LEDAPS Overview and Status

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NACP

The central objective of the North American Carbon Program is to measure and understand the sources and sinks of Carbon Dioxide (CO2), Methane (CH4), and Carbon Monoxide (CO) in North America and in adjacent ocean regions.

Specific Program Goals

Develop quantitative scientific knowledge, robust observations, and models to determine the emissions and uptake of CO2, CH4, and CO, changes in carbon stocks, and the factors regulating these processes for North America and adjacent ocean basins.

Develop the scientific basis to implement full carbon accounting on regional and continental scales.

Support long-term quantitative measurements of fluxes, sources, and sinks of atmospheric CO2 and CH4, and develop forecasts for future trends.

http://www.nacarbon.org

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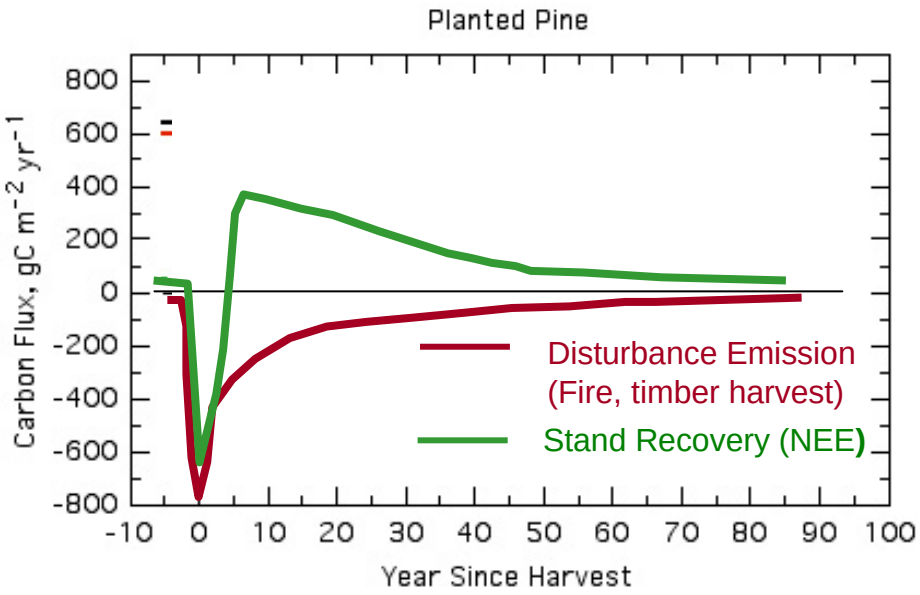
Background

- Forest disturbance (fire, harvest, insect damage) and recovery critical for carbon cycling
  - direct emissions
  - recovery ~ age distribution ~ NEE

- Patch size often small – requires Landsat-type data analysis

- NACP Science Plan calls for analysis of disturbance from satellite data



1985 1988 1999

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LEDAPS Goals

- **Generate surface reflectance (SR) products 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**
  - *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 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**.

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LEDAPS Processing Overview

Landsat TM, ETM+

Landsat MSS

- Calibration
- Atmospheric Correction
- Cloud/Snow masking

- Radiometric Normalization

Radiometrically Consistent Surface Reflectance Dataset (1975-2000)

Preprocessing

Analysis

MODIS Products

- Disturbance Rate via Disturbance Index
- Biophysical change from canopy reflectance model

Aggregation

QA/ Validation

Disturbance/Recovery Products for Carbon Assessments

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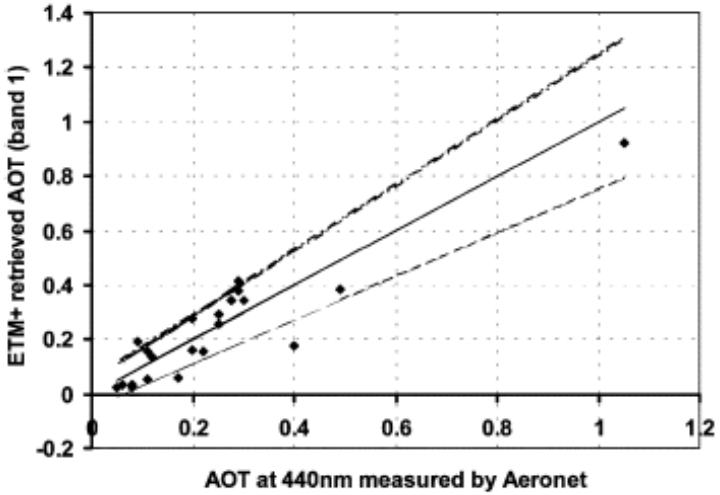
Atmospheric Correction

Based on MODIS/6S radiative transfer approach

water vapor from NCEP re-analysis data
ozone from TOMS, EP-TOMS
topographic-dependent Rayleigh correction

Aerosol optical thickness estimated from imagery using the Kaufmann et al (1997) "Dense, dark vegetation" approach

- estimate blue reflectance based on TOA SWIR 2
- difference between TOA_{blue} and SR_{blue} gives AOT
- interpolate valid targets across image



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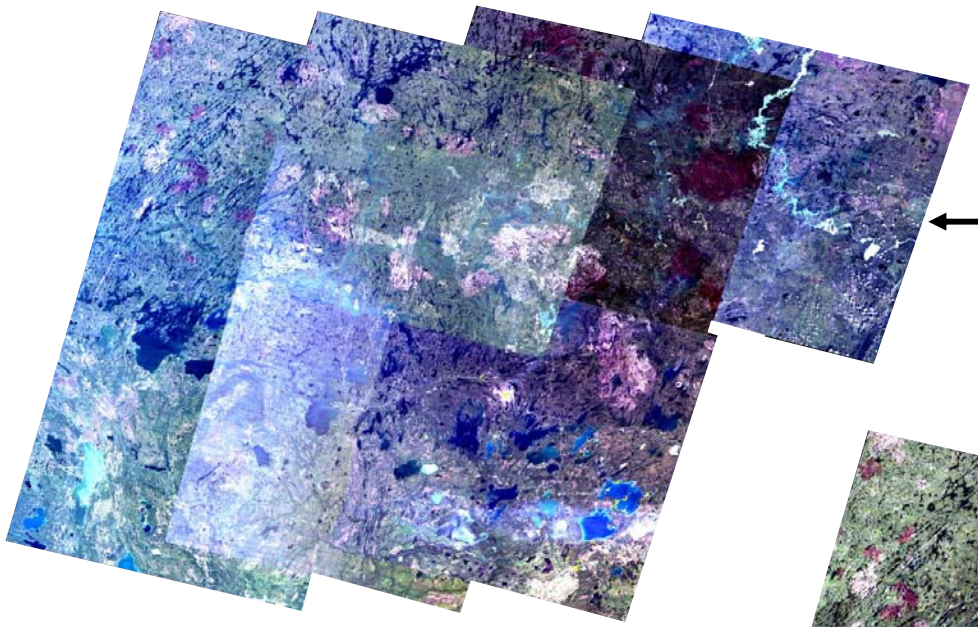
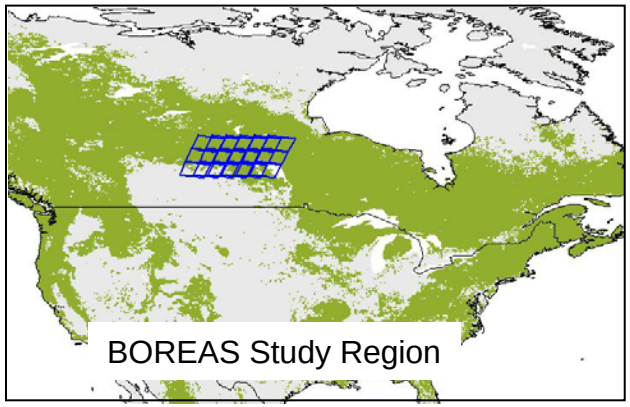
Atmospheric Correction

