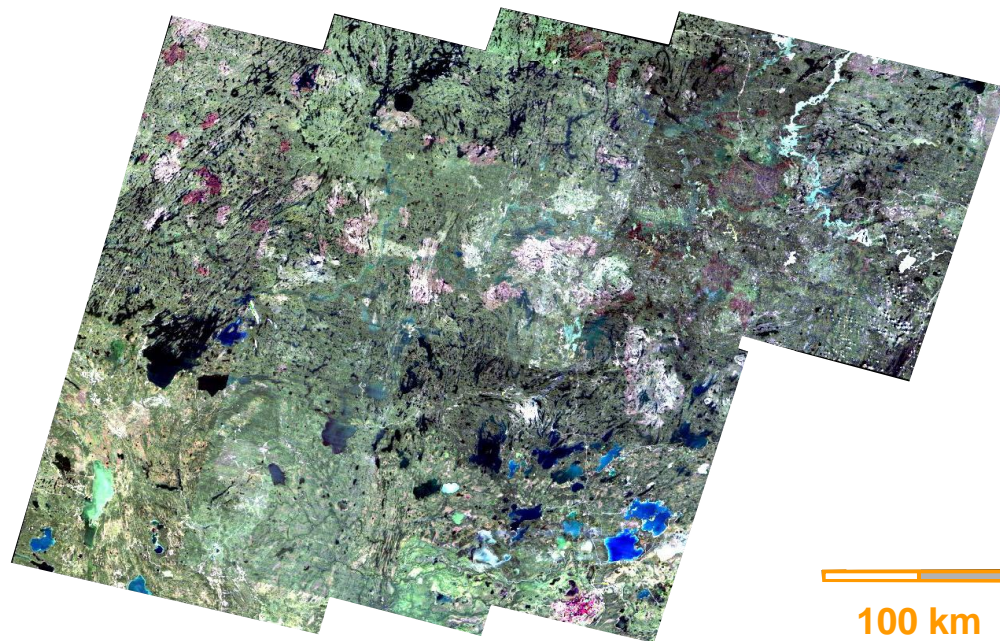
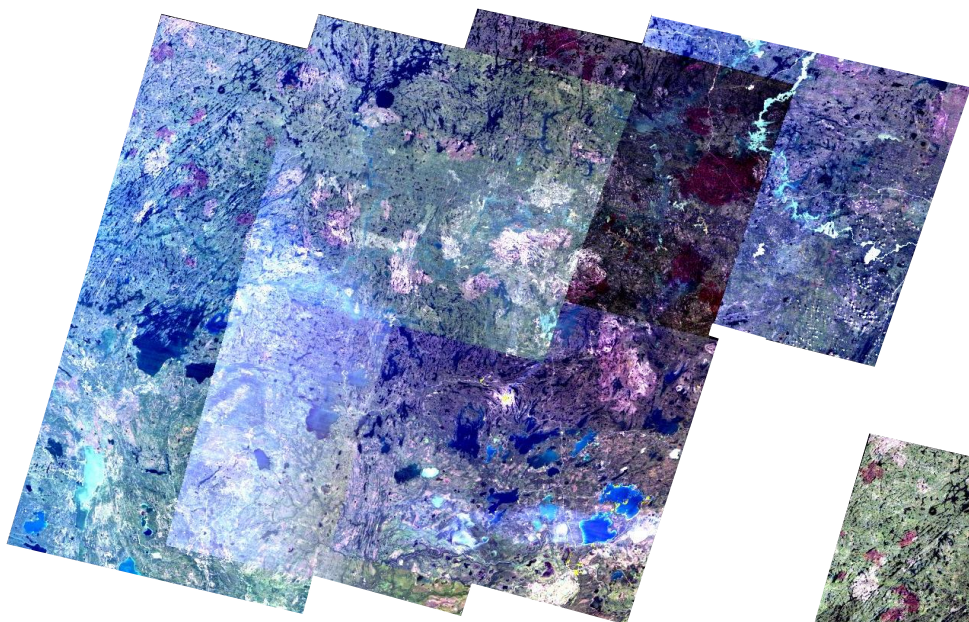
# Landsat-5: Atmospheric Correction



1990's Landsat-5 mosaic

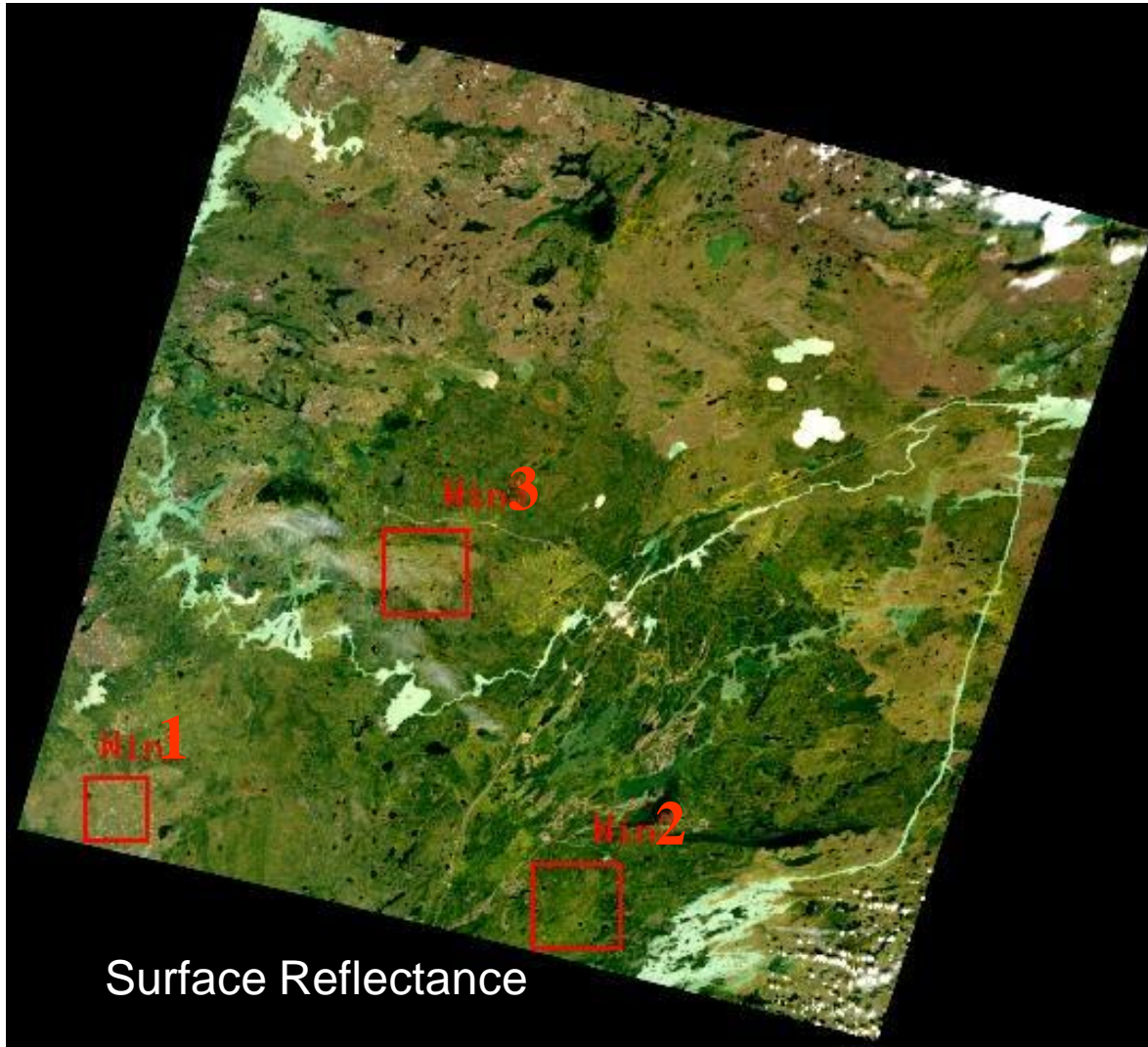
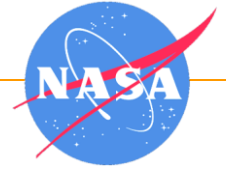
← TOA reflectance

