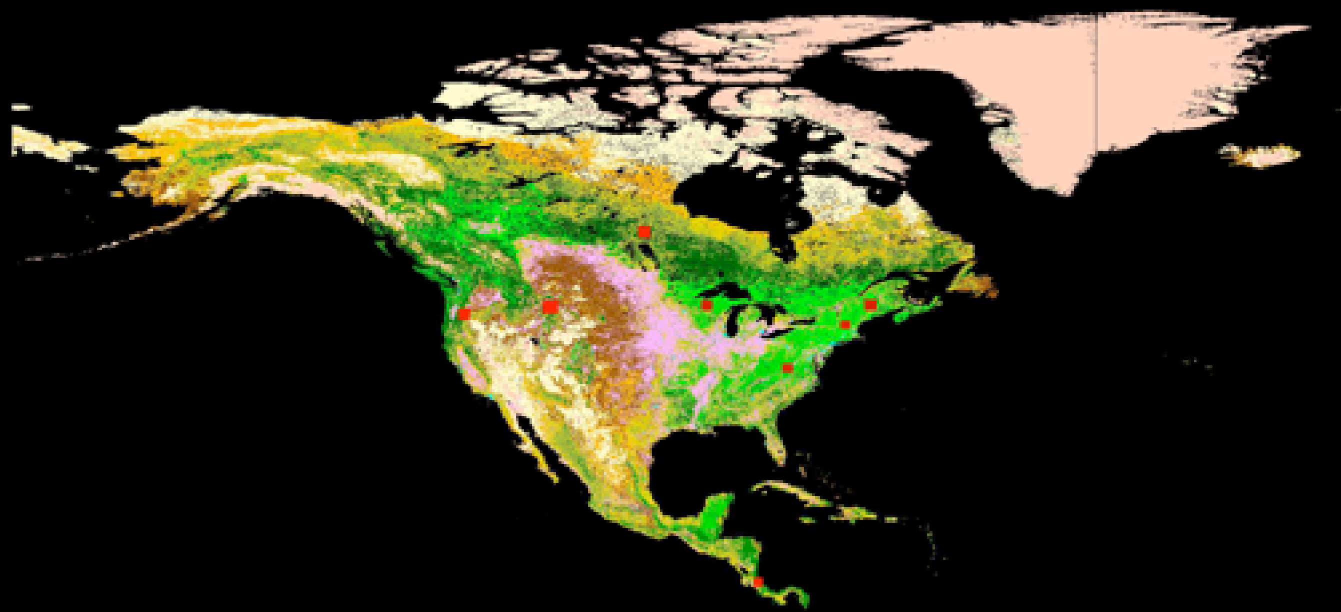
# Overview of Land Cover and Land Use Change in the North American Carbon Program



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# North American Carbon Program

U.S. Global Change Research Program

**Carbon Cycle Science Program**

*An Interagency Partnership*

**US Climate Change Science Program**

www.climatescience.gov

NSF · Forest Service · USGS science for a changing world

EPA · USDA · NIST · NASA · Department of Energy · NOAA

# NACP Questions

1. What is the carbon balance of North America and adjacent oceans? What are the geographic patterns of fluxes of $CO_2$, $CH_4$, and CO? How is the balance changing over time? ("***Diagnosis***")

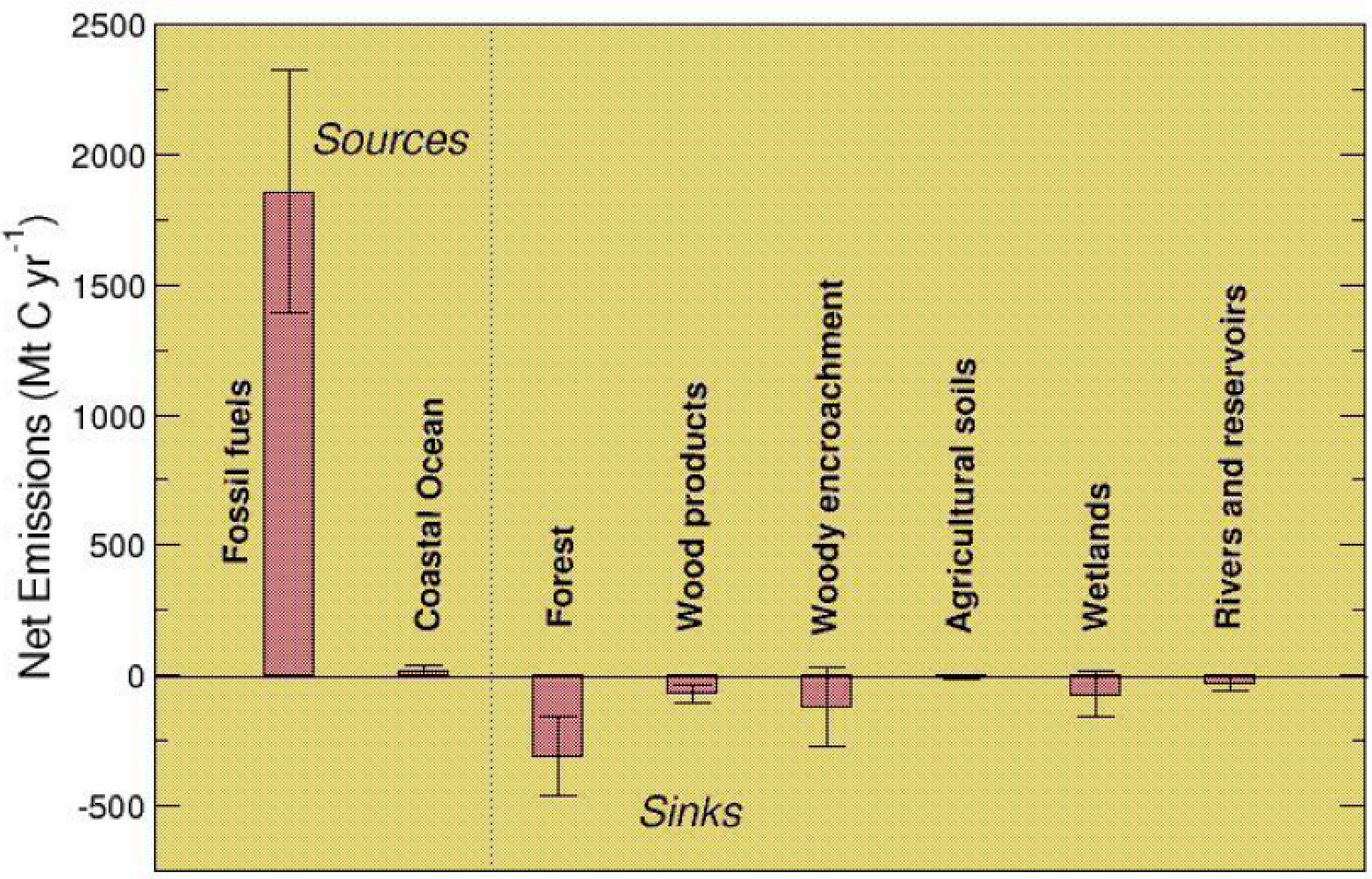
2. What processes control the sources and sinks of $CO_2$, $CH_4$, and CO, and how do the controls change with time? ("Attribution/***Processes***")