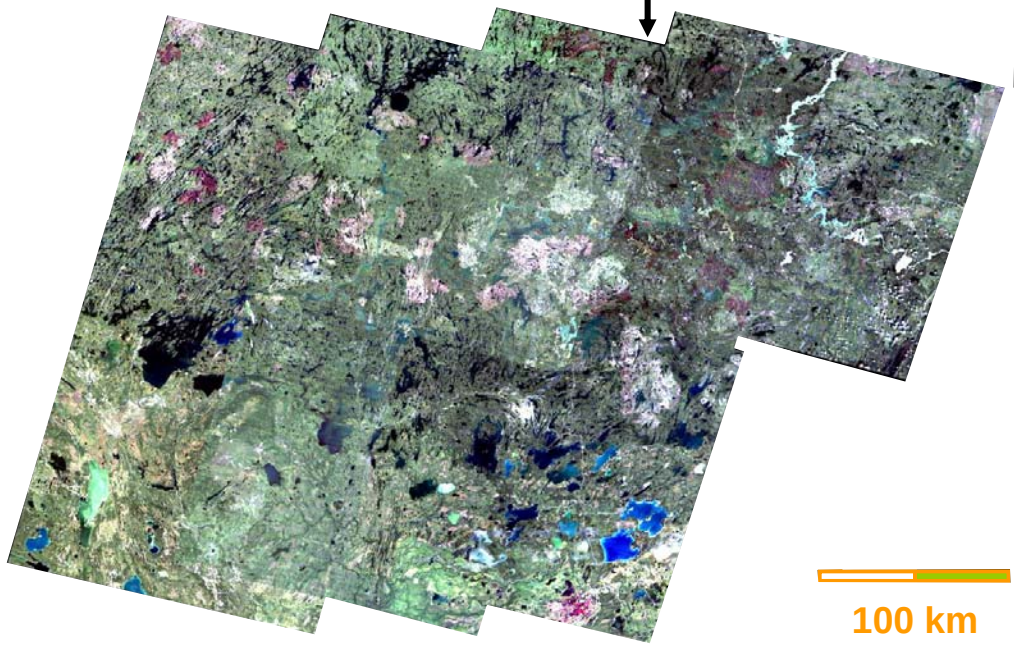
1990's Landsat-5 mosaic

TOA reflectance

Surface reflectance



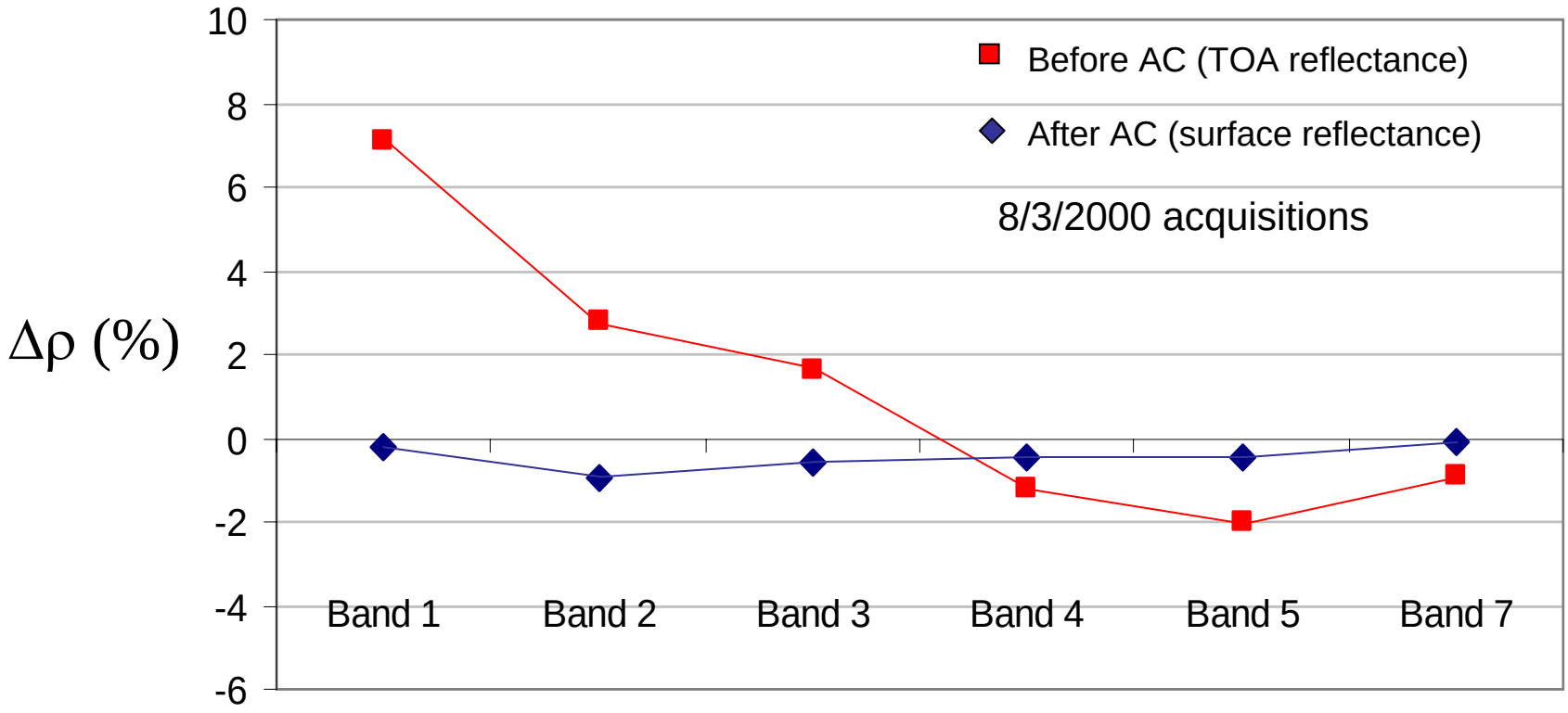




100 km

Effect of Atmospheric Correction

(MOD9A surface reflectance) – (ETM+ reflectance), 8/3/00



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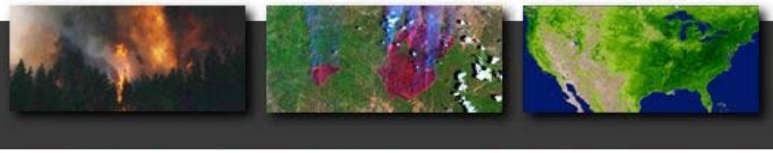
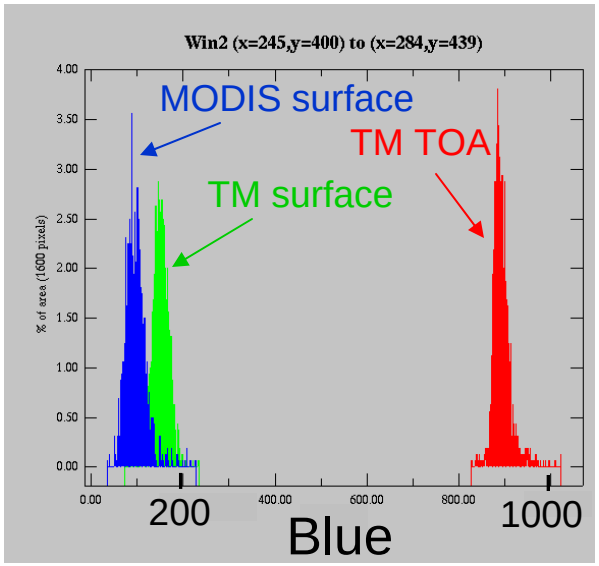
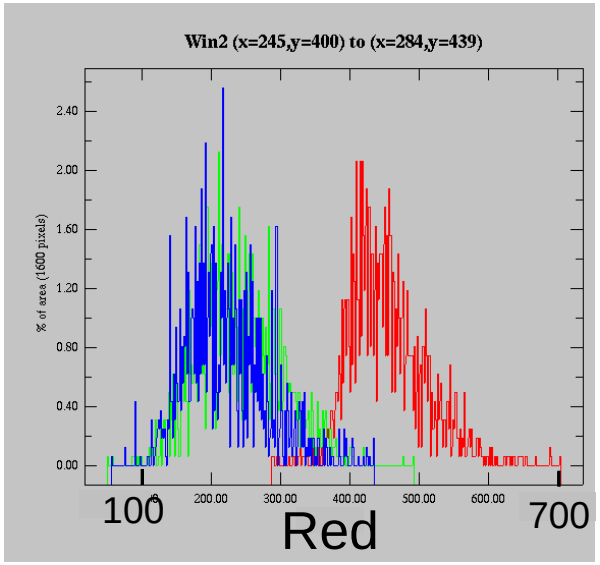
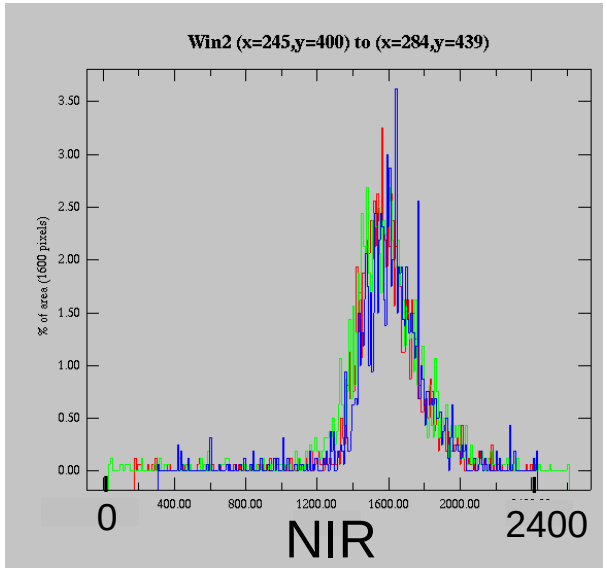
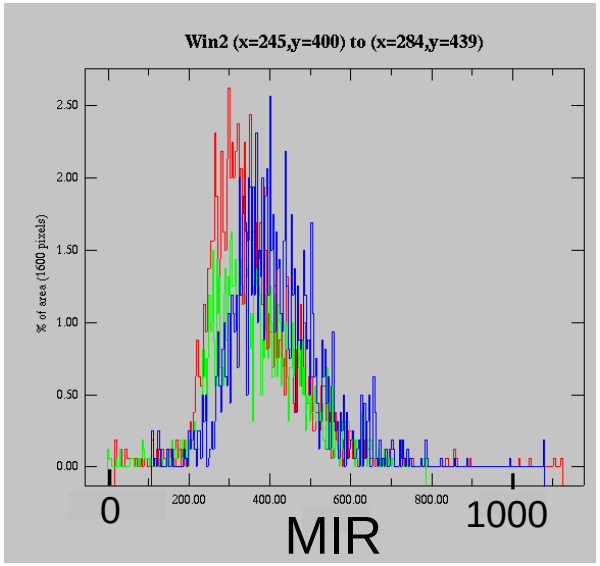