Surface reflectance



100 km

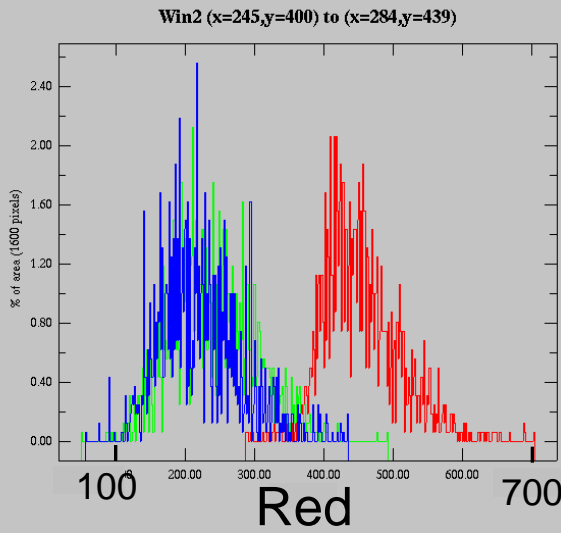
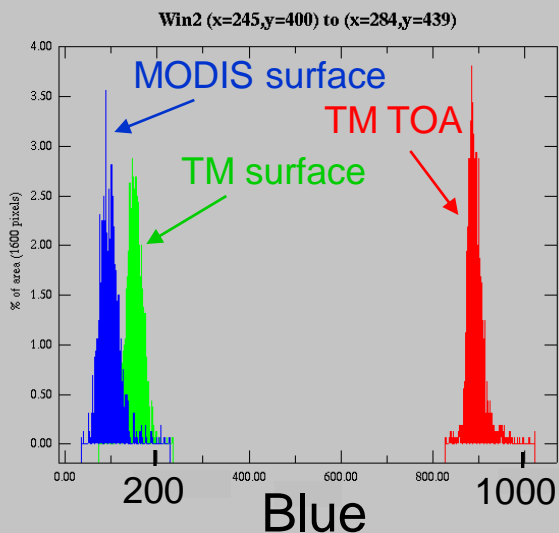
# Example: BOREAS SR Validation



Surface Reflectance

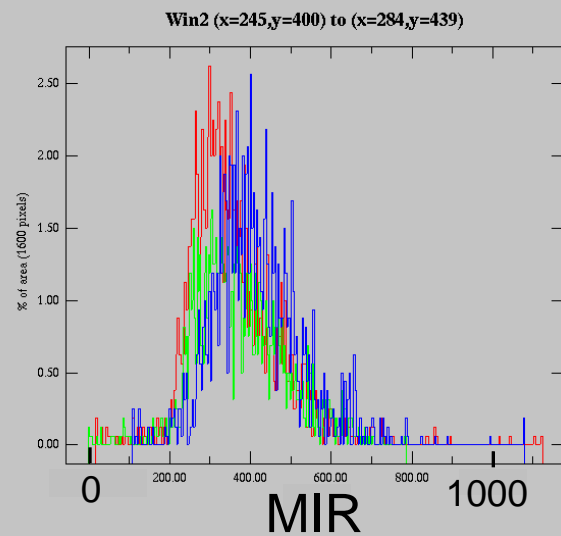
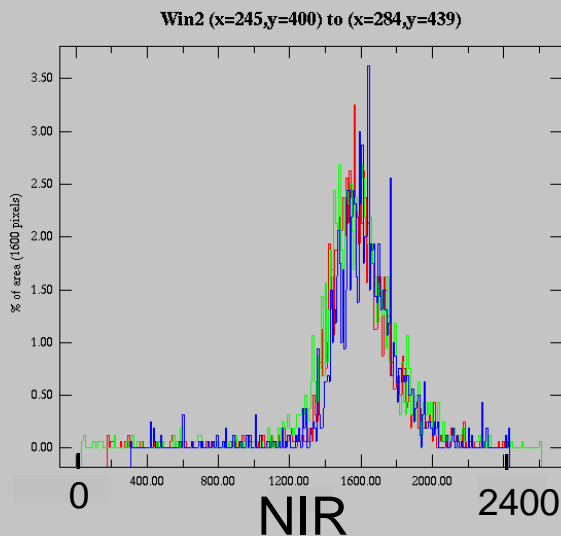
Scene: p033 r021 Date: 09/17/2001 (True Color)

# Window 2 MODIS Comparison



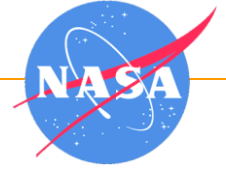
For typical vegetated target, when compared to MODIS:

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



Units:  
Reflectance  
(x 10000)

# Forest Disturbance Mapping

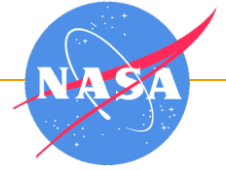


Initial Goal: stand-clearing disturbances (harvest, fire) and secular changes in forest cover

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)