3. Are there potential surprises (could sources increase or sinks disappear)? ("***Prediction***")

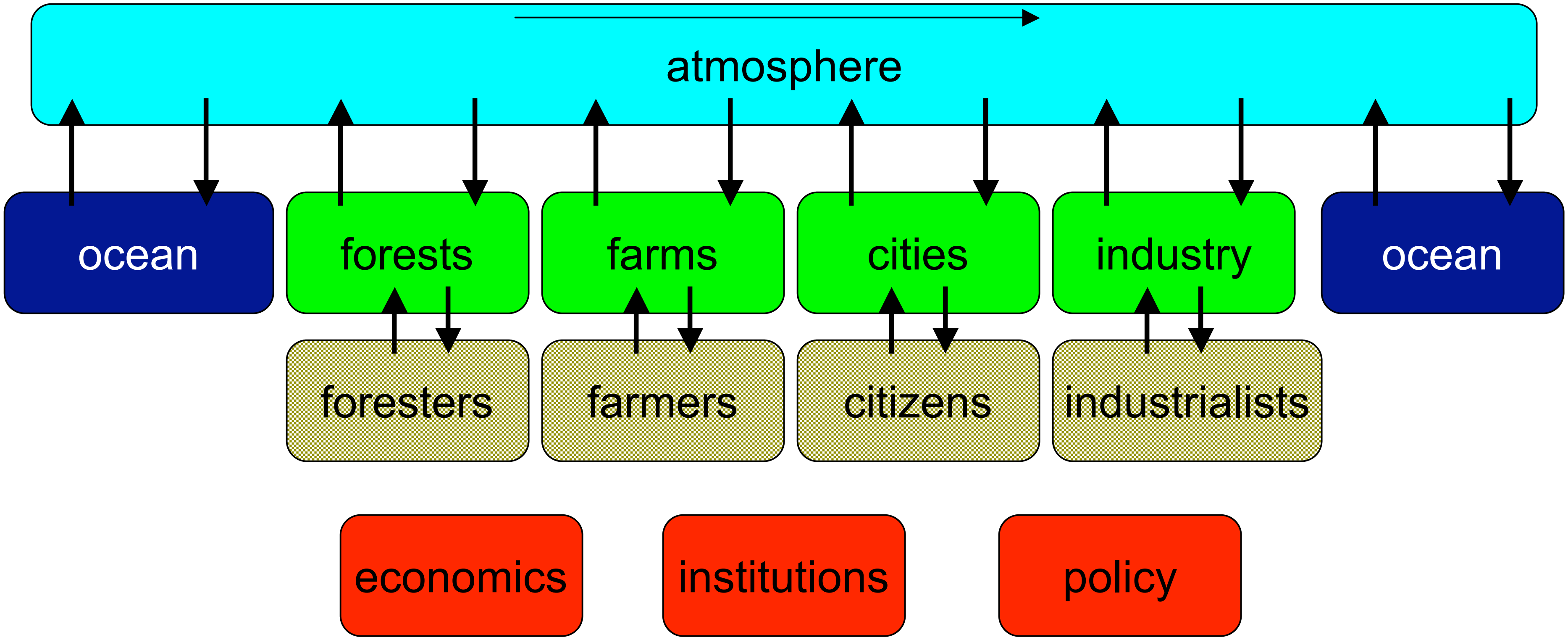
4. How can we enhance and manage long-lived carbon sinks ("sequestration"), and provide resources to support decision makers? ("***Decision support***")

S. Denning, NACP

# North American carbon sources and sinks (Mt C $yr^{-1}$) circa 2003



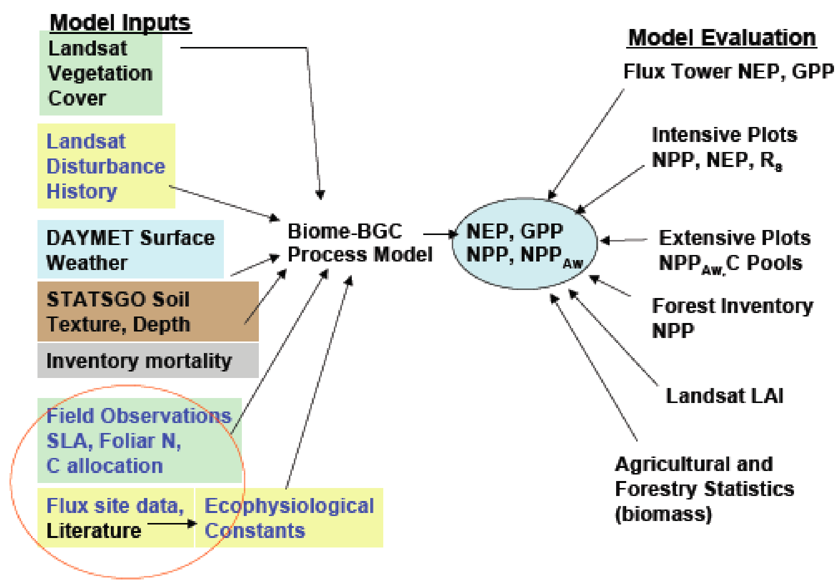
# Sources, Sinks, and Processes




- Carbon exchanges with the atmosphere over North America are managed by people
- Decision Support Task Force to engage stockholders and help coordinate research & reporting

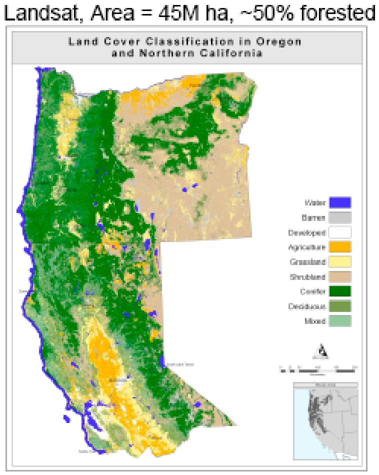
# Highlights of NACP Report

## Data Assimilation

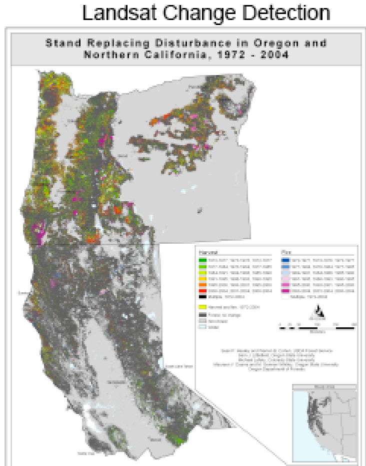



## Geographic/Spatial Information

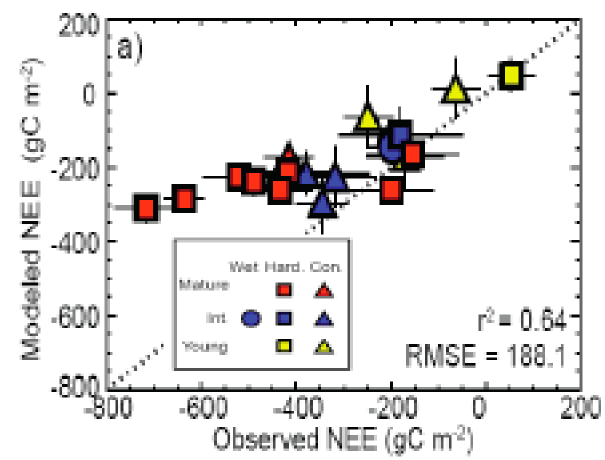
Landsat, Area = 45M ha, ~50% forested




Landsat Change Detection




## Uncertainties



# Strategies for Linking with Other NACP Elements

## Uncertainties in field data

- Leverage inventory estimates with intermediate/intensive site data

## Uncertainties in spatial data

- Spatial weather data – evaluate with AmeriFlux meteorology
- Remote sensing LAI, foliar N, GPP, land-cover, forest age – evaluate with AmeriFlux/intensive/intermediate site data
- Disturbance mapping – evaluate with intermediate & intensive site data

## Uncertainties in models

- Flux network and modeling community conduct standardized evaluations
- Model comparisons across projects – CarbonTracker framework?