Reflectance Validation

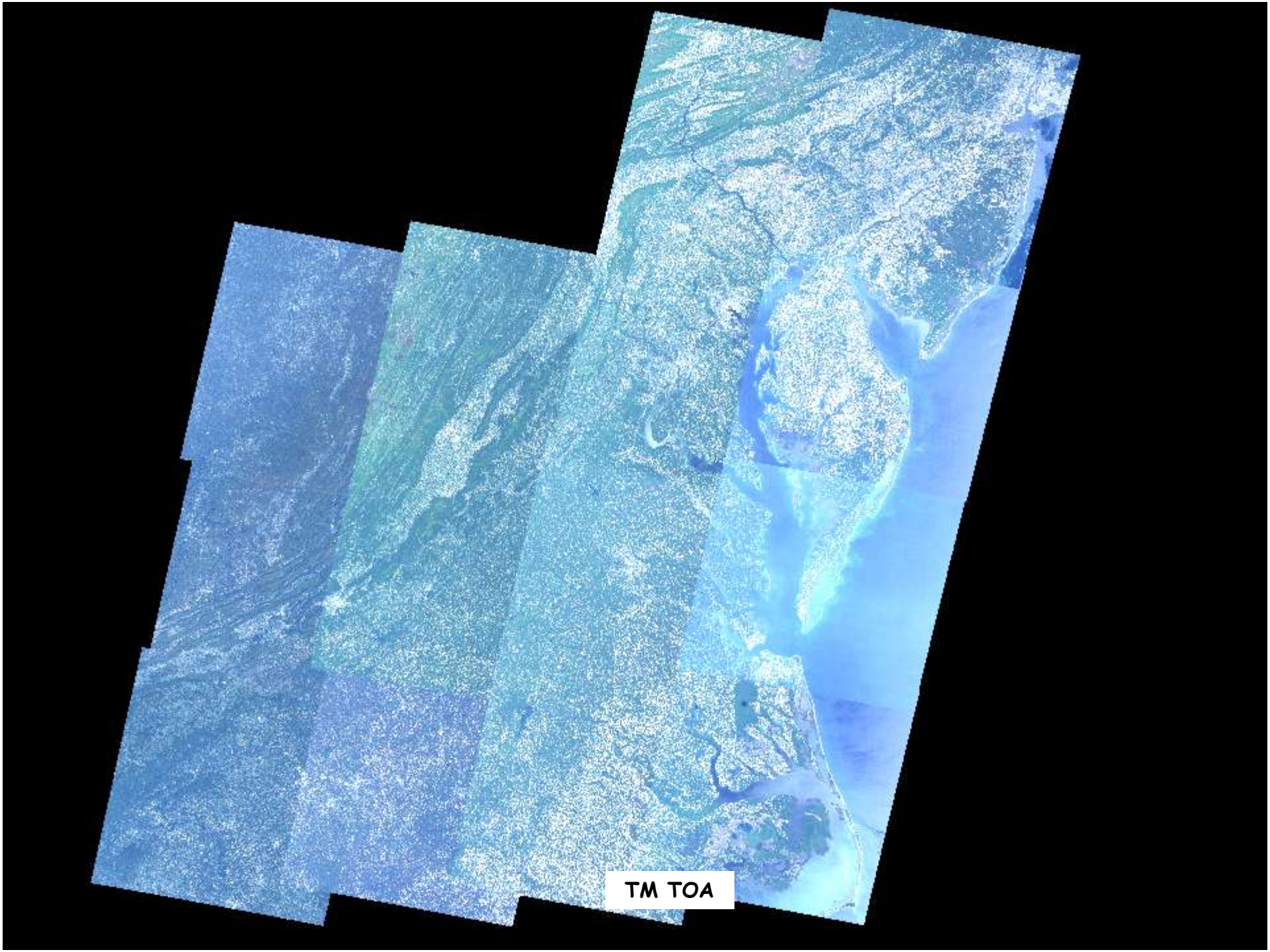


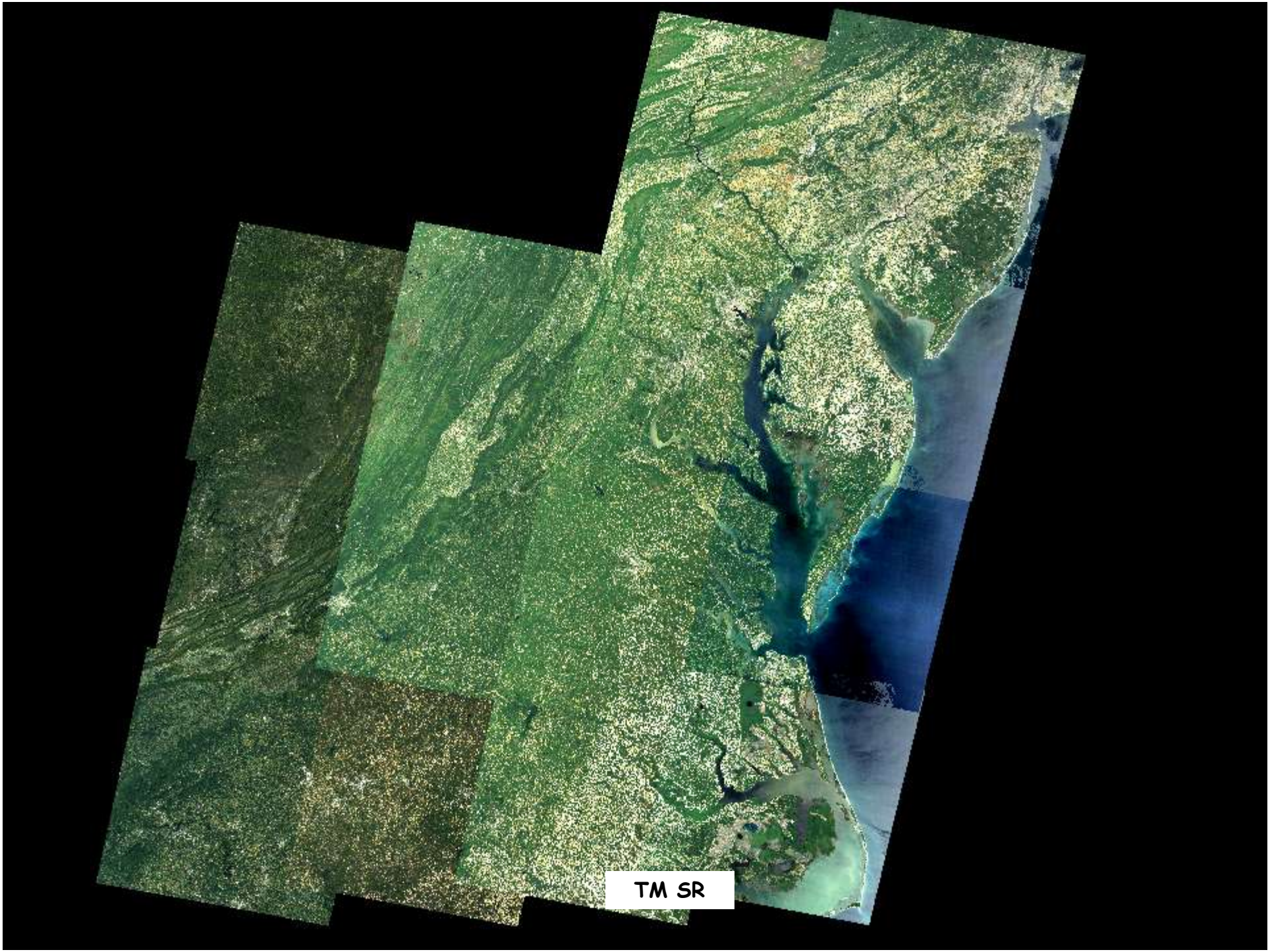






Units:
Reflectance
(x 10000)


TM TOA


TM SR

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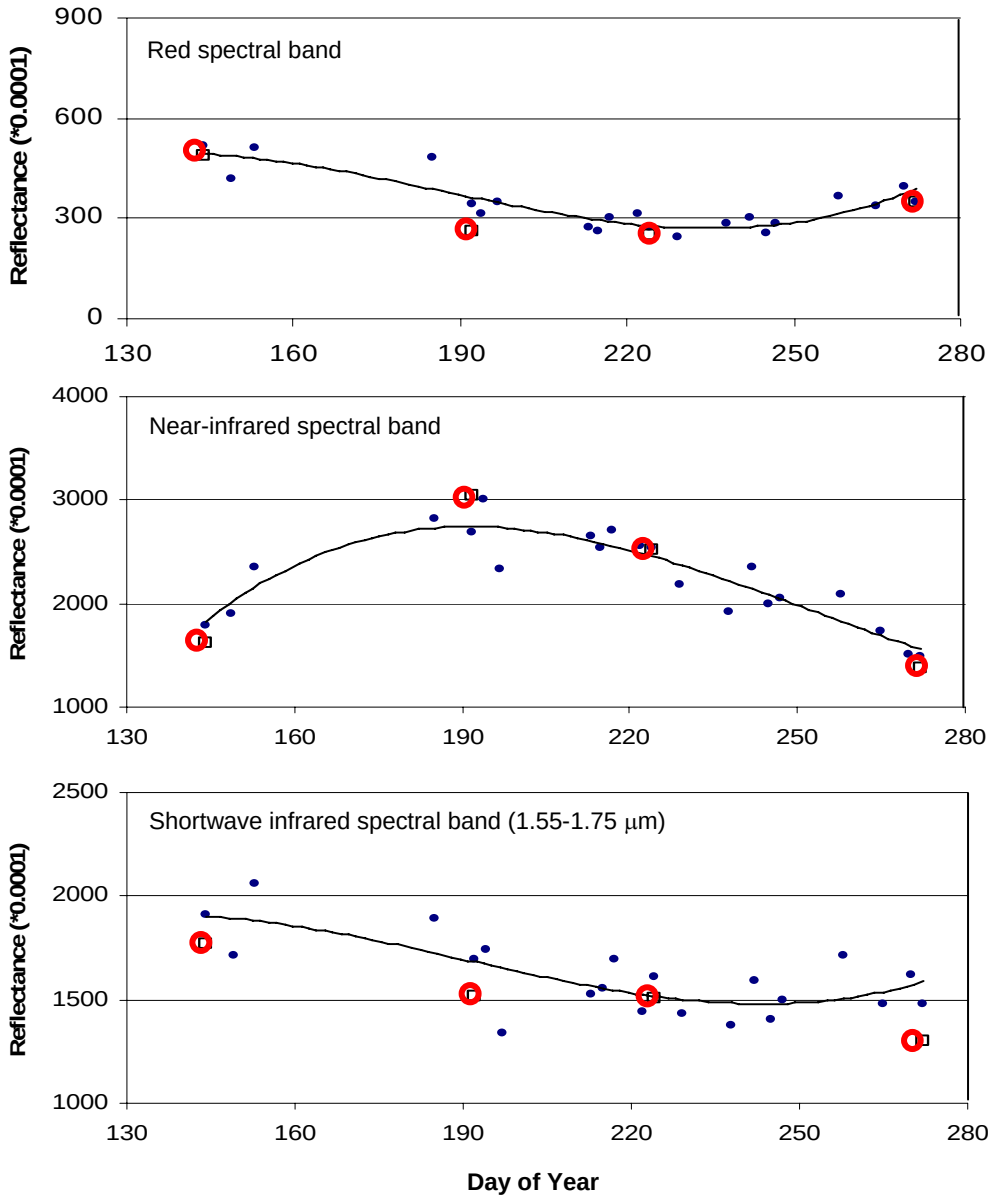
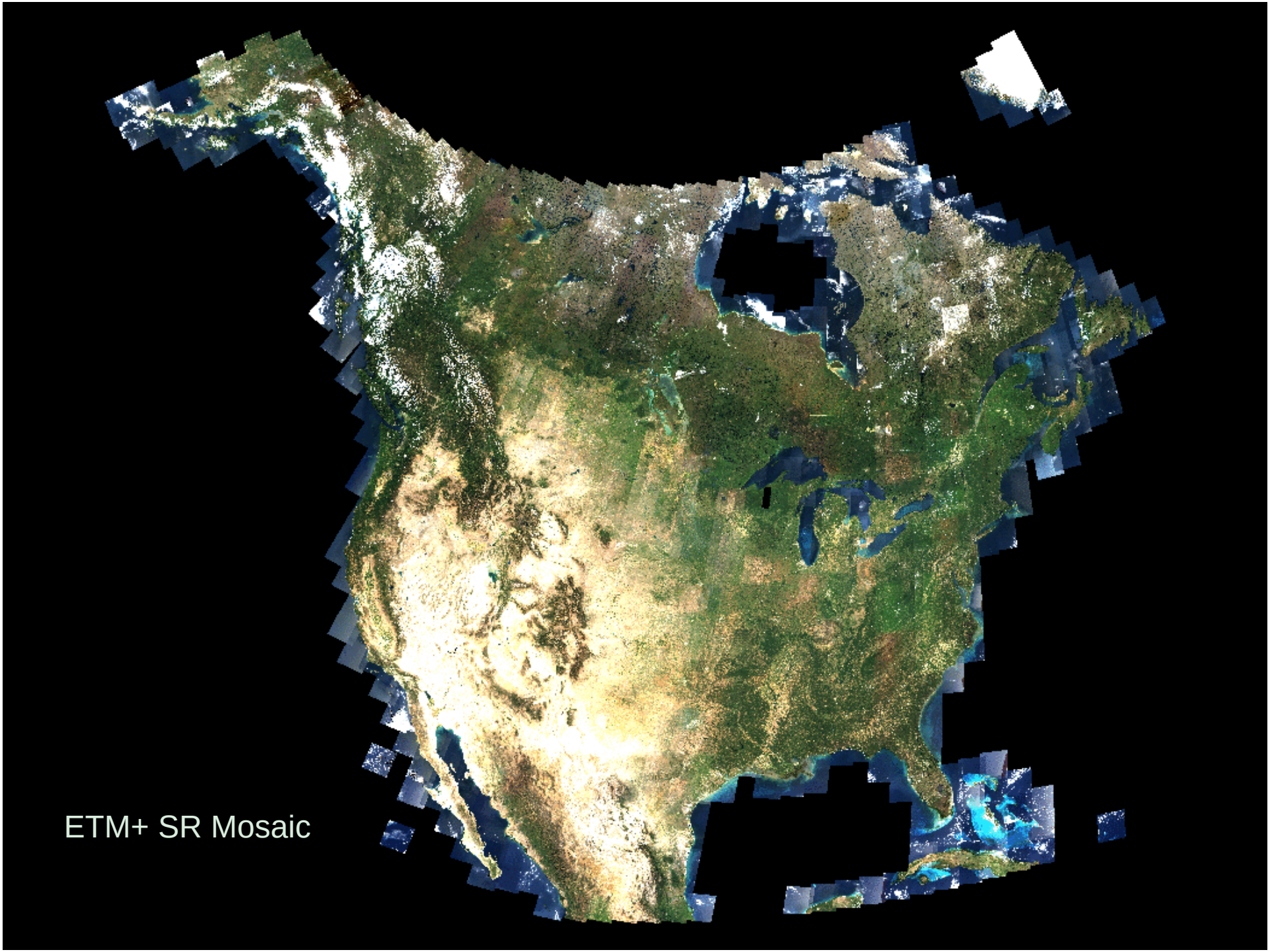
ETM+ Comparison with MODIS




ETM+ SR Mosaic

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Forest Disturbance Mapping

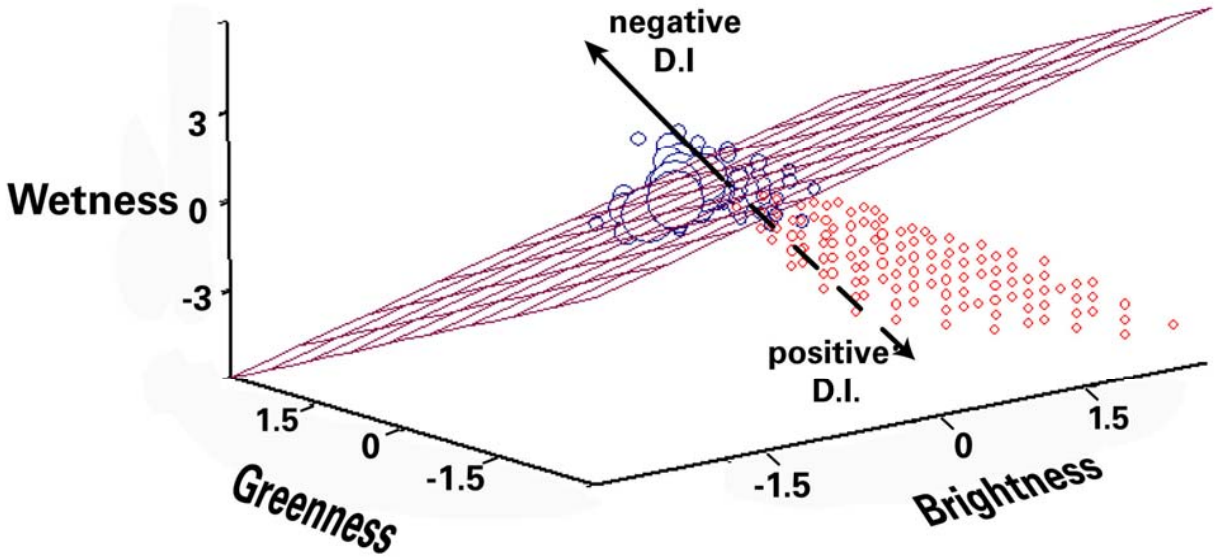
Initial Goal: stand-clearing disturbances (harvest, fire) and secular changes in forest cover

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)