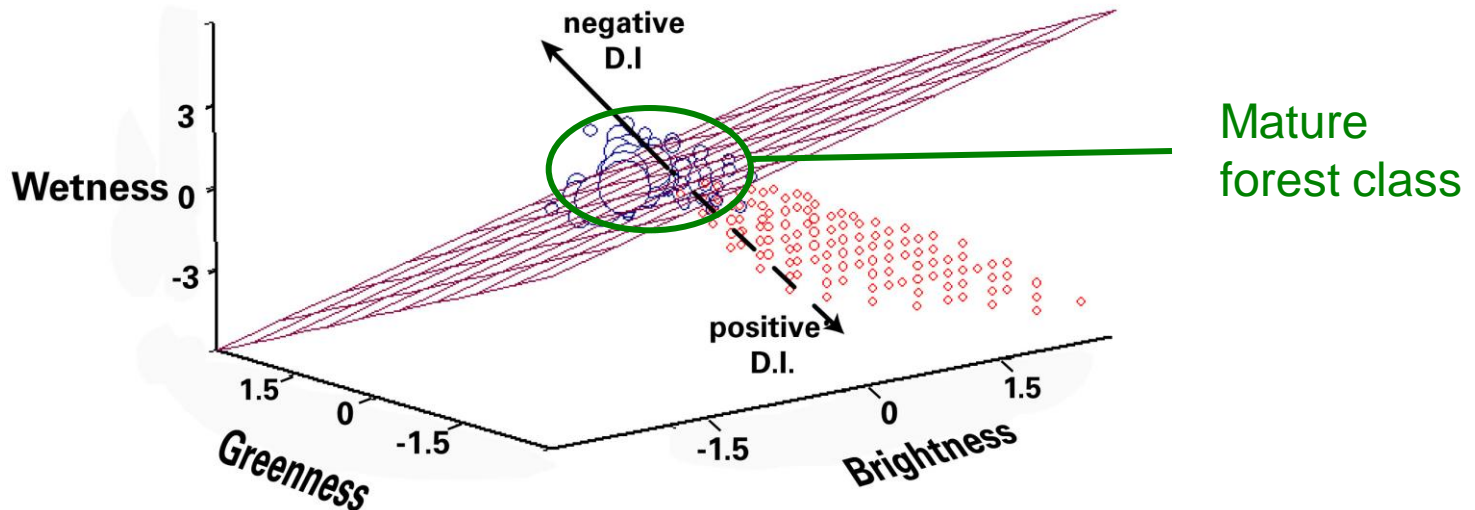
# Tasseled Cap Disturbance Index



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

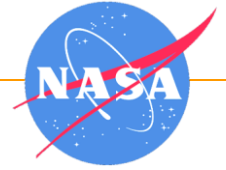
$$DI = \text{Brightness}_{\text{norm}} - (\text{Greenness}_{\text{norm}} + \text{Wetness}_{\text{norm}})$$

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





# Disturbance Index Example - Boreal

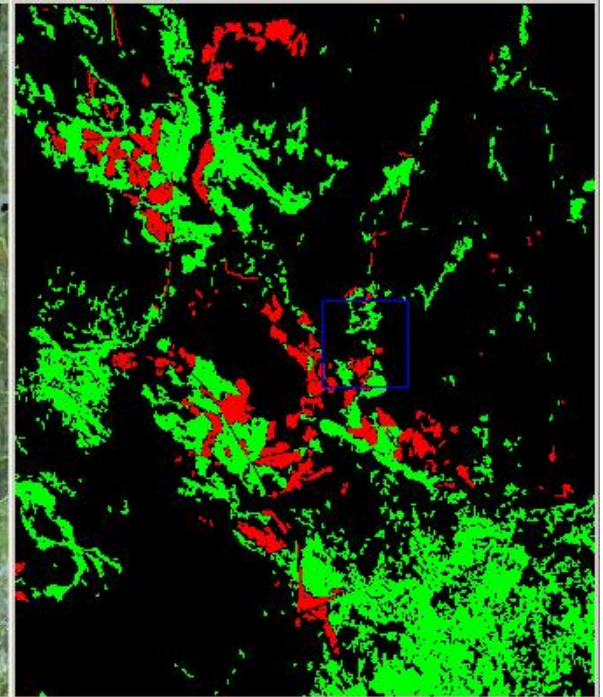


Path 37 Row 22 – Central Saskatchewan

August 1987

August 2001

Disturbance /Recovery



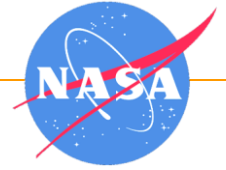
Fire scars

Logging



15 km

# Disturbance Index Example - Virginia



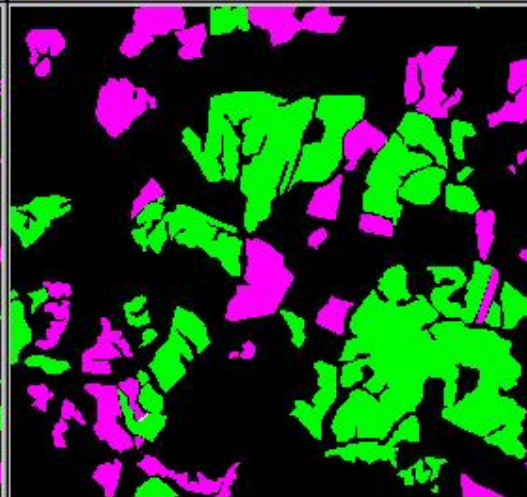
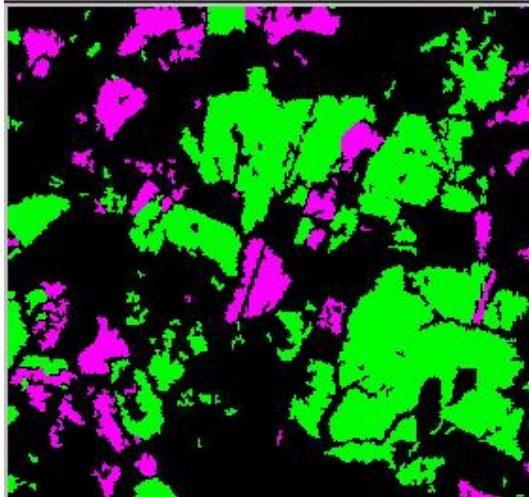
May 1990