# Sources & Sinks from Land Use Change, Management, Disturbance Across US

**Objective**: Estimate annual C flux from land use change
- Focus on forests
- Include processes missing from historical census-based estimates
- Include spatial satellite products on land use change and disturbance
- Include carbon stock and growth from FIA or remote sensing measurements

**Uncertainties** in analysis of land use change
- Age-specific growth rates of forests
- Spatial variability in forest age and growth rates
- Decomposition rates
- Natural variations in CWD

**Missing** from analysis of land use change
- Management effects (thinning & planting)
- Natural disturbances (e.g. fire, windthrow)
- Growth enhancement
- Woody encroachment

From NACP Report

# LCLUC Projects:

0.Scott Goetz

**Monitoring and Modeling Ecosystem Response to Climate Change in Northern High Latitude**

Land Use Change and Disturbance:

1. Compton Tucker
   (C. Neigh, J. Collatz)

**Carbon Cycle Implications of North American Natural and Anthropogenic Disturbances**

2. Jeffrey Masek
   (F. Hall, R. Wolfe, E. Vermote, J. Kutler, T-K. Lim, W. Cohen, C. Haung, S. Goward)

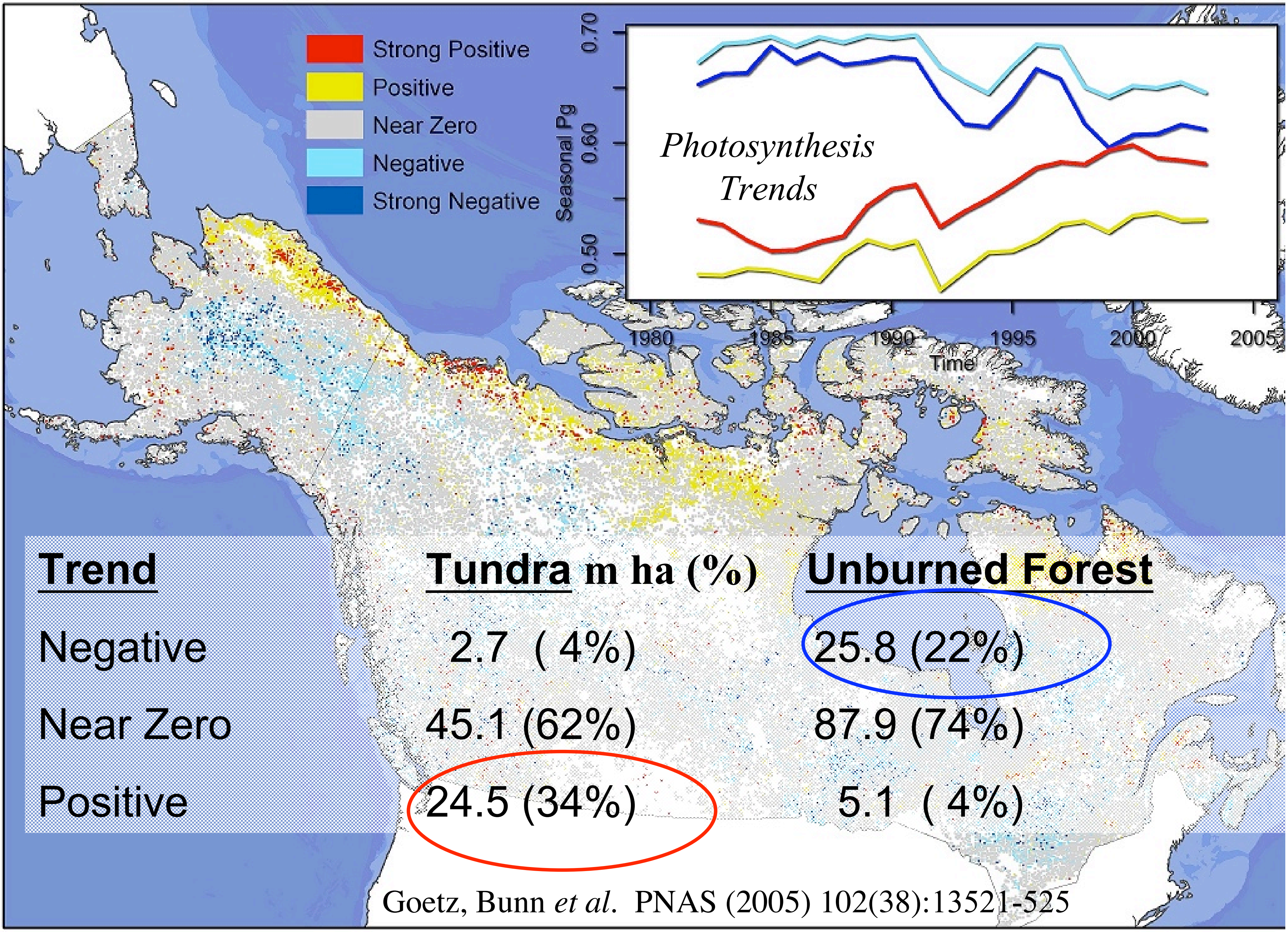
**LEDAPS (Landsat Ecosystem Distruabance Adaptive Processing System)**

3. Samuel Goward
   (J. Townshend, C. Haung, K.F. Huemmrich, J. Masek, W. Cohen, R. Kennedy)

**North American Forest Disturbance and Regrowth Since 1972**

4. Sassan Saatchi
   (R. Myneni, L. Heath, M. Apps, Y. Knyazikhin, Y. Fu, A. Baccini)

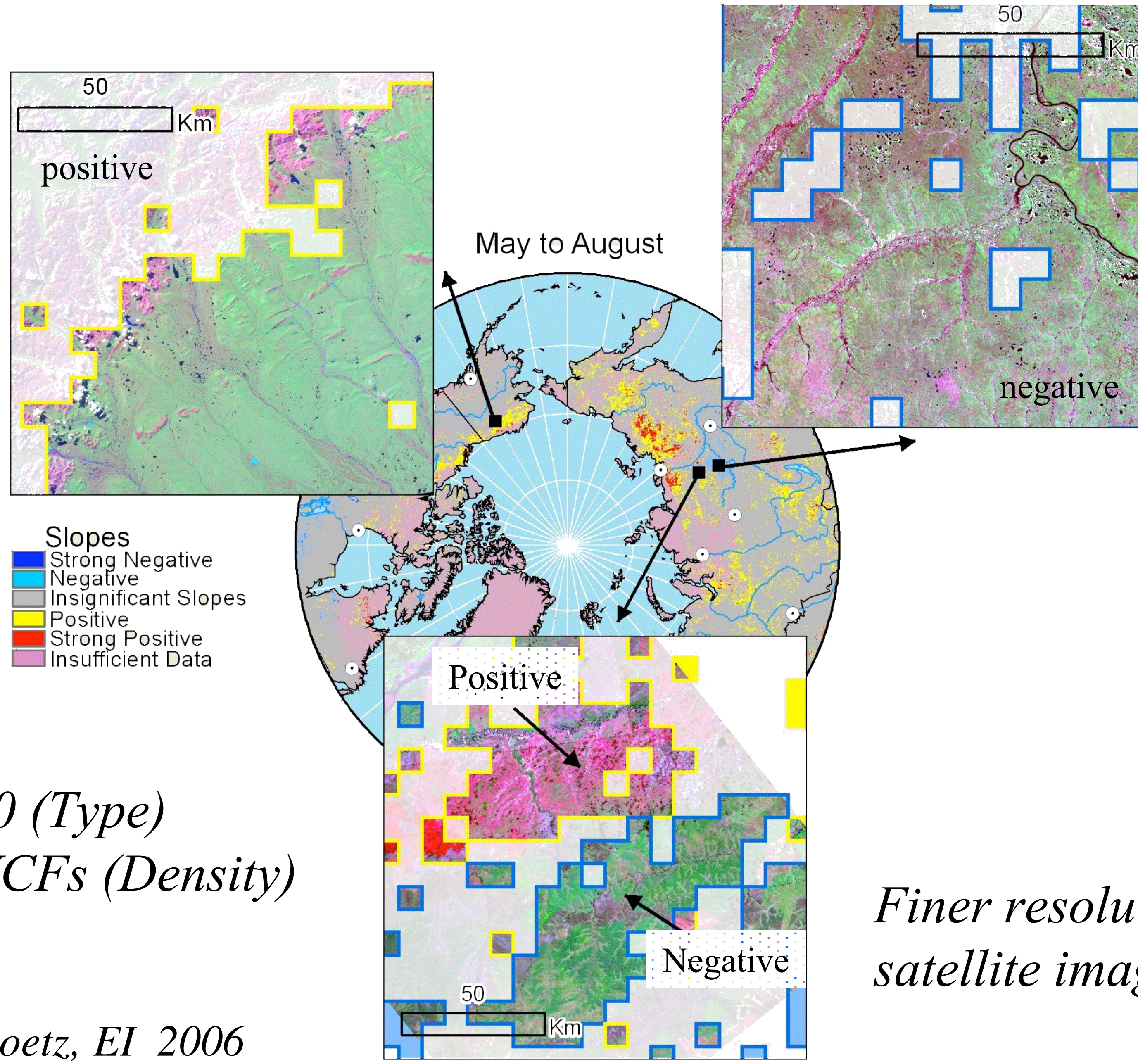
**Distribution of Forest Woody Biomass/Carbon of North America**




| Trend | Tundra m ha (%) | Unburned Forest |
| --- | --- | --- |
| Negative | 2.7 ( 4%) | 25.8 (22%) |
| Near Zero | 45.1 (62%) | 87.9 (74%) |
| Positive | 24.5 (34%) | 5.1 ( 4%) |