Disturbance Index: $Brightness_{rescaled} - (Greenness_{rescaled} + Wetness_{rescaled})$



$$Brightness_{rescaled} = (B - \mu_{forest})/\sigma_{forest}$$

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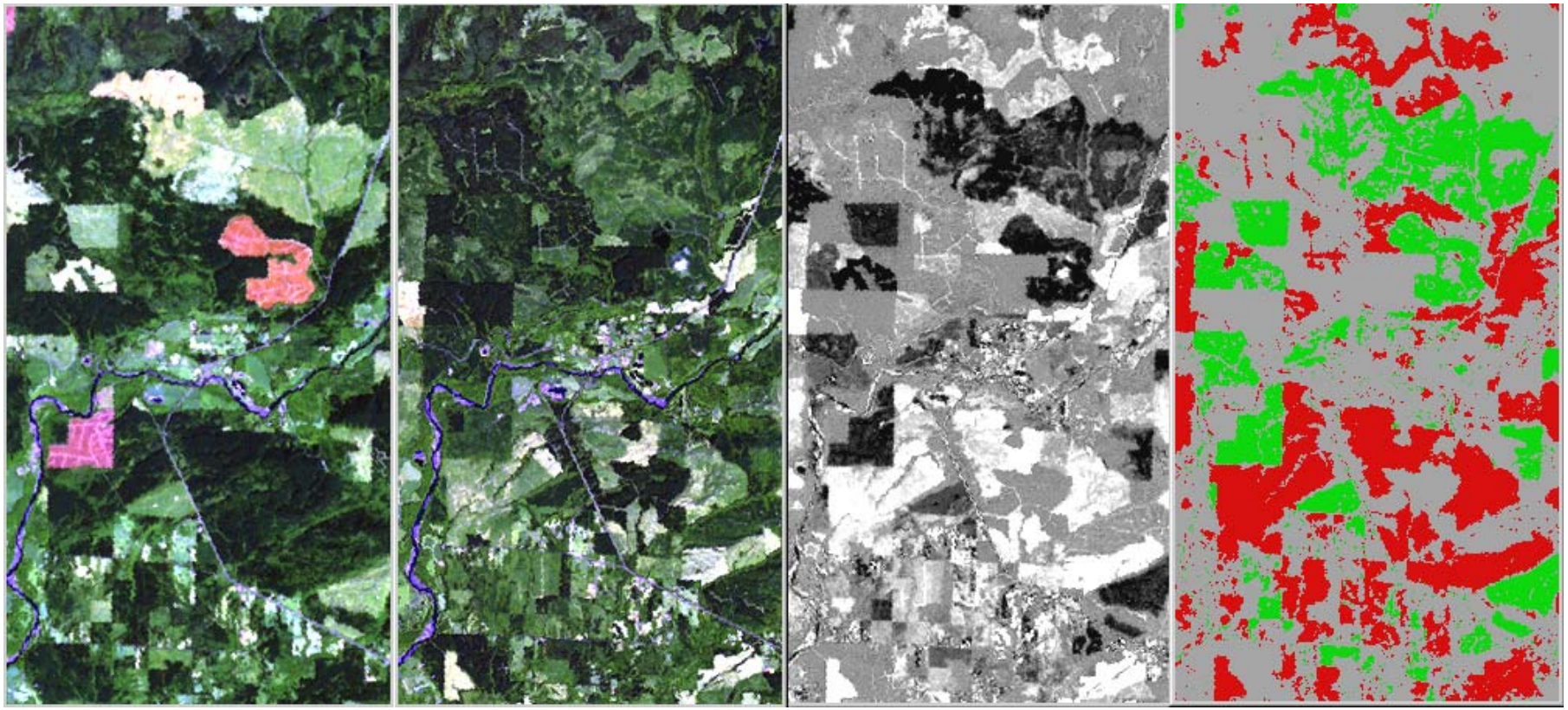
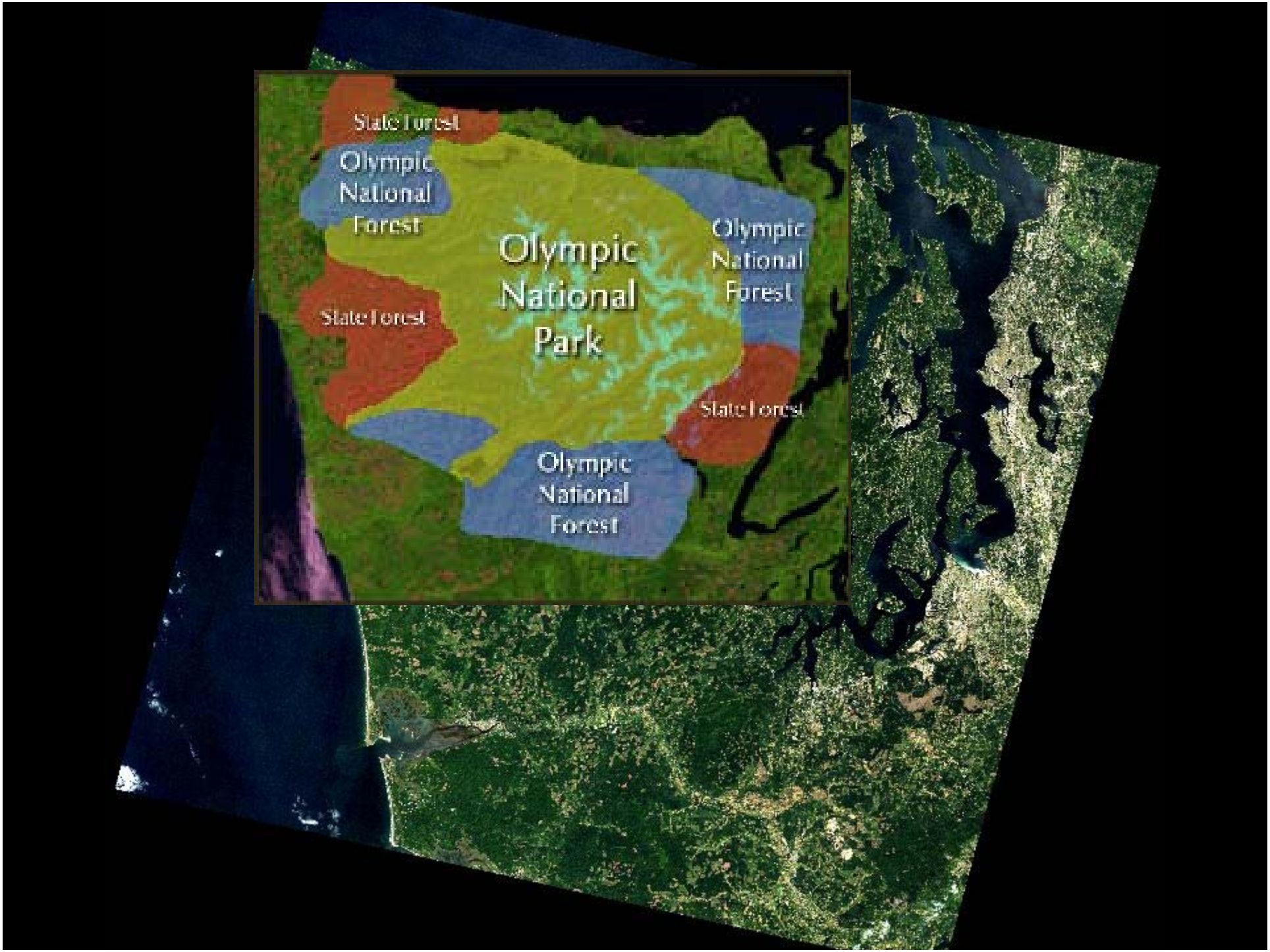
Disturbance Index Example

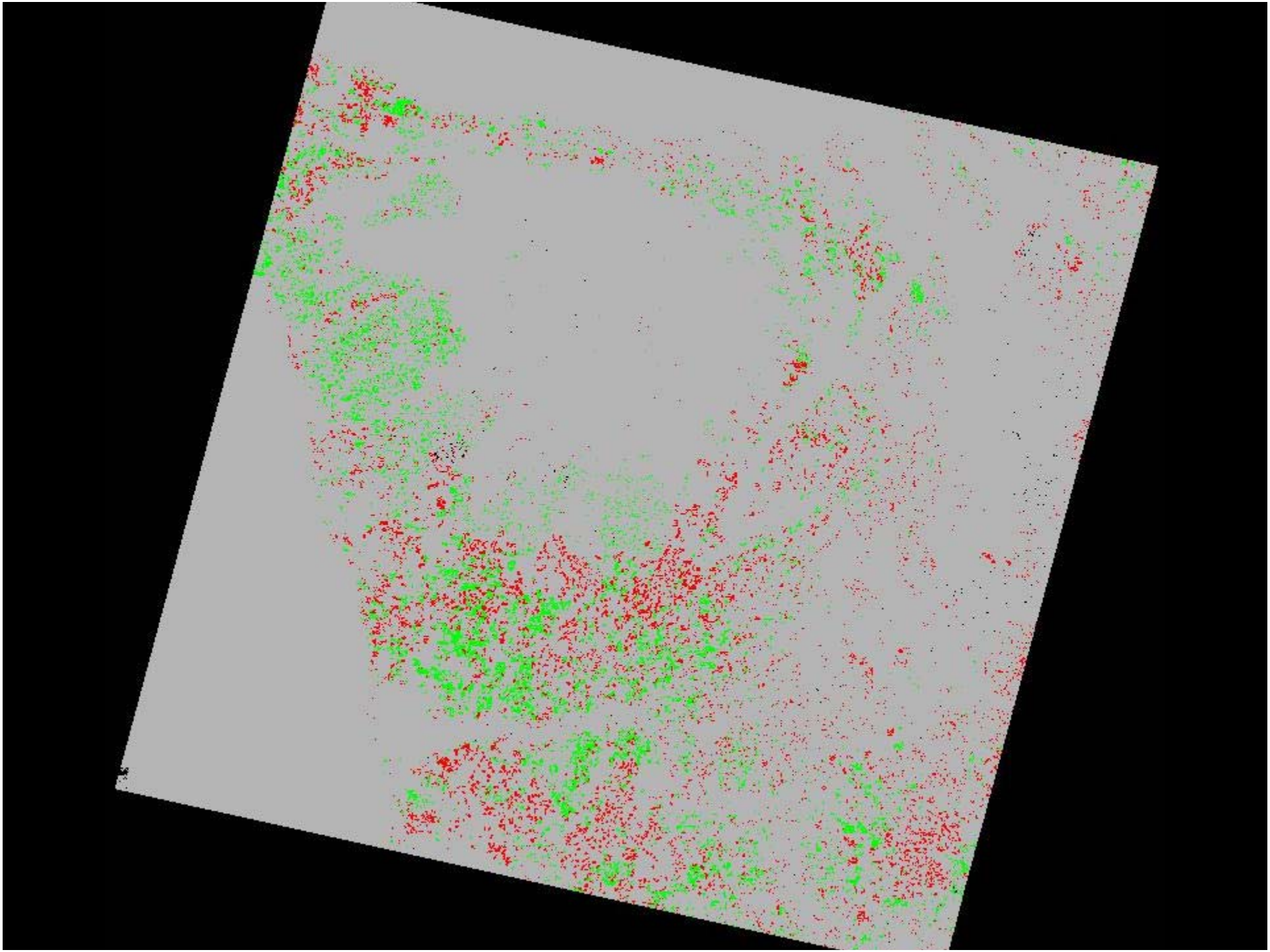
Olympic Peninsula



1988 2000 Disturbance Index Change Map

5km


State Forest
Olympic National Forest
Olympic National Park
Olympic National Forest
State Forest
State Forest
Olympic National Forest