Sep 1999



Rapid rotation planted pine + mixed hardwoods

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



Some tendency to undercount disturbance, overcount regrowth

 Disturbance  
 Regrowth

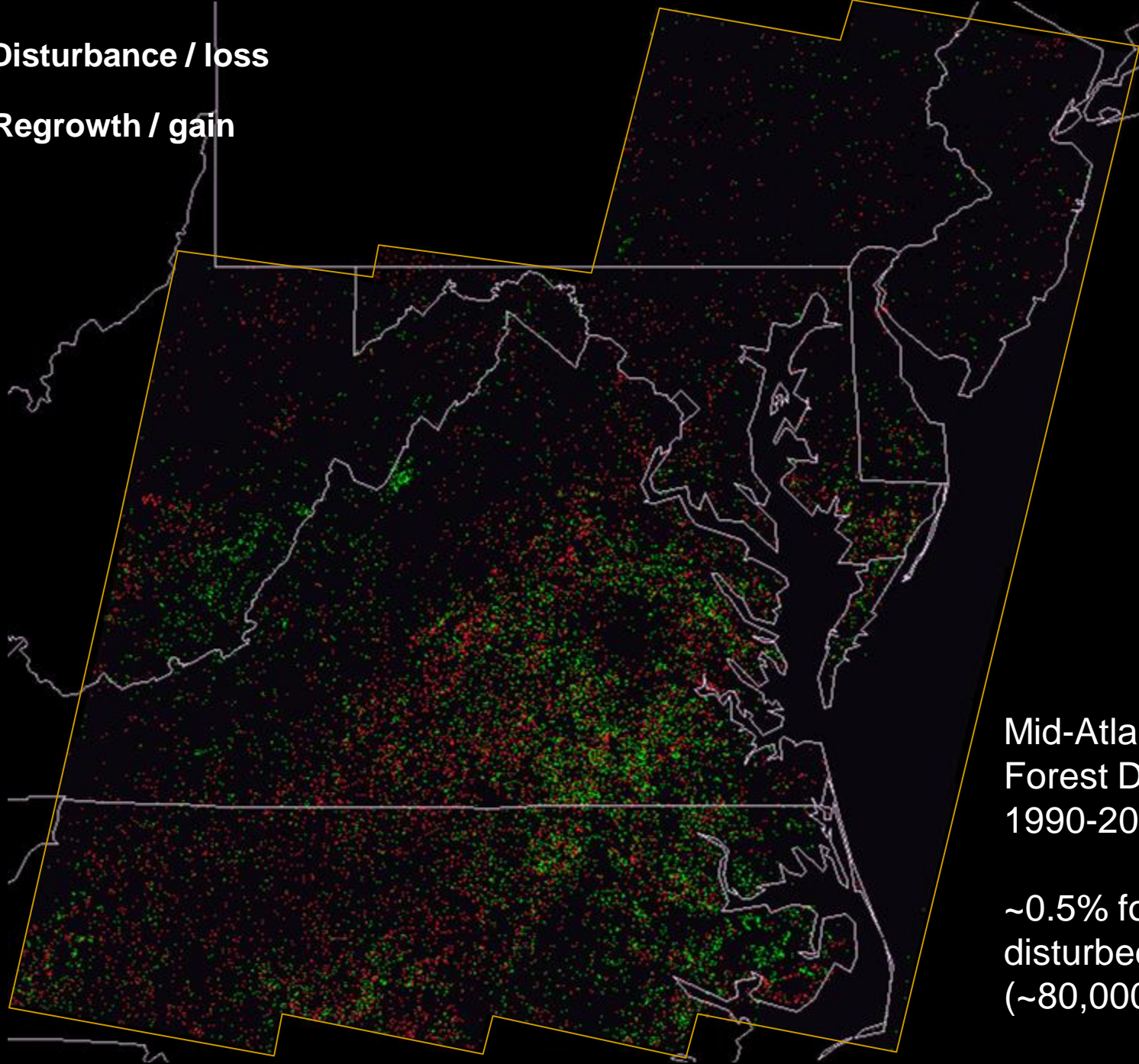
 4 km

LEDAPS

Visual Interpretation

 Disturbance / loss

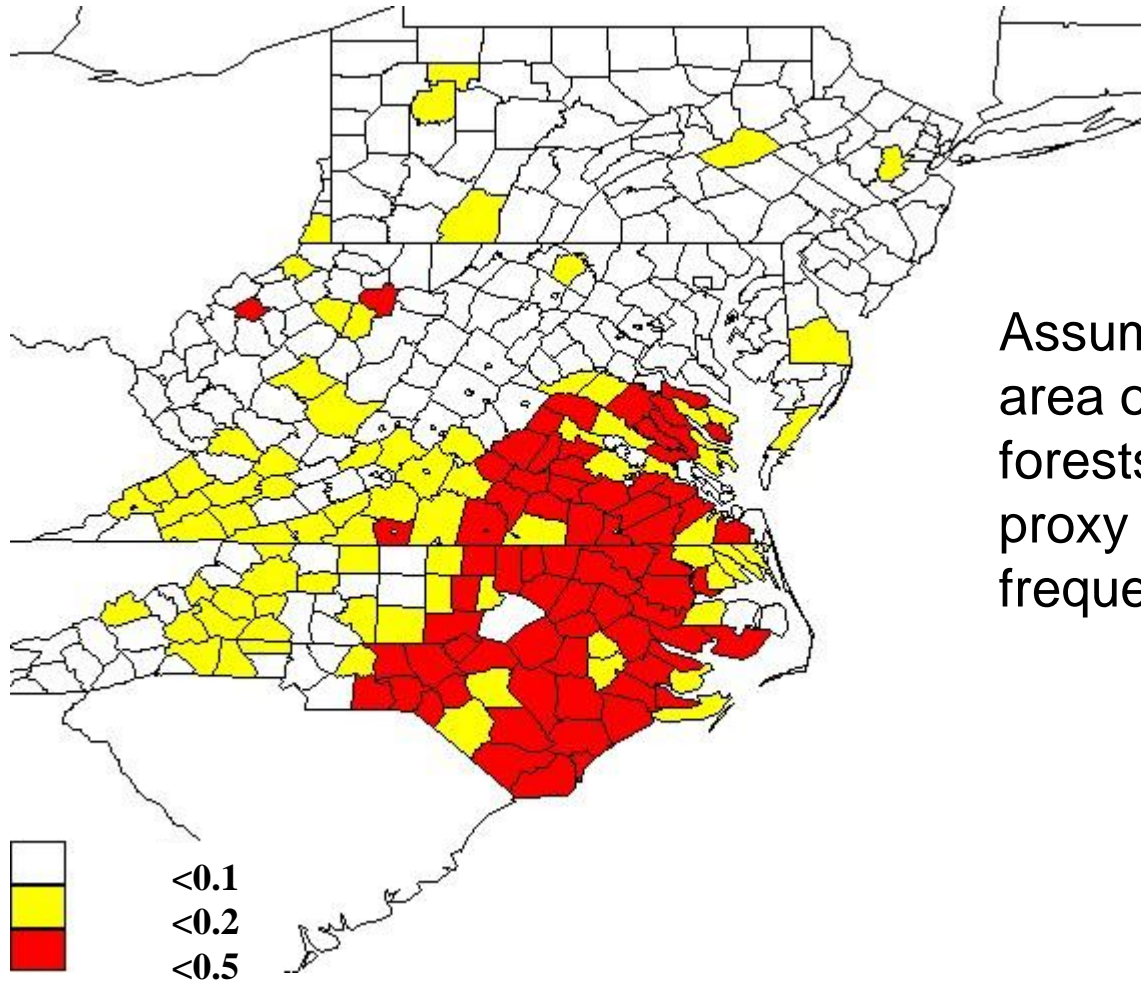
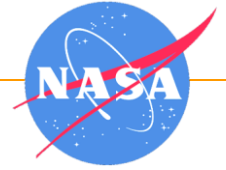
 Regrowth / gain