Goetz, Bunn *et al*. PNAS (2005) 102(38):13521-525

# Trends differ with vegetation type (and density)

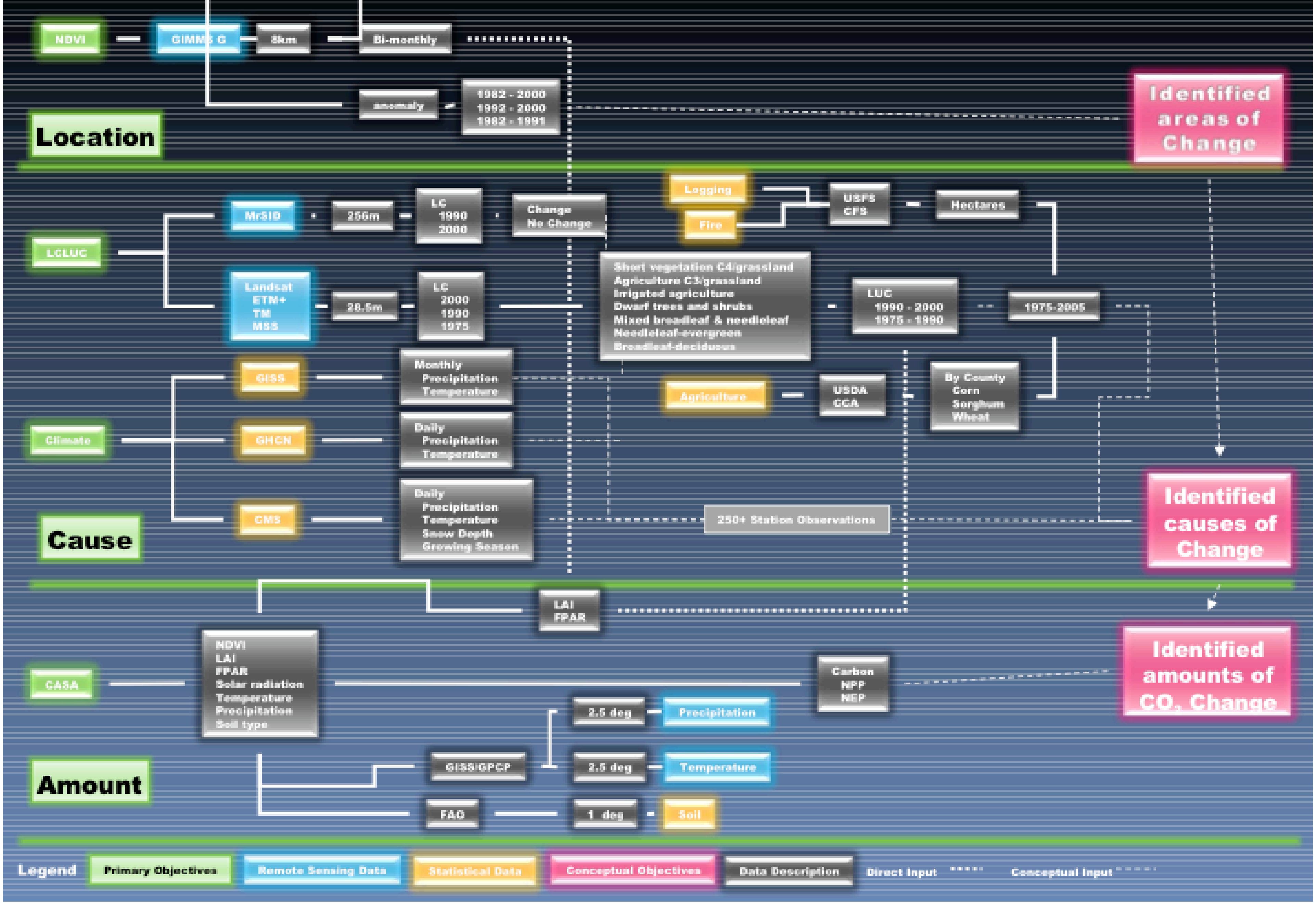



*GLC-2000 (Type)*
*MODIS VCFs (Density)*

*Finer resolution satellite imagery*

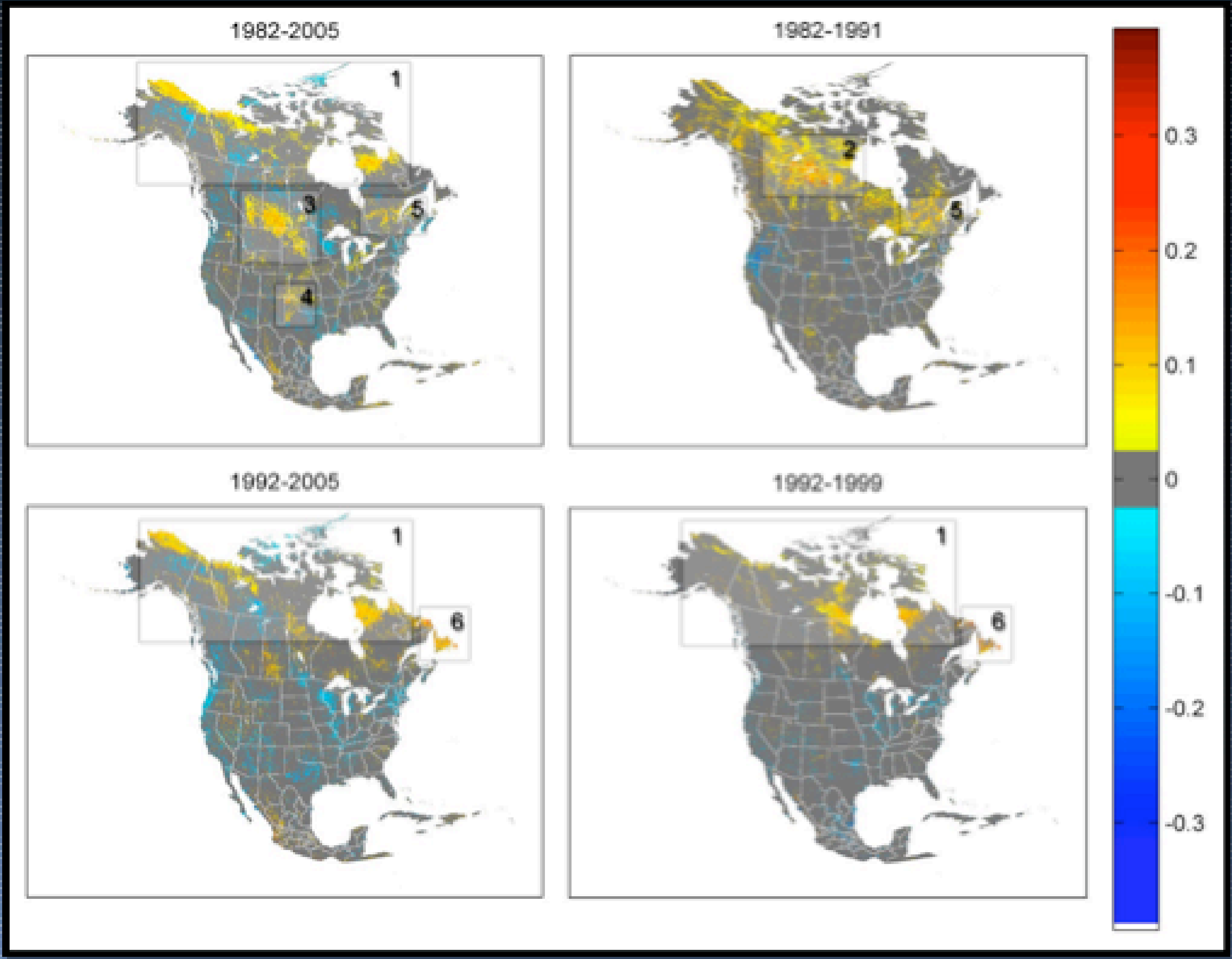
*Bunn & Goetz, EI 2006*