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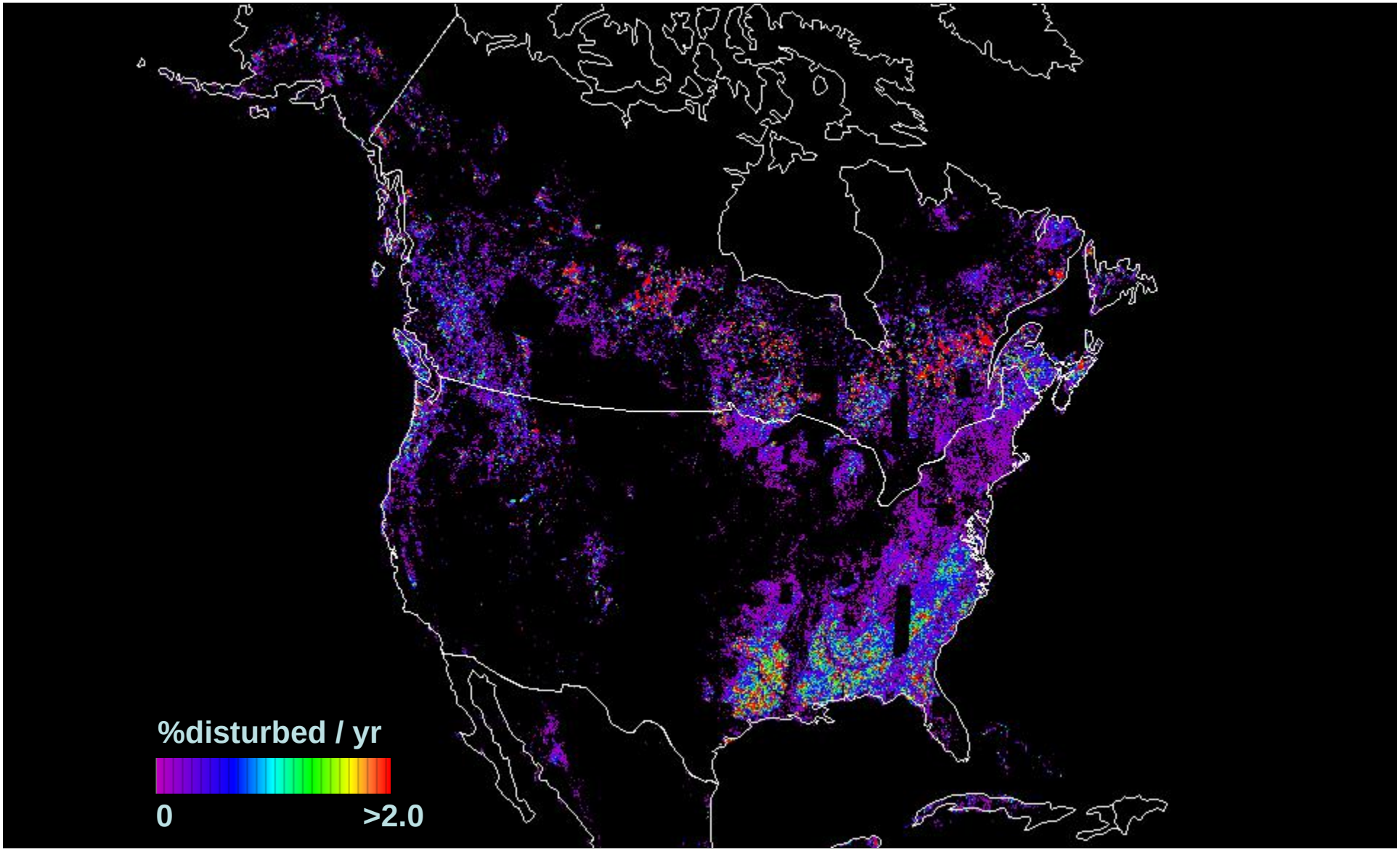
Forest Disturbance



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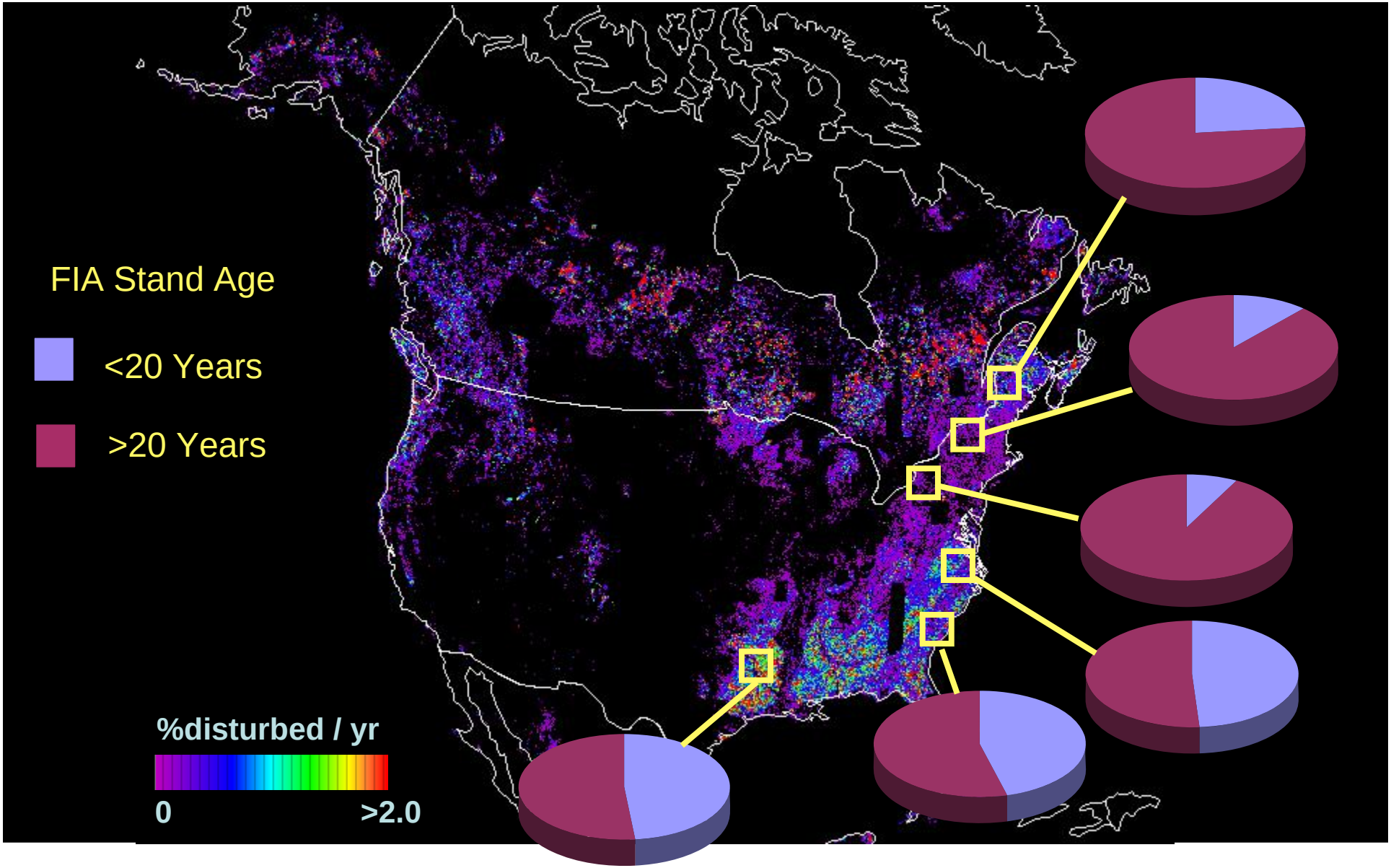
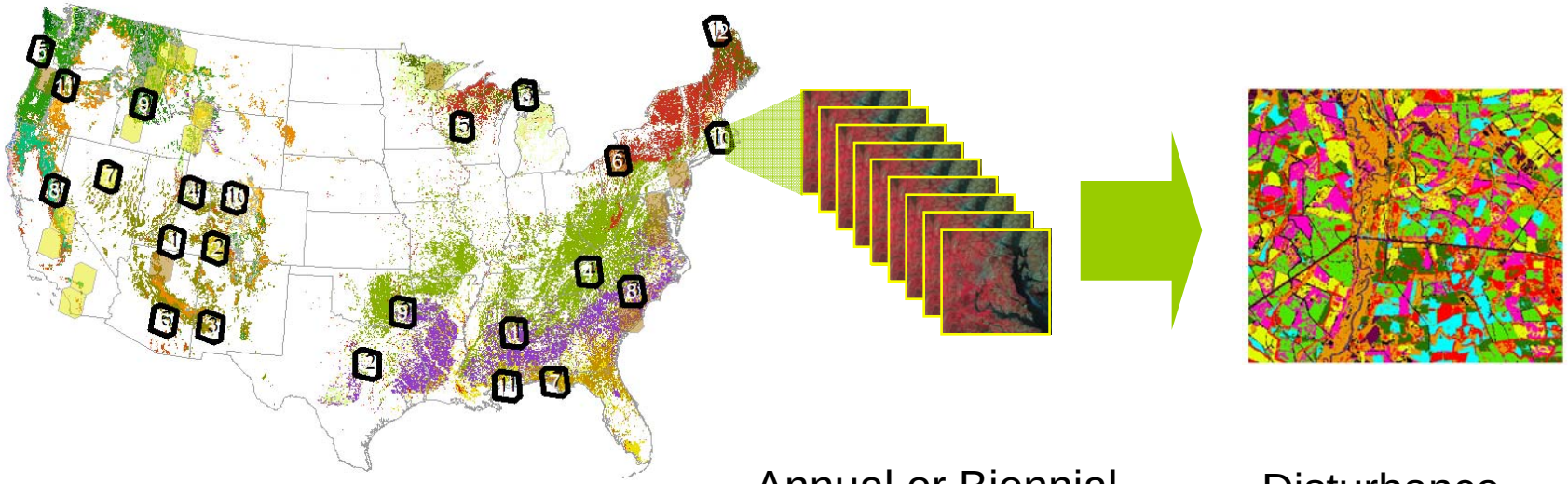


Sampling Approach

S.N. Goward, "*North American Forest Disturbance and Regrowth since 1972*"



~25 Sample Sites

Annual or Biennial Image Time Series "Data Cubes" (1972-2004)

Disturbance history / stand age + regrowth rate (~ biomass?)