Mid-Atlantic  
Forest Disturbance,  
1990-2000

~0.5% forest  
disturbed/yr  
(~80,000 Ha/yr)

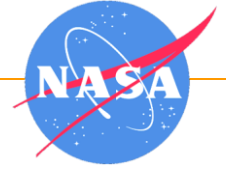
# Forest Service FIA Comparison



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

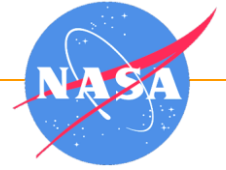
**% county area < 20yr**

# 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)

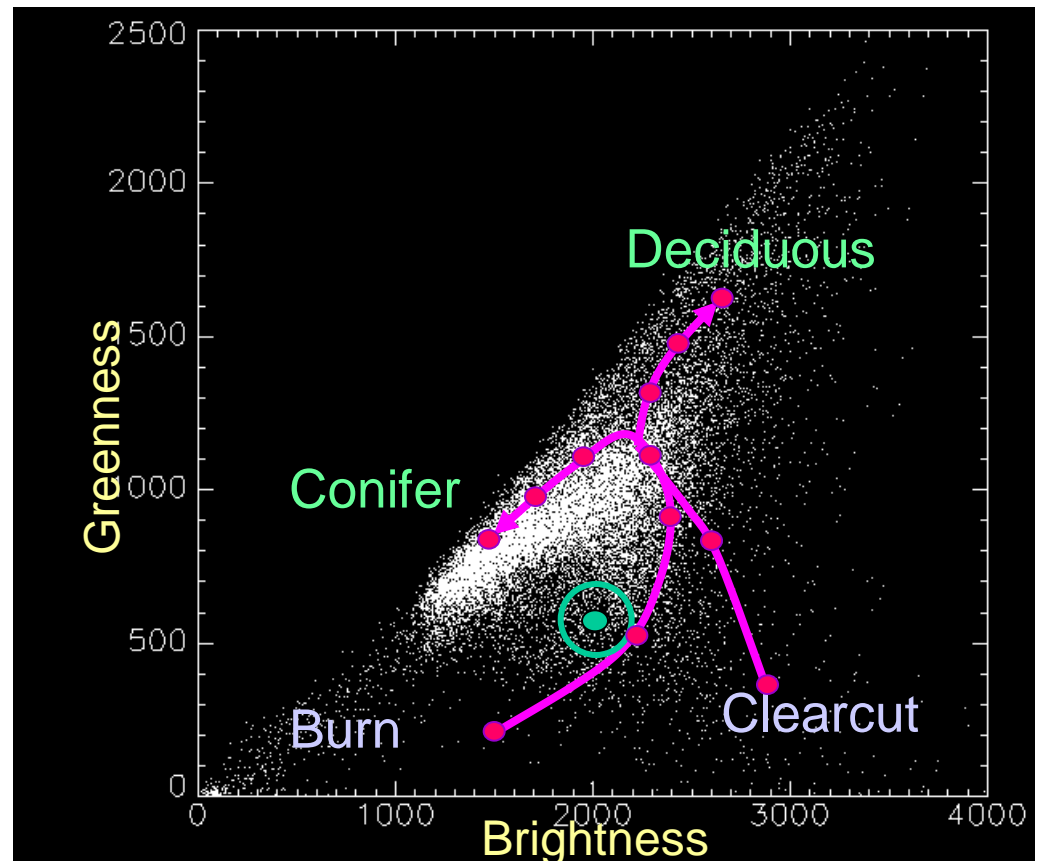
# Canopy Reflectance Modeling Approach



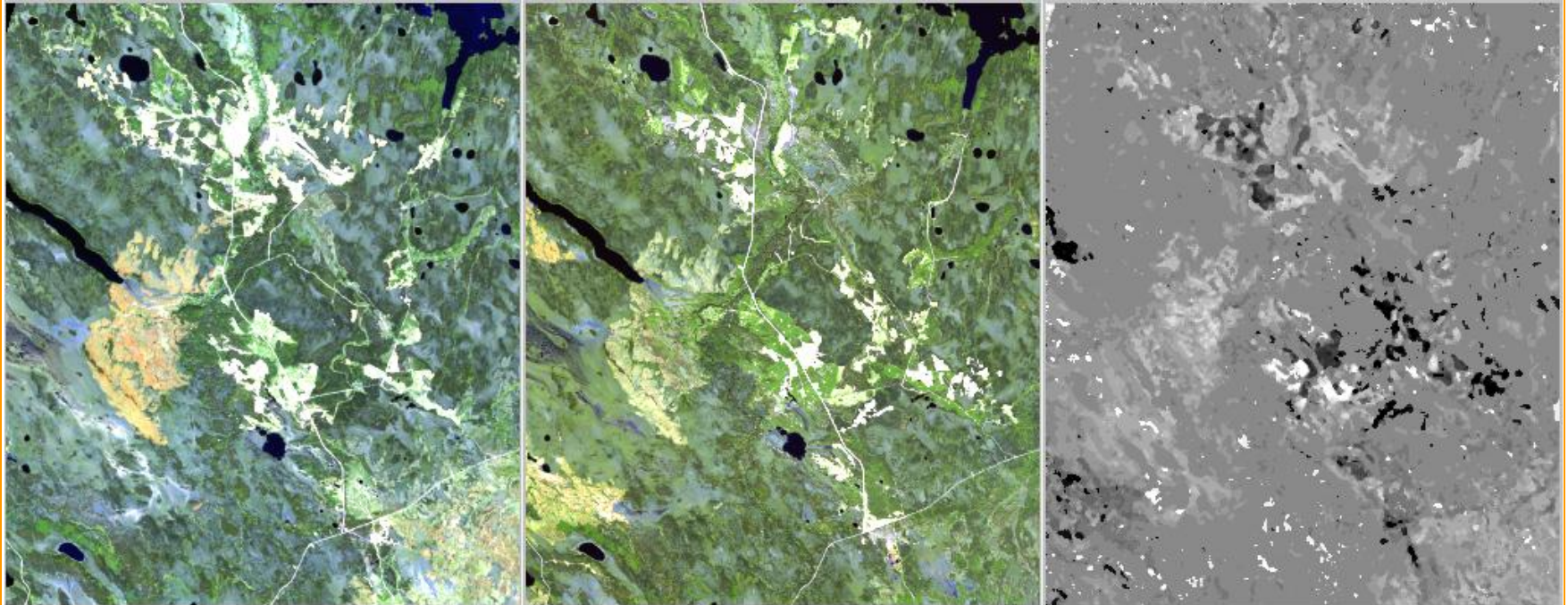
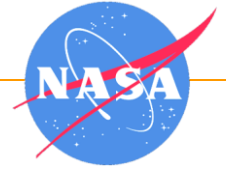
Use canopy reflectance model to predict spectral trajectories for different stand types, background conditions, and illumination conditions