# Theoretical model of Proposed Research Tasks

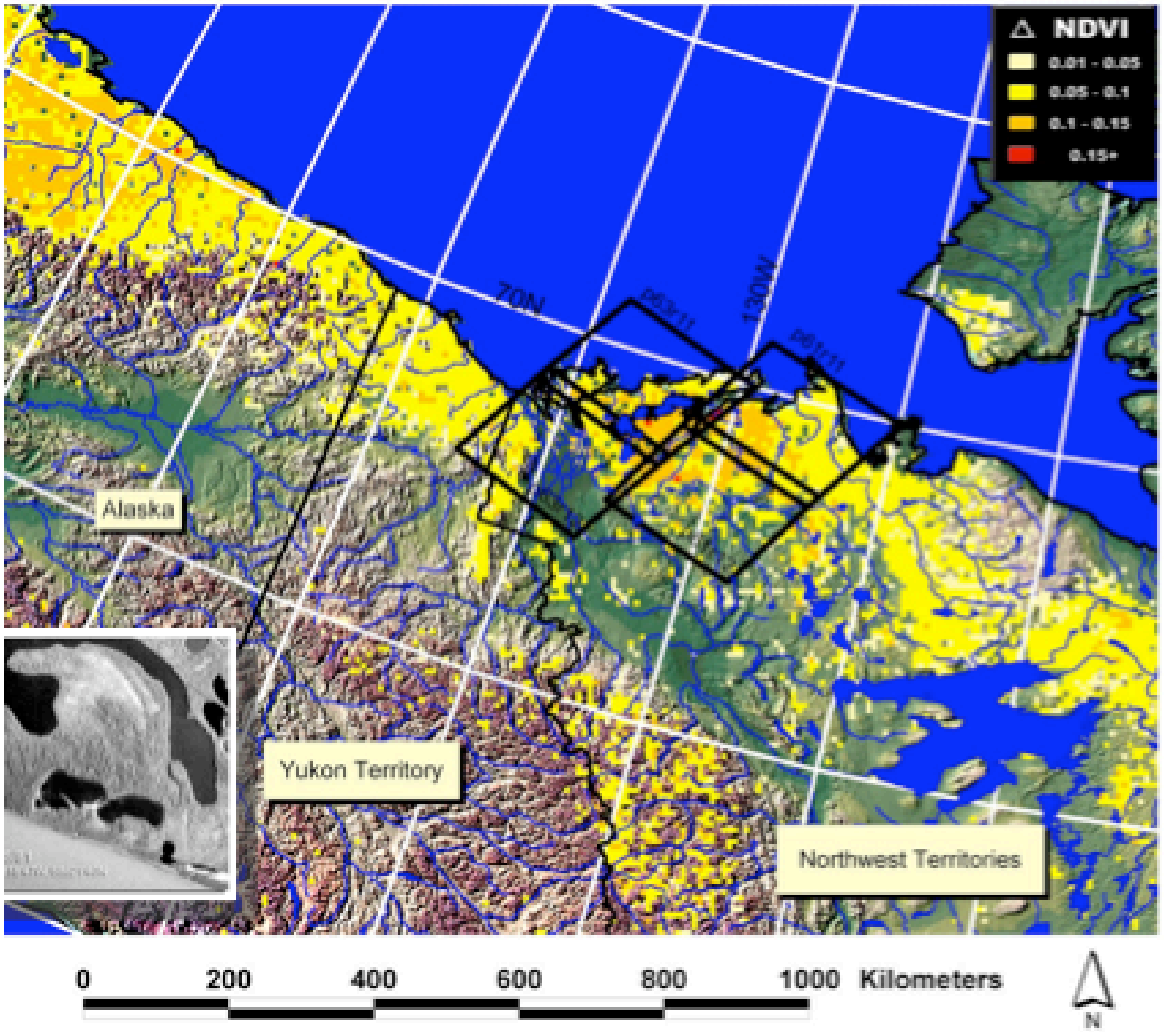


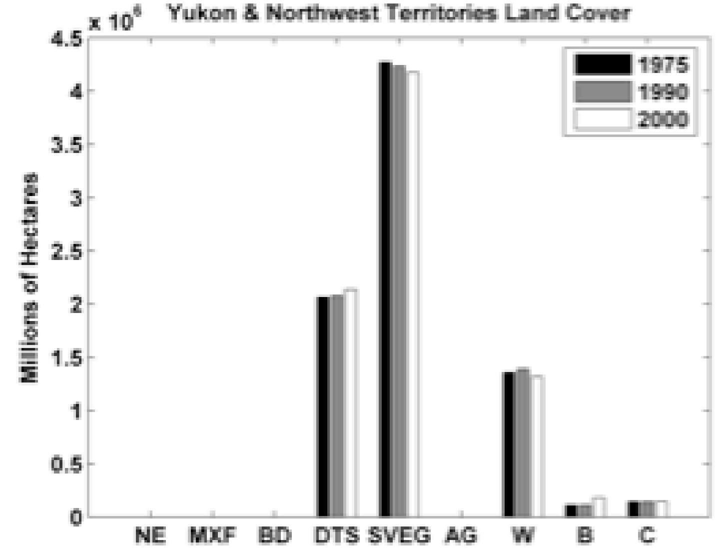
# Methods

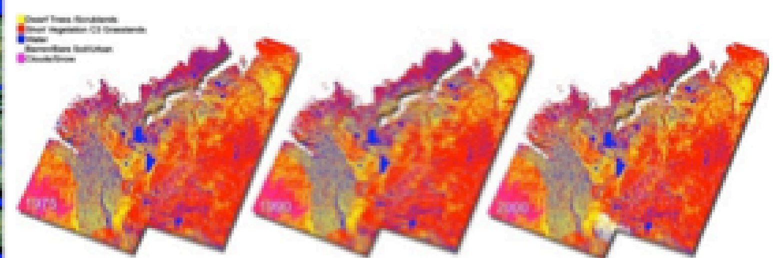
- 6 study regions defined by:
  - NDVI anomalies >.1,
  - & available validation data