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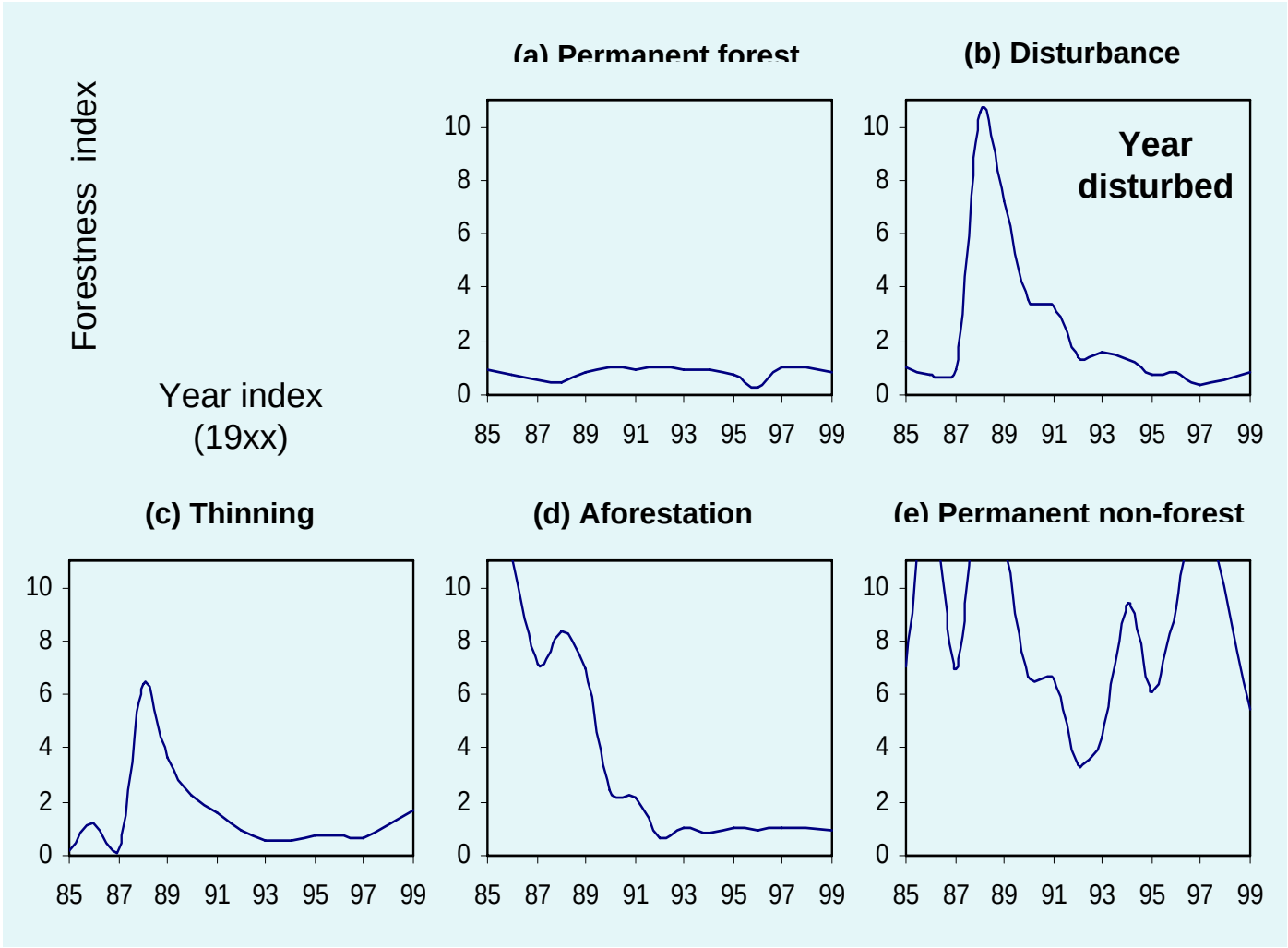
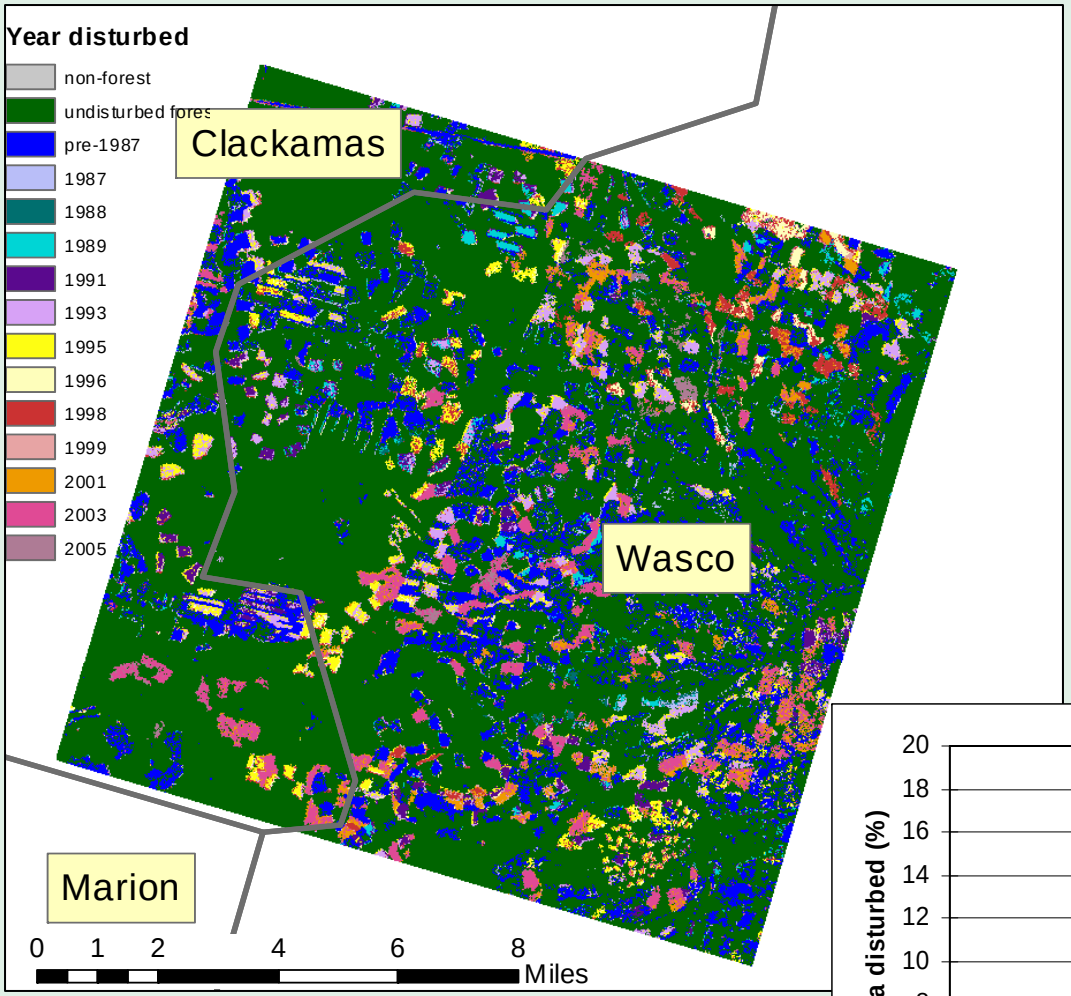
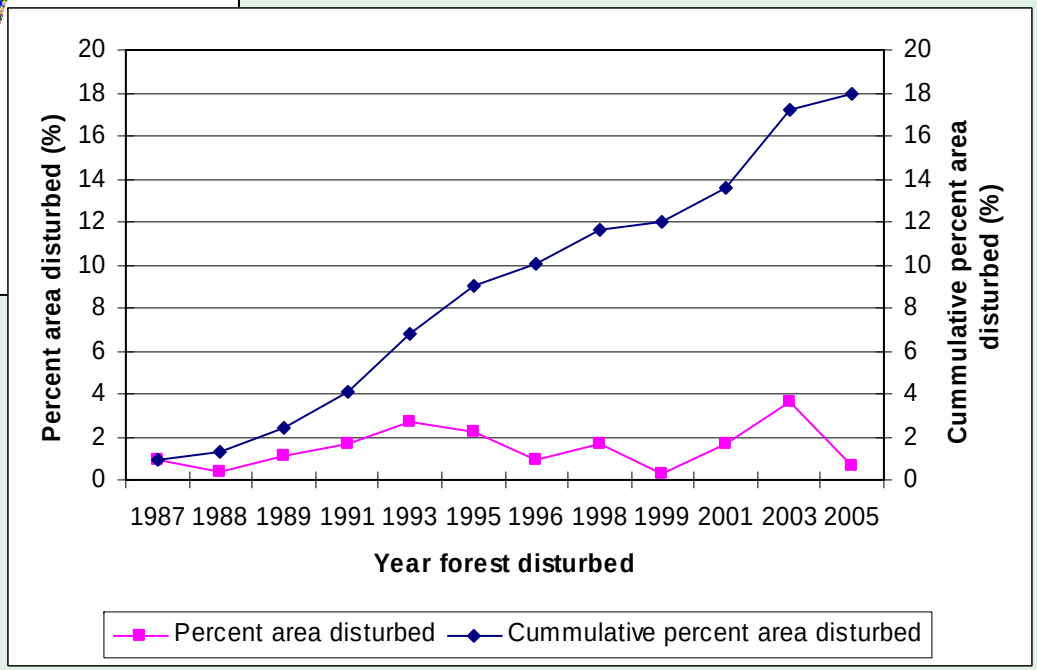
Time Series Analysis





Landsat mapped forest change between 1987 and 2005 in western Oregon along the Clackamas County-Wasco County border (left)

Temporal variation of the percentage of change area (below)



Year disturbed

non-forest
undisturbed forest
pre-1987
1987
1988
1989
1991
1993
1995
1996
1998
1999
2001
2003
2005

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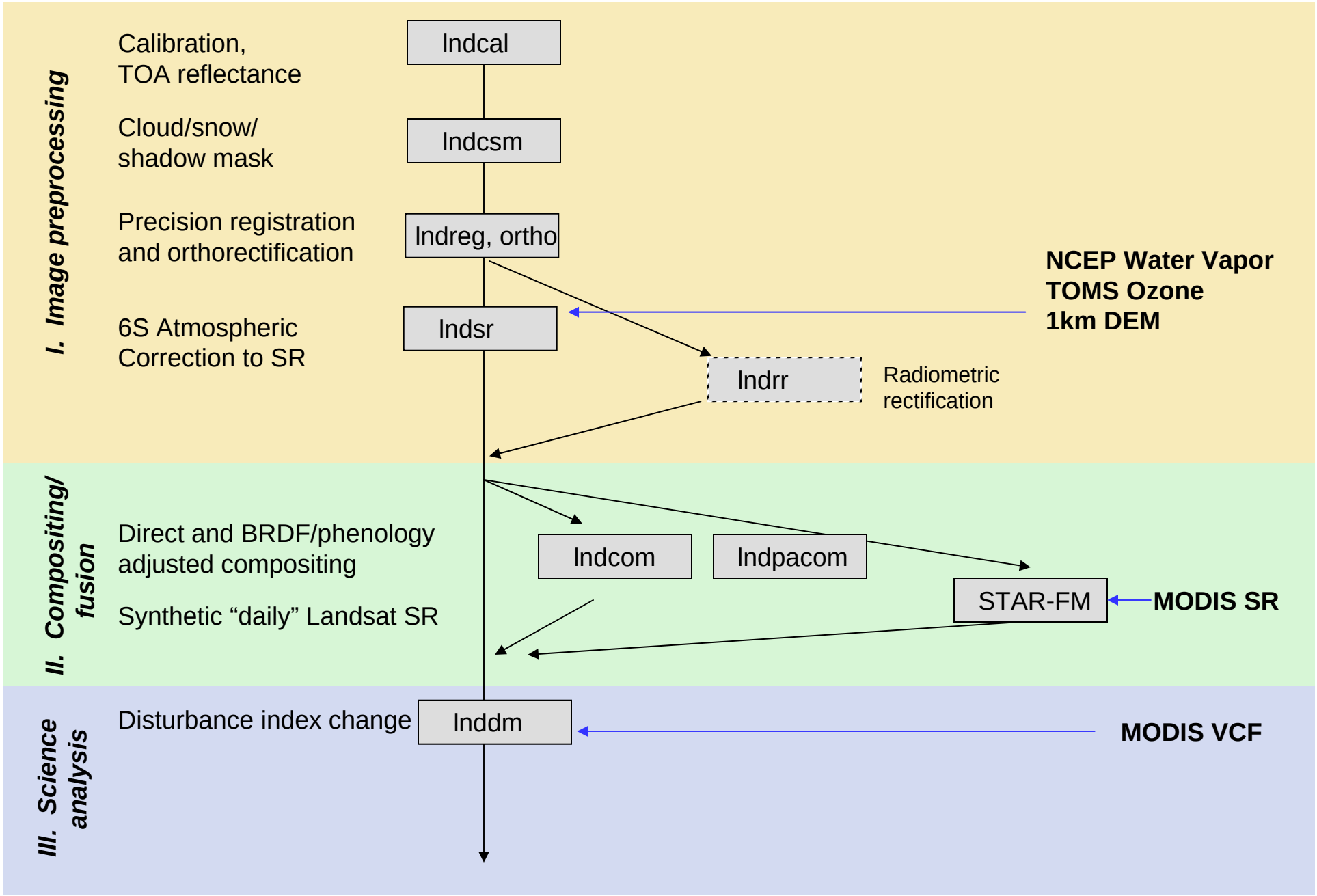