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



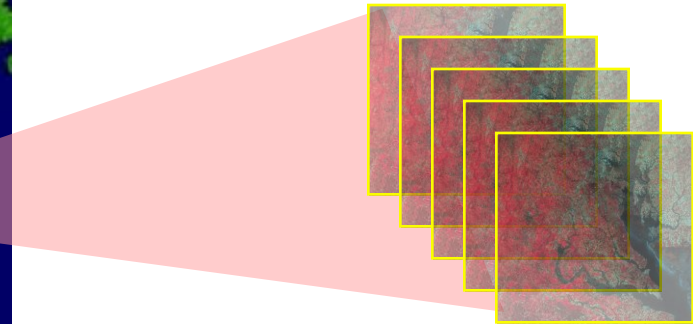
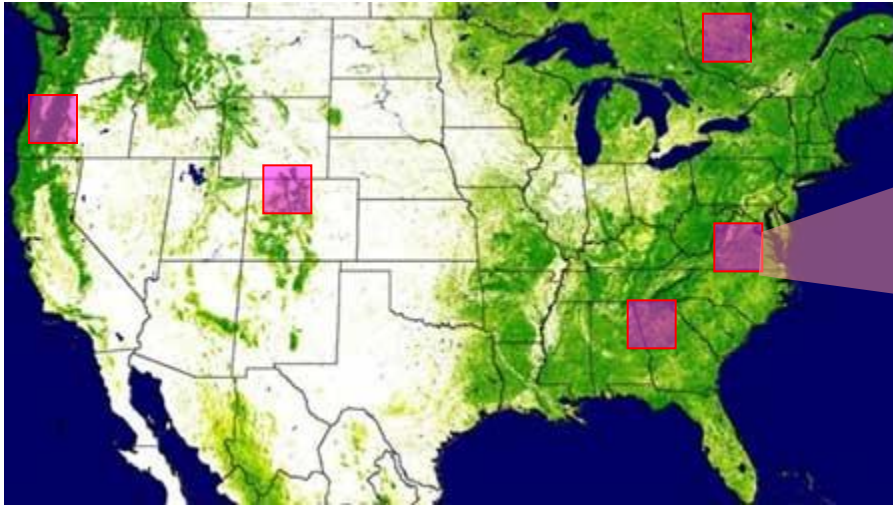
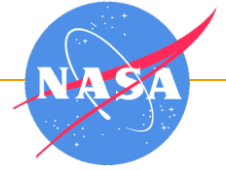
August 1987

August 2001

$\Delta$  Canopy Cover



# “Three-Dimensional” Disturbance Mapping



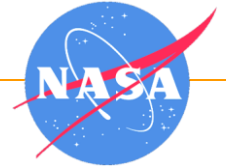
~20 “dense” time series  
(1 image every 2-3 years)

*Decadal, wall-to-wall mapping*

- **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*)