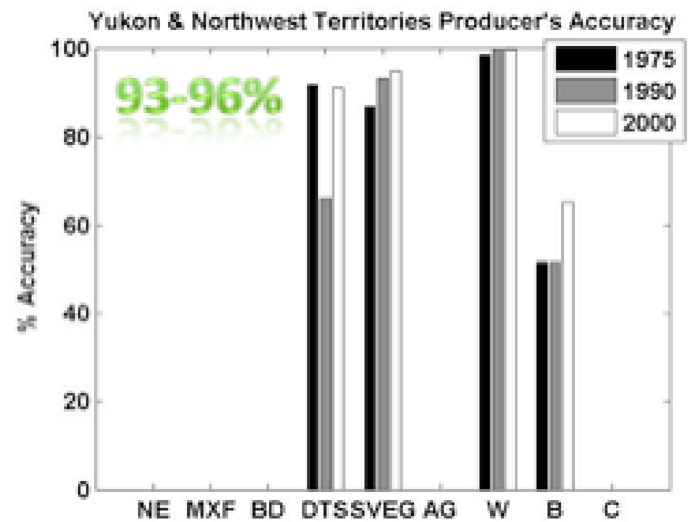


# Land cover/Validation Yukon

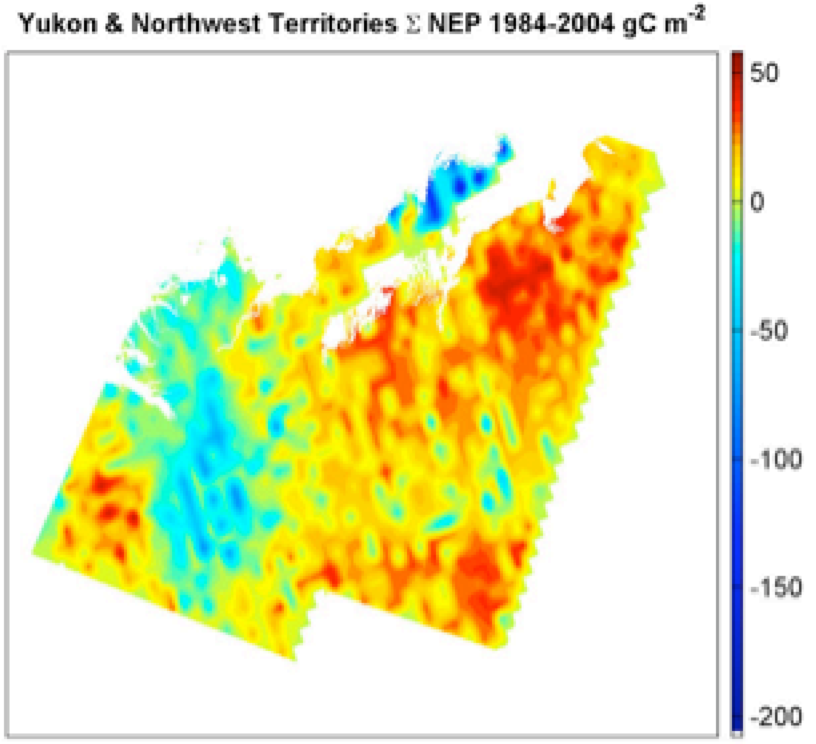


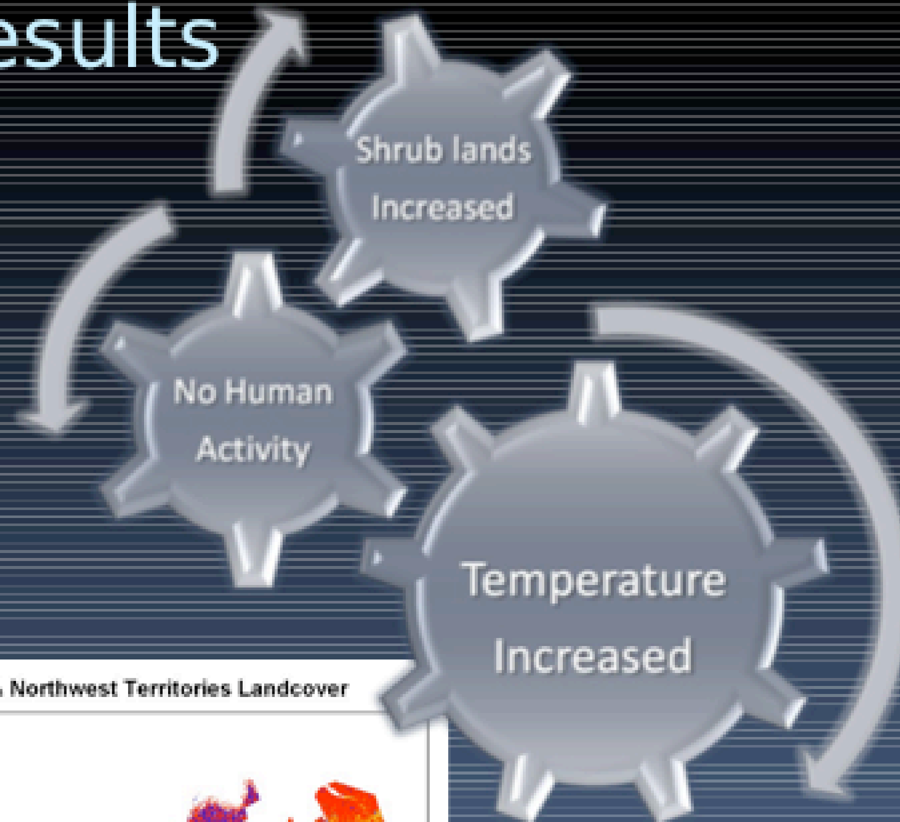



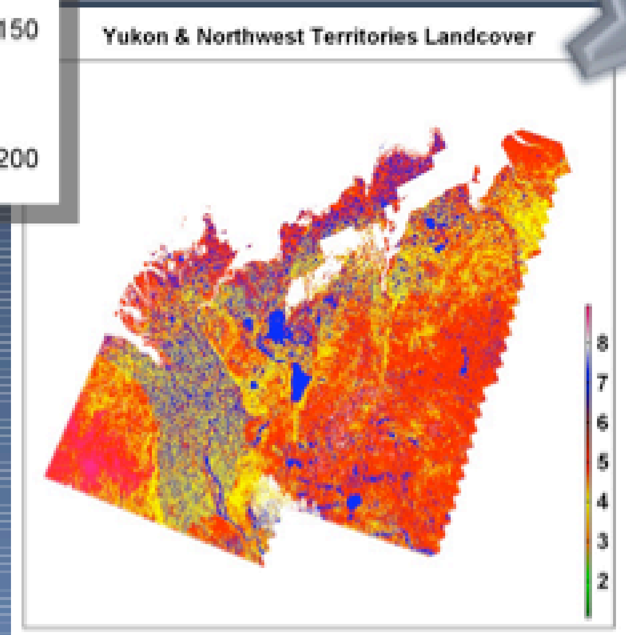



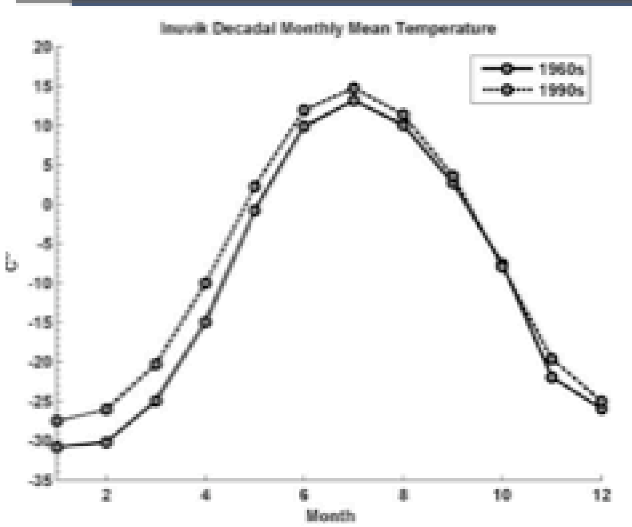


# Yukon Simulation Results

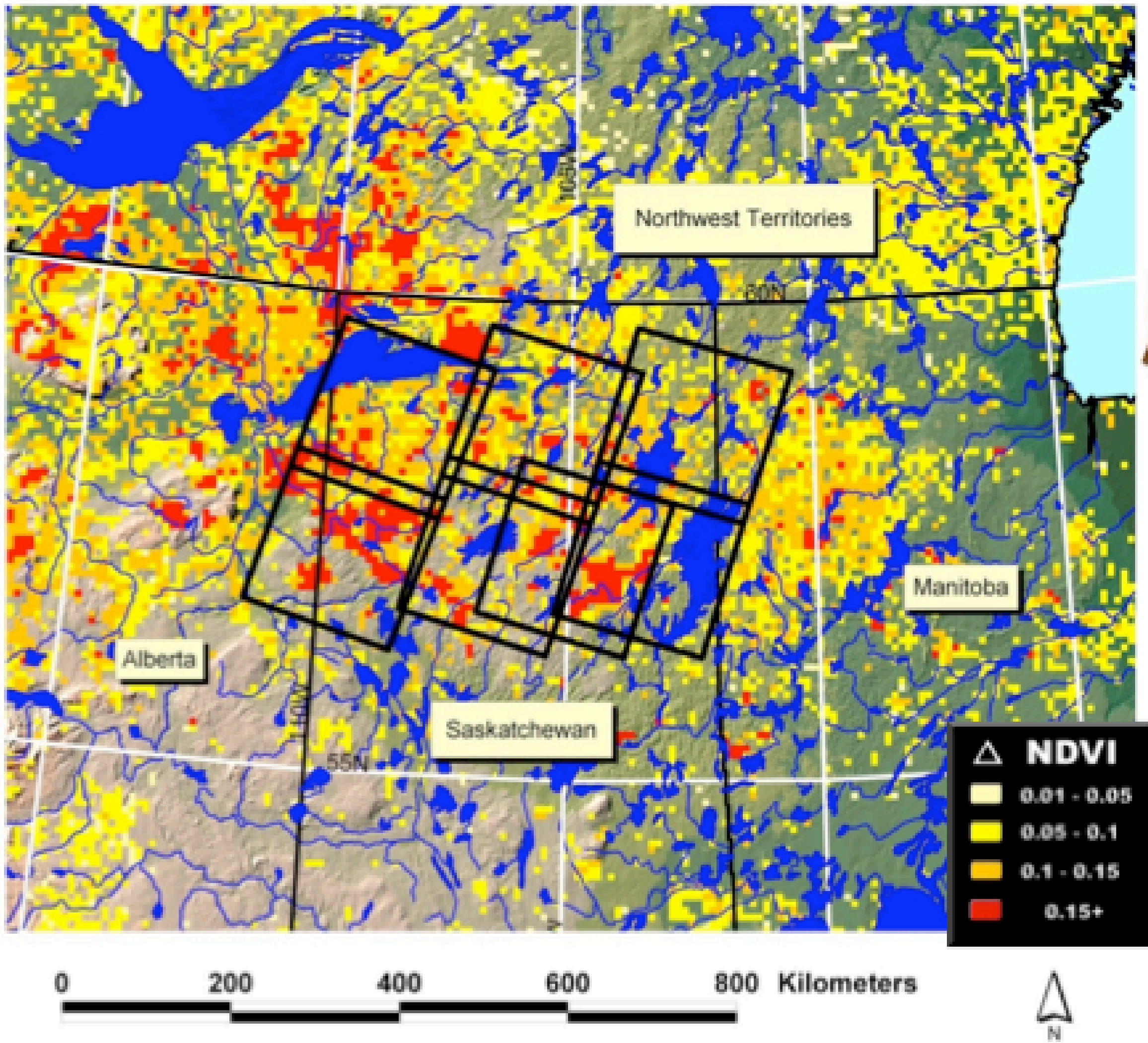


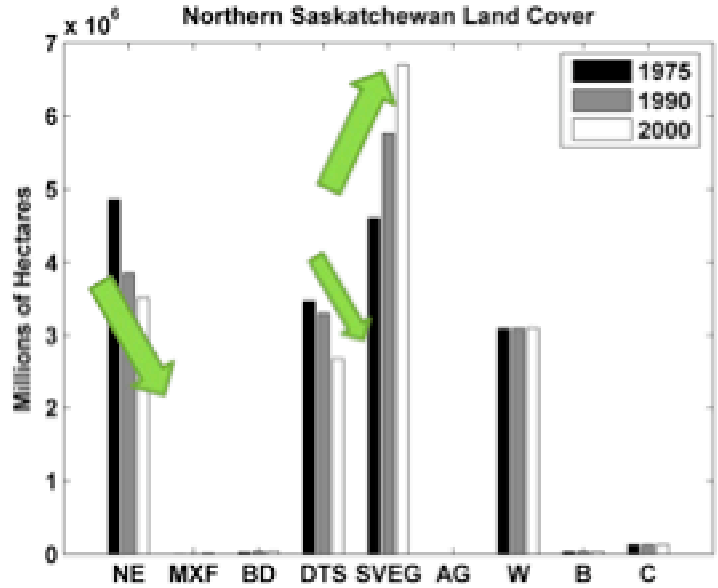



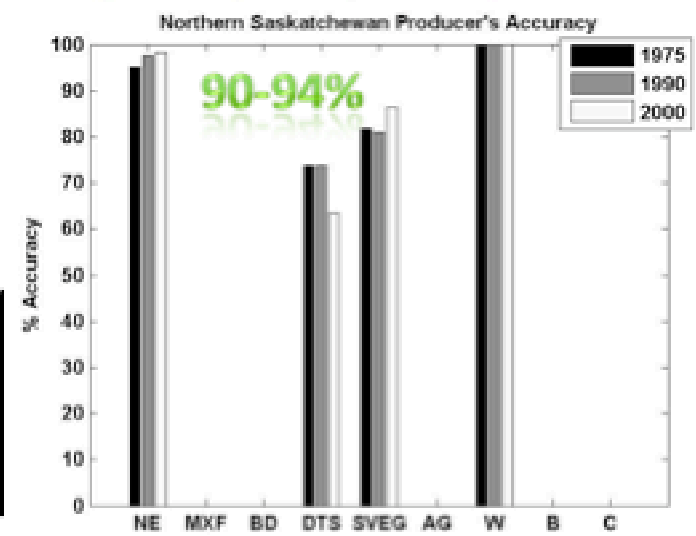