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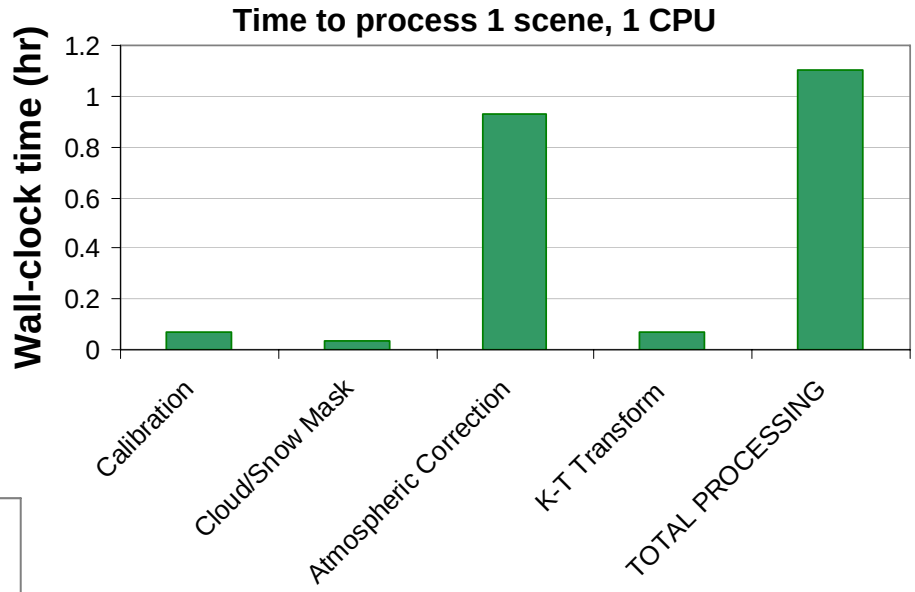
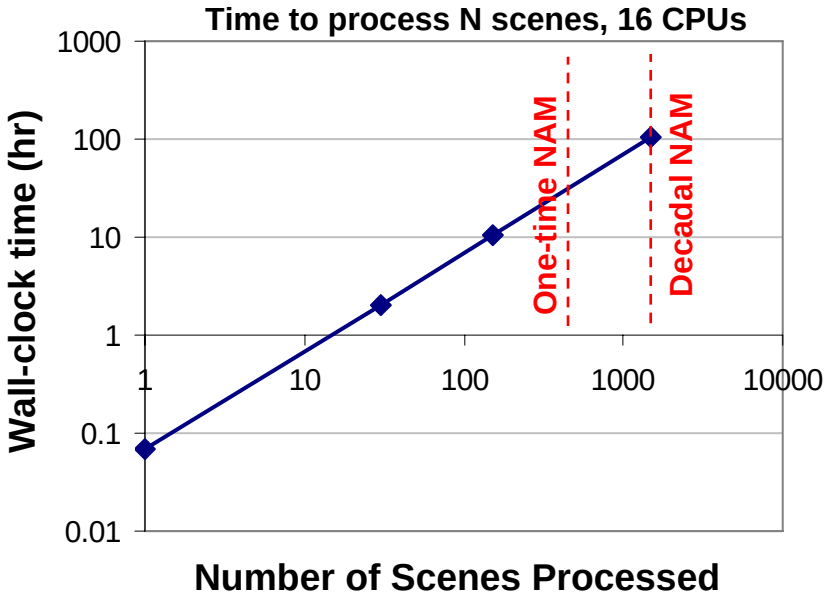
System Performance

- MODAPS architecture allows rapid processing of large data volumes
- Uses commodity PC's – one scene per processor
- PGE (product generation executables) are C/C++ modules designed to work with standard library routines (HDF, geographic)





Processing a 30-year North American surface reflectance dataset should take < 4 days

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Summary and Current Status

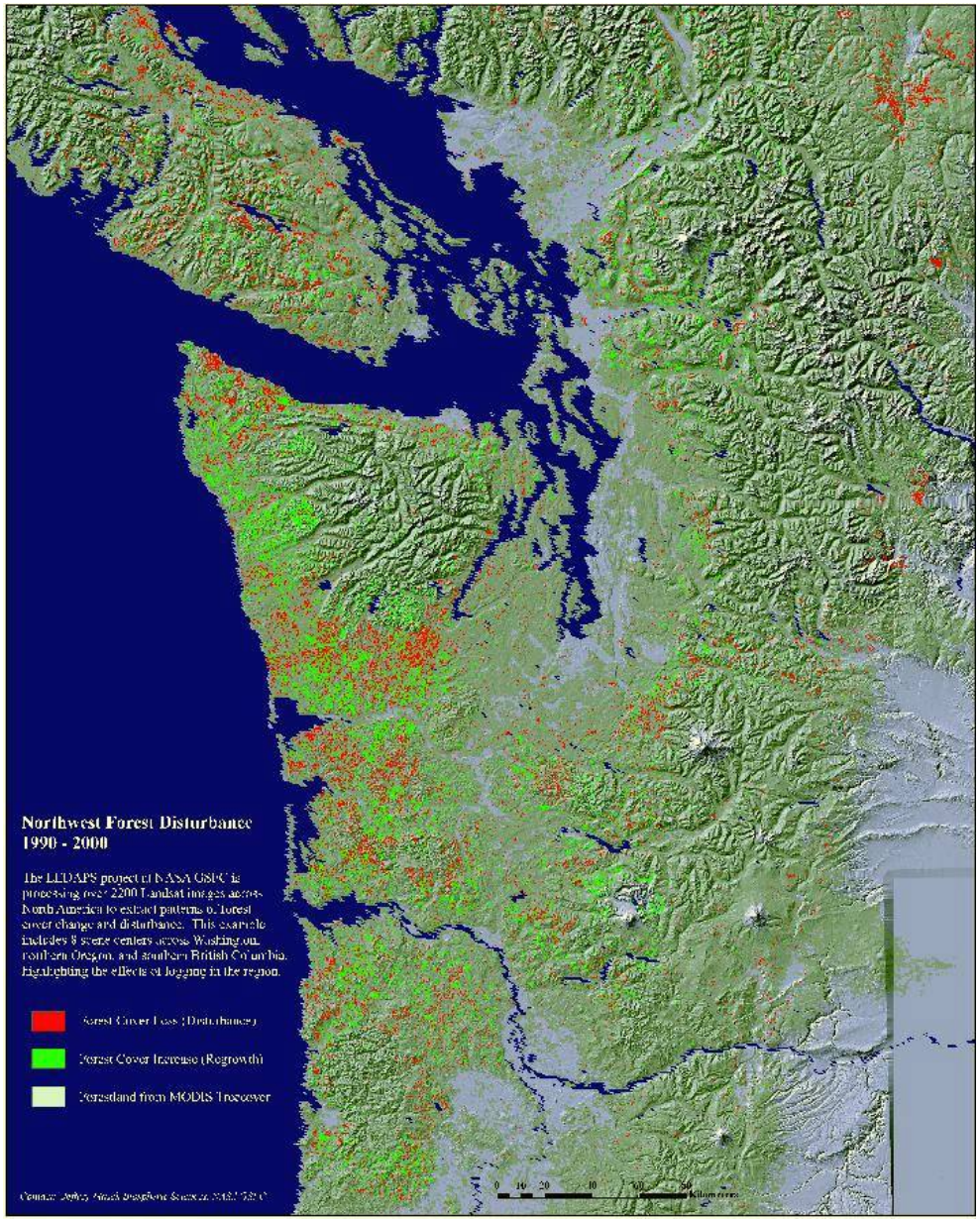
-**LEDAPS offers one way to move toward:**

- automated processing chains for Landsat data
- higher level Landsat products (reflectance, biophysics, LC/ΔLC)
- reflectance-based analyses of land cover condition
- merging of multiple RS sources (Landsat, MODIS, IRS, etc)

•Current LEDAPS project funding 2003-2007

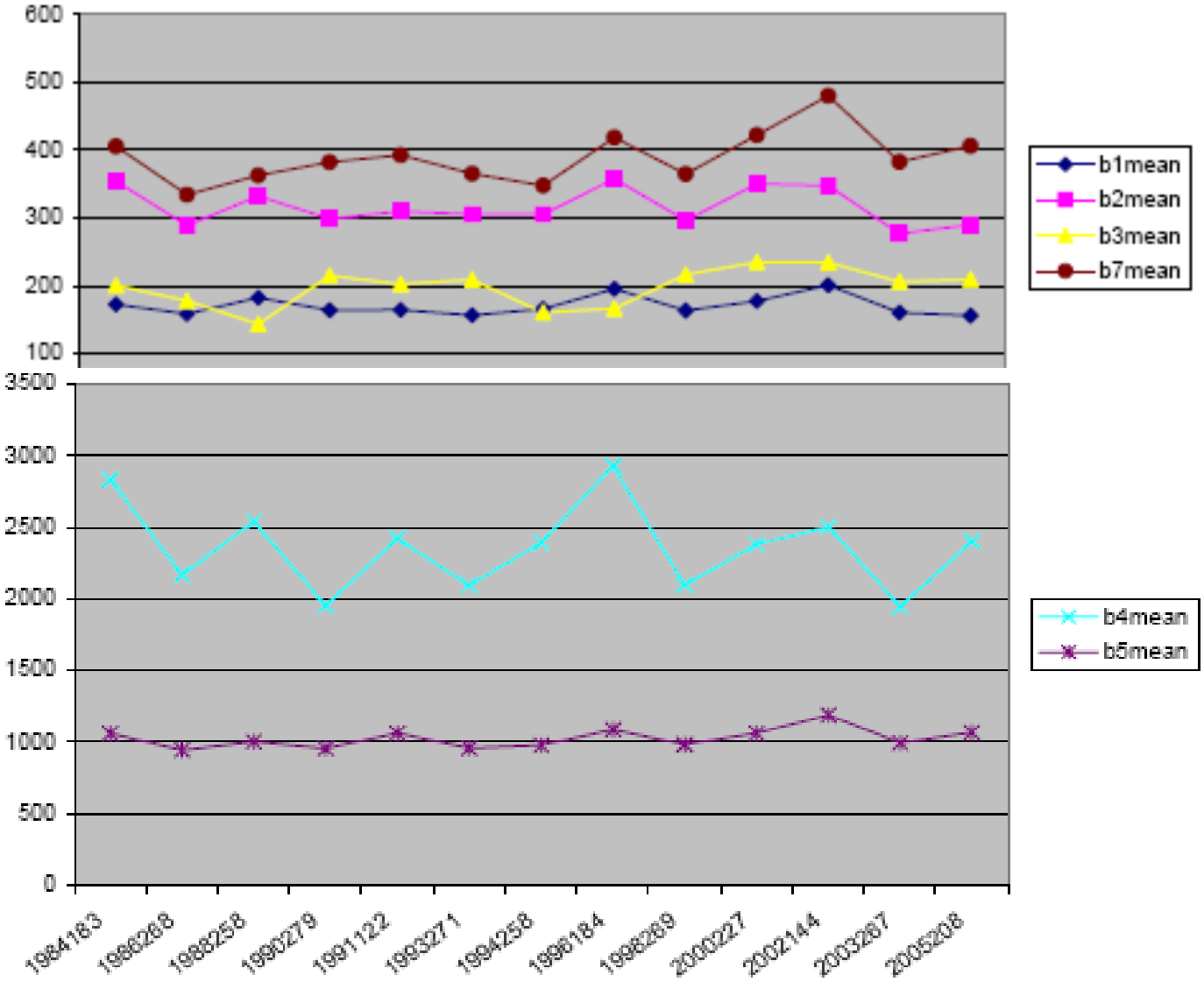
•Two pending proposals to continue LEDAPS capability at GSFC through 2010

•Vermote et al project funded through Landsat Science Team to continue development of atmospheric correction work


Northwest Forest Disturbance
1990 - 2000
The LEDAPS project at NASA GSFC is processing over 2200 Landsat images across North America to extract patterns of forest cover change and disturbance. This example includes 8 scene centers across Washington, northern Oregon, and southern British Columbia. Highlighting the effects of logging in the region.
Forest Cover Loss (Disturbance)
Forest Cover Increase (Regrowth)
Forestland from MODIS Treecover

Thank You

Florence, SC, p16r36



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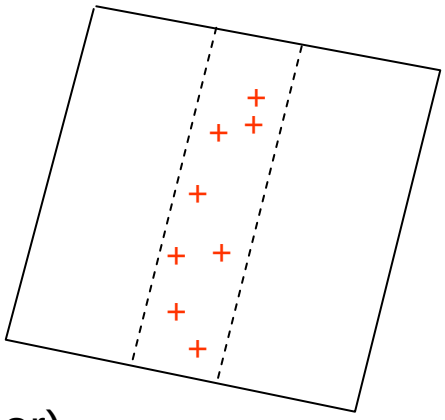
LEDAPS Orthorectification Algorithm

$$X' = X + \Delta X_{transl} + \Delta X_{topo}(x,y) \{+ ROT\}$$

1. Automated GCP selection to calculate ΔX_{transl}
   - Select candidate points along nadir
   - Subpixel cross-correlation within window