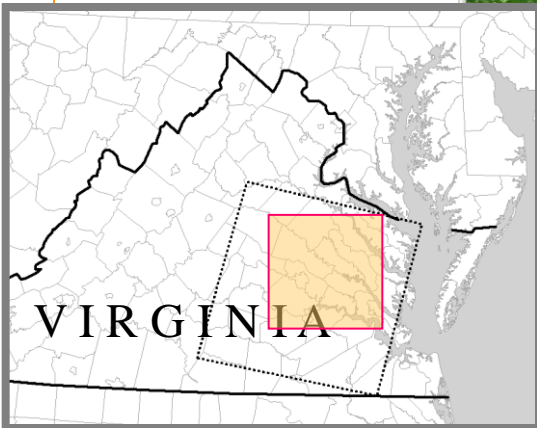


# Disturbance History Example: Virginia

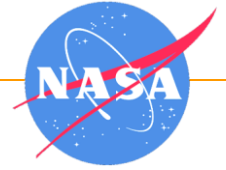


RGB (753)  
image, Eastern  
Virginia

Oct 5, 2001



# Disturbance History Example: Virginia



**Clearing  
Epoch**

**1985-88**

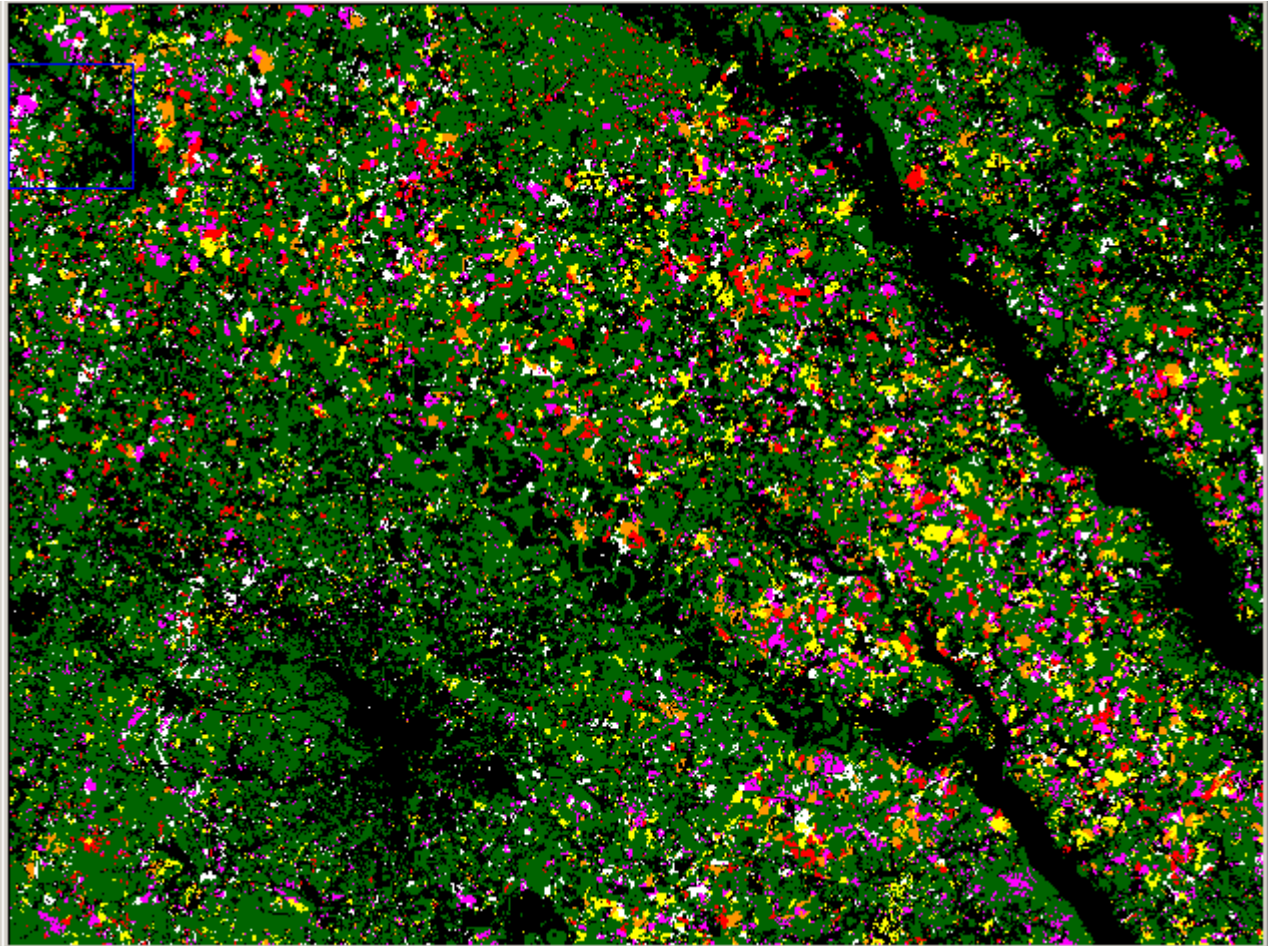
**1988-91**

**1991-95**

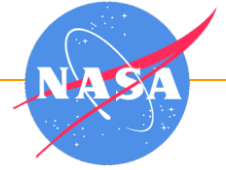
**1995-99**

**1999-01**

**Undisturbed  
Forest**



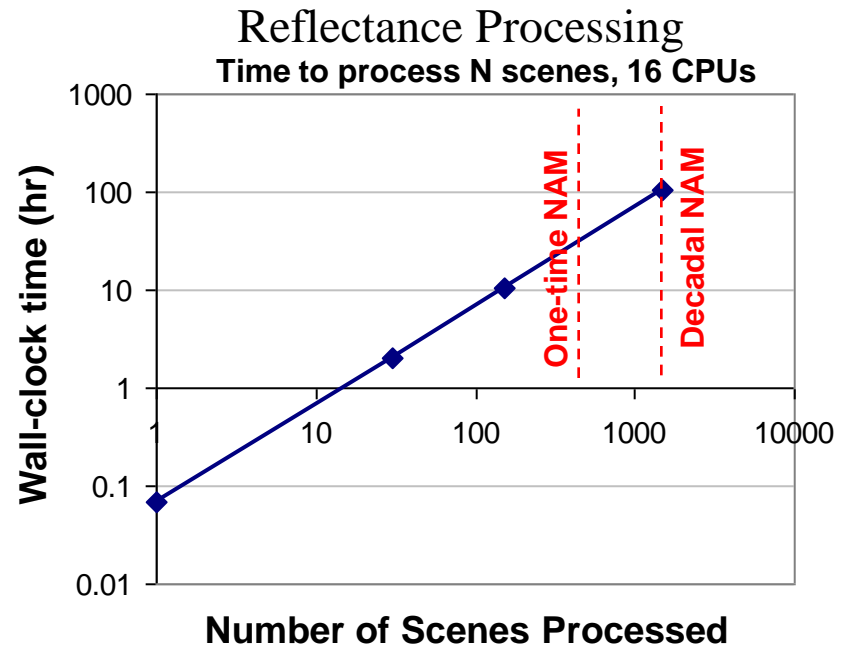
# Processing System



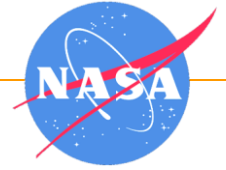
Project requires repeated, automated processing of ~1800 scenes (~0.5 TB).

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



## *Carbon Management*

**LEDAPS**

**USFS FIA**

- biomass assimilation
- Improved plot stratification

**CQUEST DSS**

- improved forest NEP

**USDA BARC**

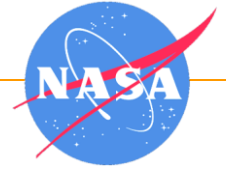
- modeling soil carbon
- Inputs from crop residues

## *Agriculture Efficiency*

**USDA FAS/NASS**

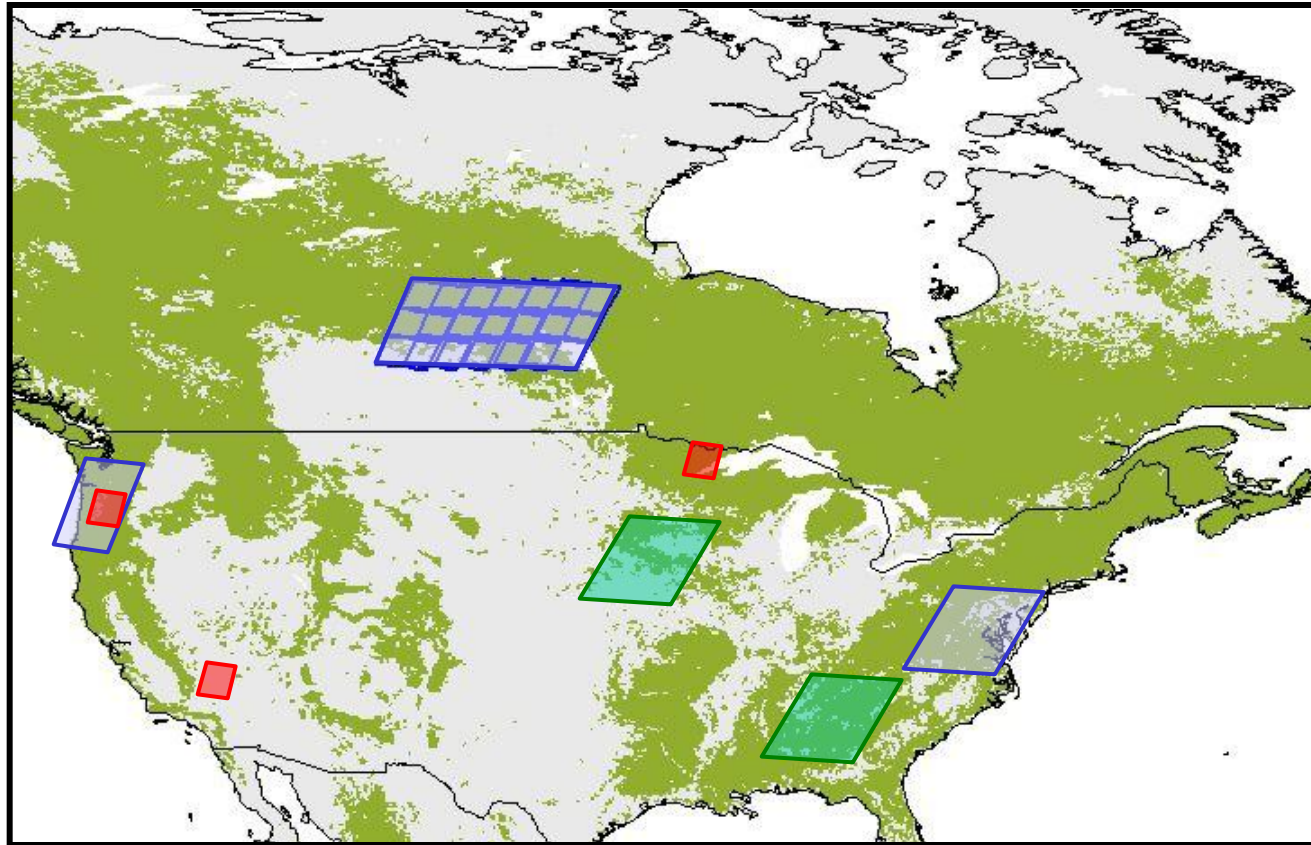
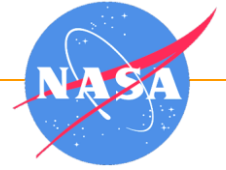
- improved crop assessment