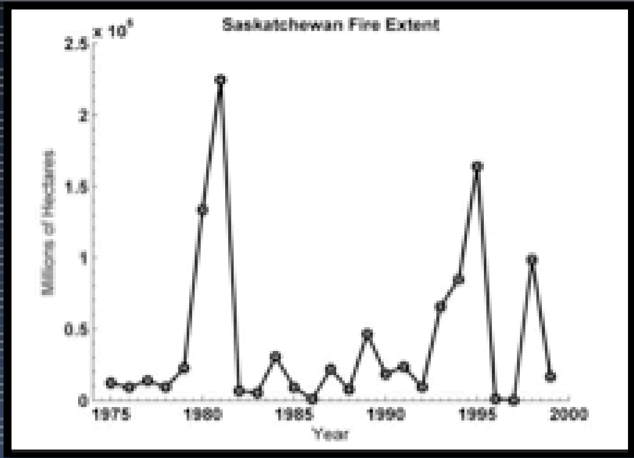
# Land cover/Validation Northern Saskatchewan



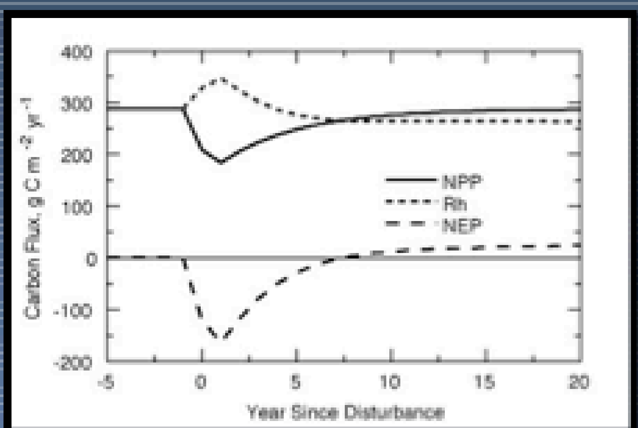



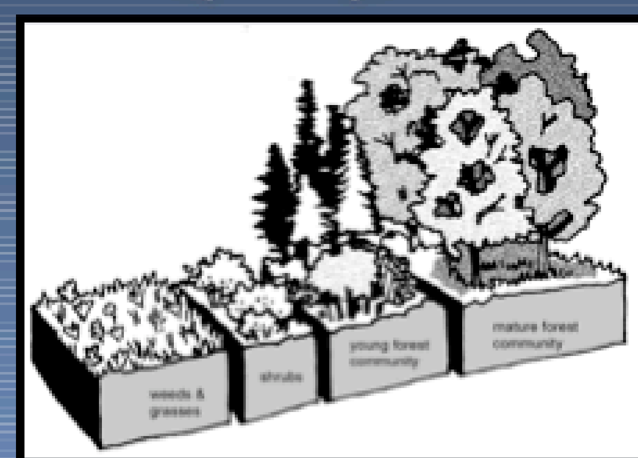



# Land cover Dynamics
## Northern Saskatchewan








**After the initial "Disturbance" it has been noted net primary productivity exceeds respired carbon for ~120 years into the future creating a Carbon Pool**