2. Apply ΔX_{transl} to target image

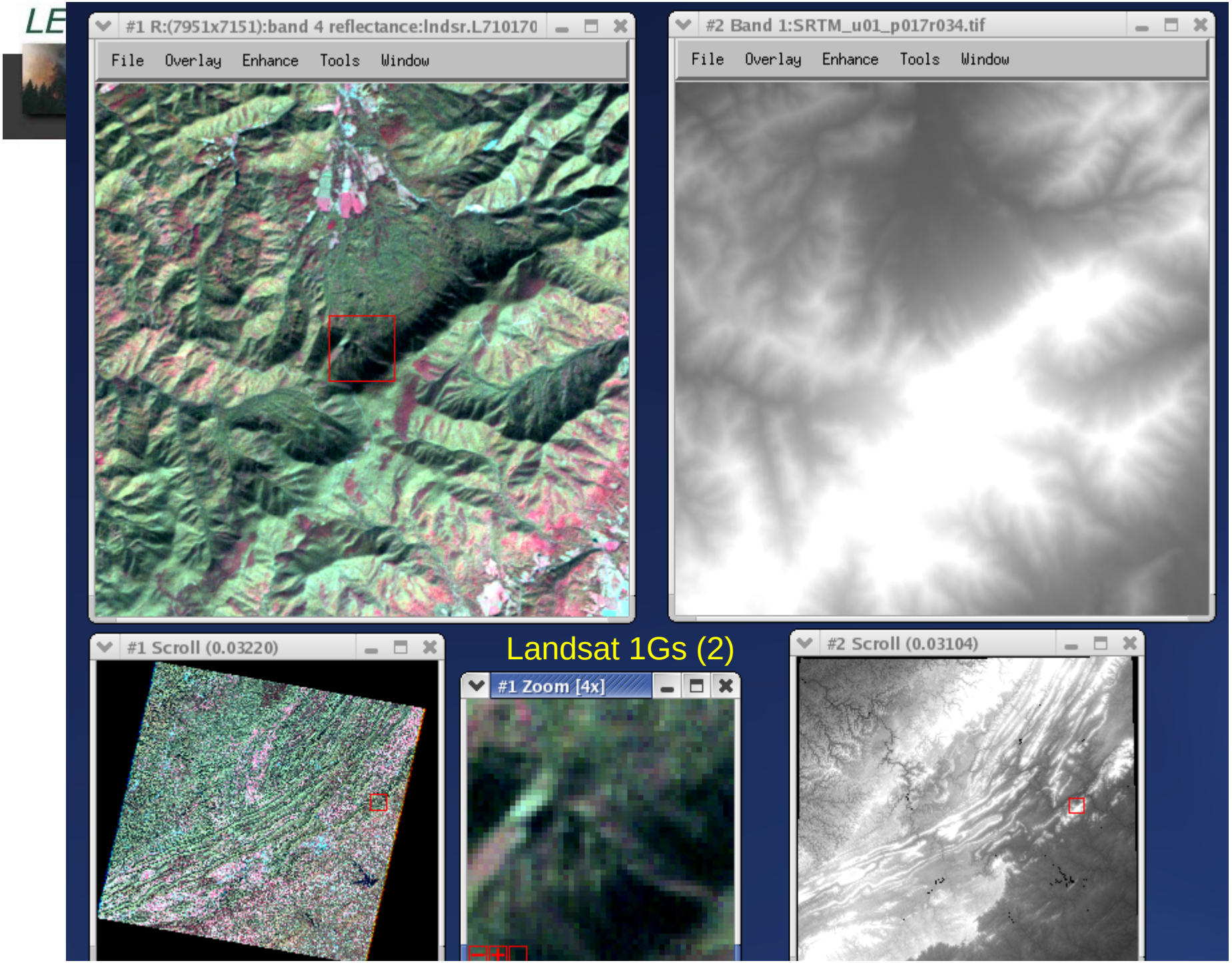
3. Calculate topographic displacement using DEM and LOS calculation

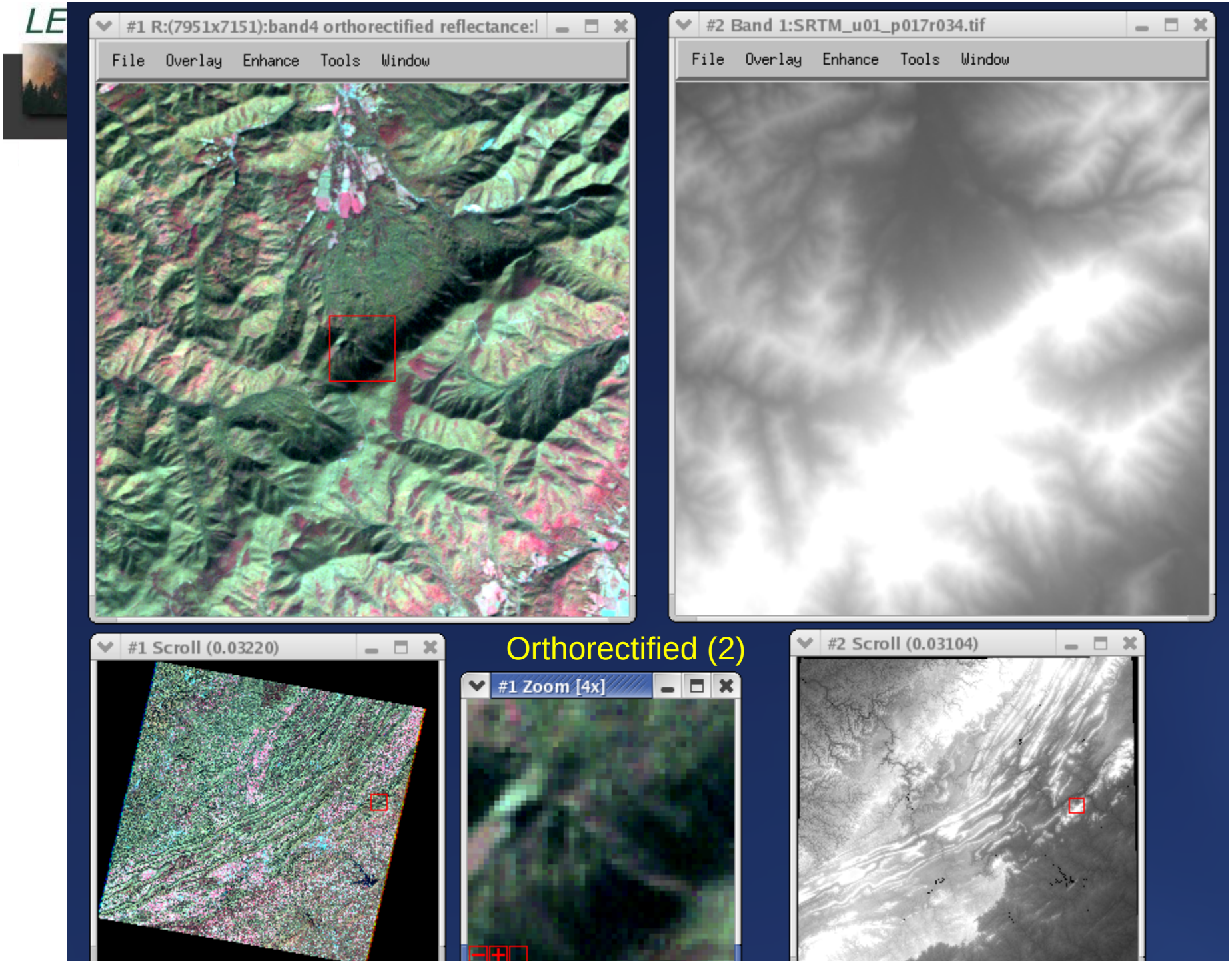
4. Resample image (cubic convolution or nearest-neighbor)

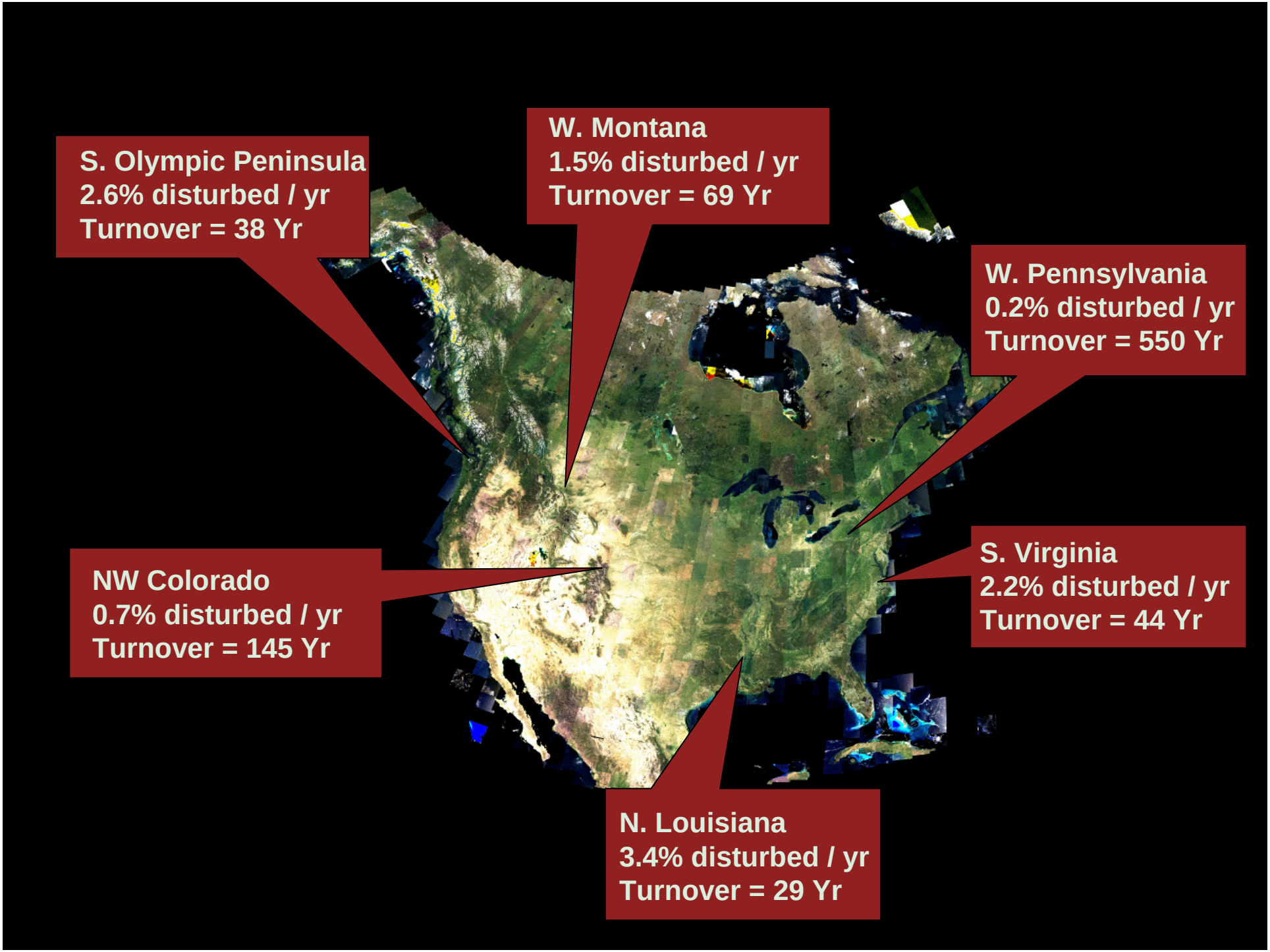
5. Check RMS via GCP selection across whole scene

6. If RMS is high, go back to (1) and include rotation term

NOTE: Currently assumes UTM projection


#1 R:(7951x7151):band 4 reflectance:lndsr.L710170
File Overlay Enhance Tools Window
#2 Band 1:SRTM_u01_p017r034.tif
File Overlay Enhance Tools Window
#1 Scroll (0.03220)
Landsat 1Gs (2)
#1 Zoom [4x]
#2 Scroll (0.03104)


#1 R:(7951x7151):band4 orthorectified reflectance:
File Overlay Enhance Tools Window
#2 Band 1:SRTM_u01_p017r034.tif
File Overlay Enhance Tools Window
#1 Scroll (0.03220)
Orthorectified (2)
#1 Zoom [4x]
#2 Scroll (0.03104)


S. Olympic Peninsula
2.6% disturbed / yr
Turnover = 38 Yr
W. Montana
1.5% disturbed / yr
Turnover = 69 Yr
W. Pennsylvania
0.2% disturbed / yr
Turnover = 550 Yr
NW Colorado
0.7% disturbed / yr
Turnover = 145 Yr
S. Virginia
2.2% disturbed / yr
Turnover = 44 Yr
N. Louisiana
3.4% disturbed / yr
Turnover = 29 Yr