# 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

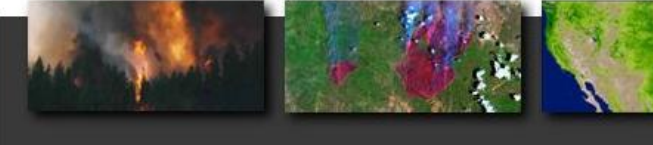
■ Collaborators

■ Large-Area/Disturbance

# LEDAPS Web Page



## LEDAPS



### Landsat Ecosystem Disturbance Adaptive Pro

LEDAPS is a NASA-funded project to map North American forest disturbance satellite record. LEDAPS will also produce comprehensive maps of surface re for the United States and Canada. LEDAPS is part of NASA's contribution to Carbon Program (NACP), a component of the [USGCRP Carbon Cycle Science](#)

- [Project Overview and Science Background](#)
- [Documents and Presentations](#)
- [Data Products](#)
- [Browse Images](#)
- [Participants](#)
- [Feedback](#)

http://modland.nascom.nasa.gov/ledaps/Landsat\_browse5... - Microsoft Internet Explorer

Address: http://ledaps.nascom.nasa.gov/browse.cgi

## Landsat Browse Images

**Satellite Instrument**

- LST (Landsat-5, Thematic Mapper)
- L7E (Landsat-7, Enhanced Thematic Mapper)
- LST & L7E (Landsat-5&7, Thematic & Enhanced Thematic Mappers)

**Scene/Aggregation**

- Boreas region Aggregation(Average)
- Boreas region Aggregation(Max. ndvi)
- Individual Scene

**Range for Individual Scene:**

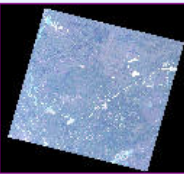

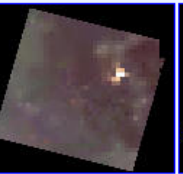
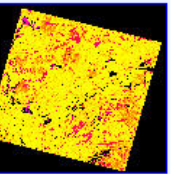
Path from  to

Row from  to

Submit Selection

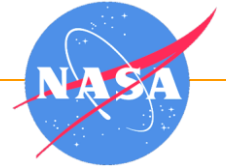
**Image Types:**

- REF (Top-of-the-atmosphere Radiance)
- DN (DN value)
- CSM (Cloud Snow Mask)
- SR (Surface Reflectance)
- AOT (Aresols)
- KT (K-T Transformation)
- HIS (histogram gb search line of Indkt)
- REG (Regression Logfile of Indreg)
- CSR (Corrected Surface Reflectance)

Scene	Top-of-the-atmosphere Radiance	Surface Reflectance	Aresols	K-T transformation
LST scene p033r021				
1992163				
Scene	Top-of-the-atmosphere Radiance	Surface Reflectance	Aresols	K-T transformation
Date				

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

# Conclusions



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

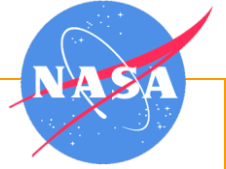
- *need community input for product definitions, validation*
- *collaboration with carbon/ecosystems modeling community to assess product utility and impact*

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)*

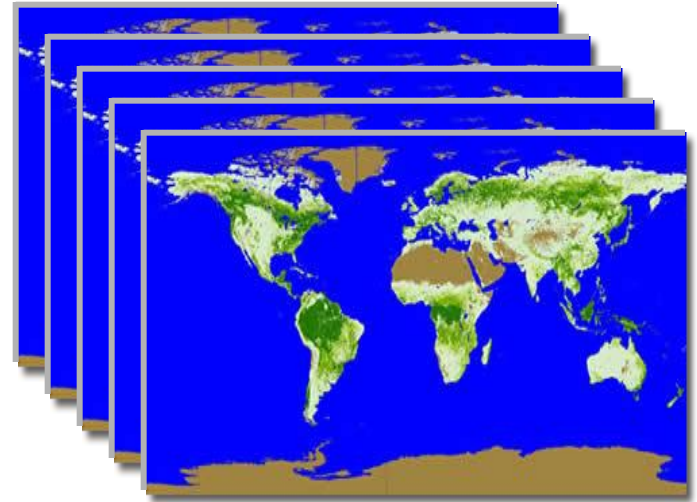


# LEDAPS

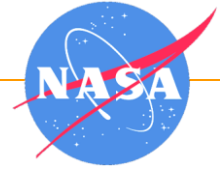


## Landsat Ecosystem Disturbance Adaptive Processing System

**Thank you!**



# LEDAPS Processing Overview



Landsat TM, ETM+

- Calibration
- Atmospheric Correction
- Cloud/Snow masking

Landsat MSS

- Radiometric Normalization

**Radiometrically Consistent Surface Reflectance Dataset (1975-2000)**

MODIS  
Spectral  
Trajectories

- Disturbance Rate, Type
- Land Cover Conversion Rate
- Spectral Unmixing for Fractional Change

Aggregation

**Disturbance/Recovery  
Products for Carbon Assessments**

QA/  
Validation

Preprocessing  
Analysis