## Two approaches for NACP forest disturbance mapping:

**GSFC LEDAPS** : Wall-to-wall disturbance patterns, 1990-2000, mapped from ~2200 TM/ETM+ scene pairs.

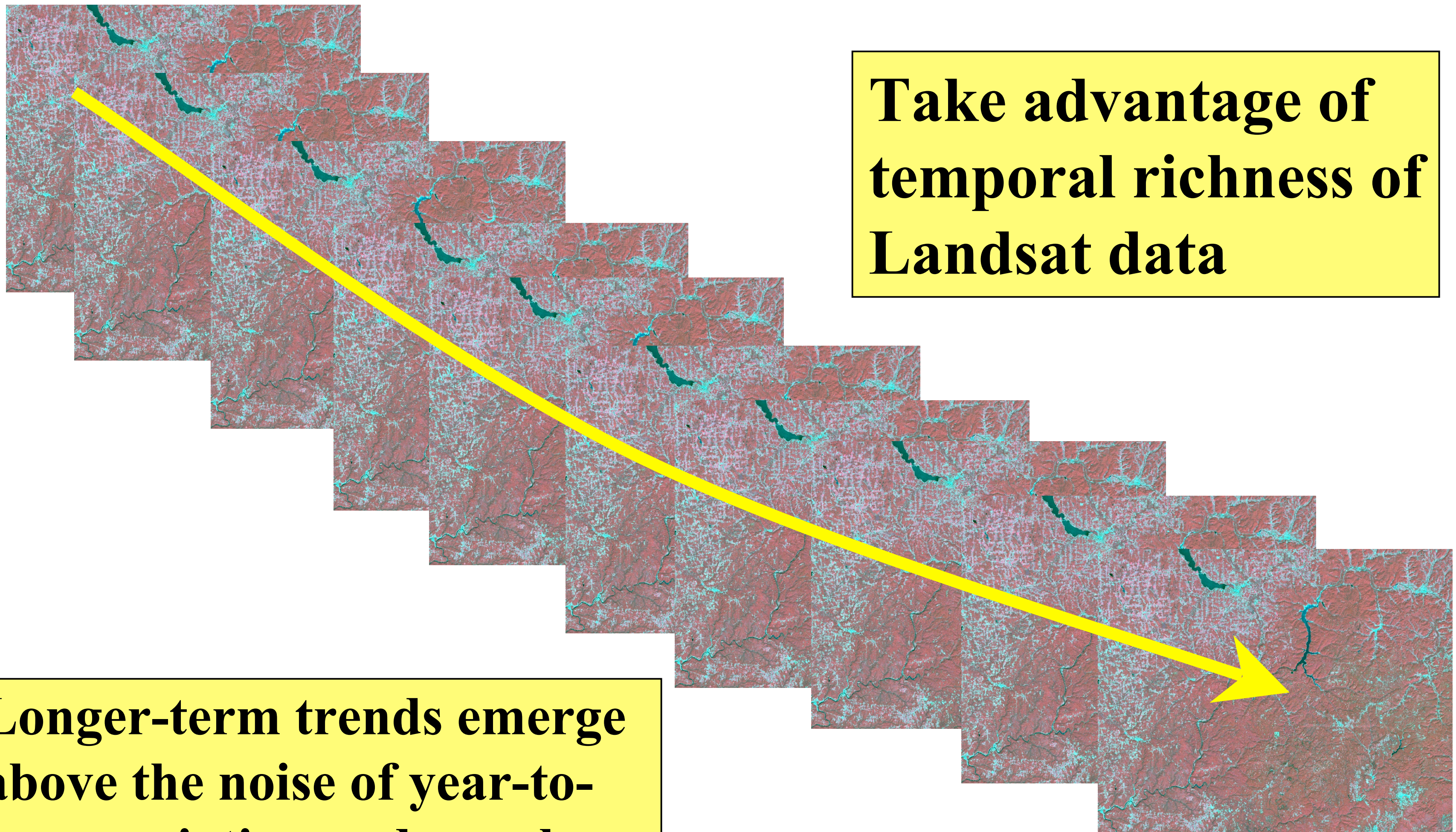
… gives spatial patterns; gross rates

**UMD NACP Project**: Sampling approach (25 U.S. locations) with dense time series of imagery

… gives precise rates, temporal variability

**Merge both approaches for optimal disturbance analysis**

**Each sample scene consists of ~ 2-year interval Landsat data cube**

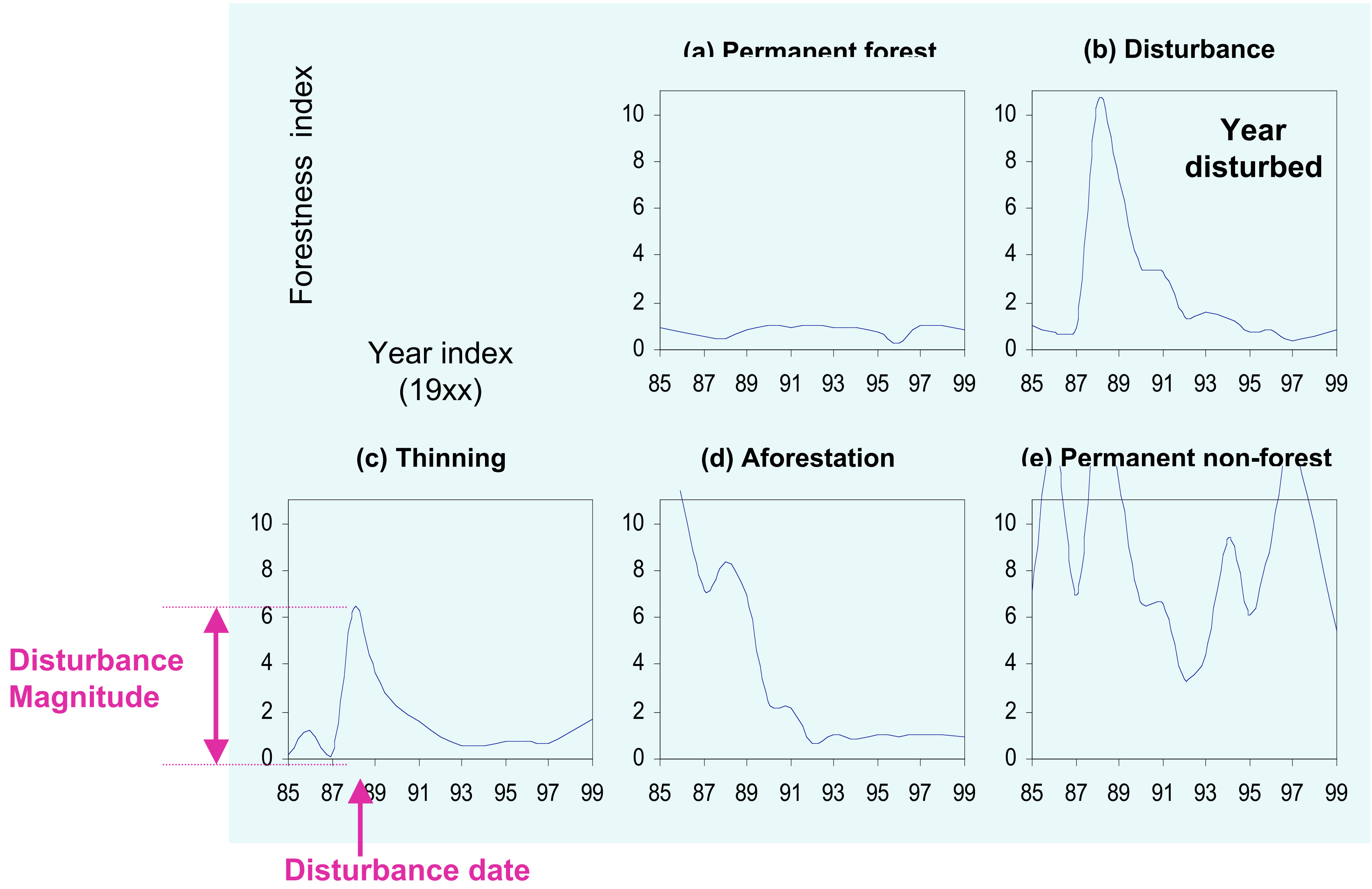


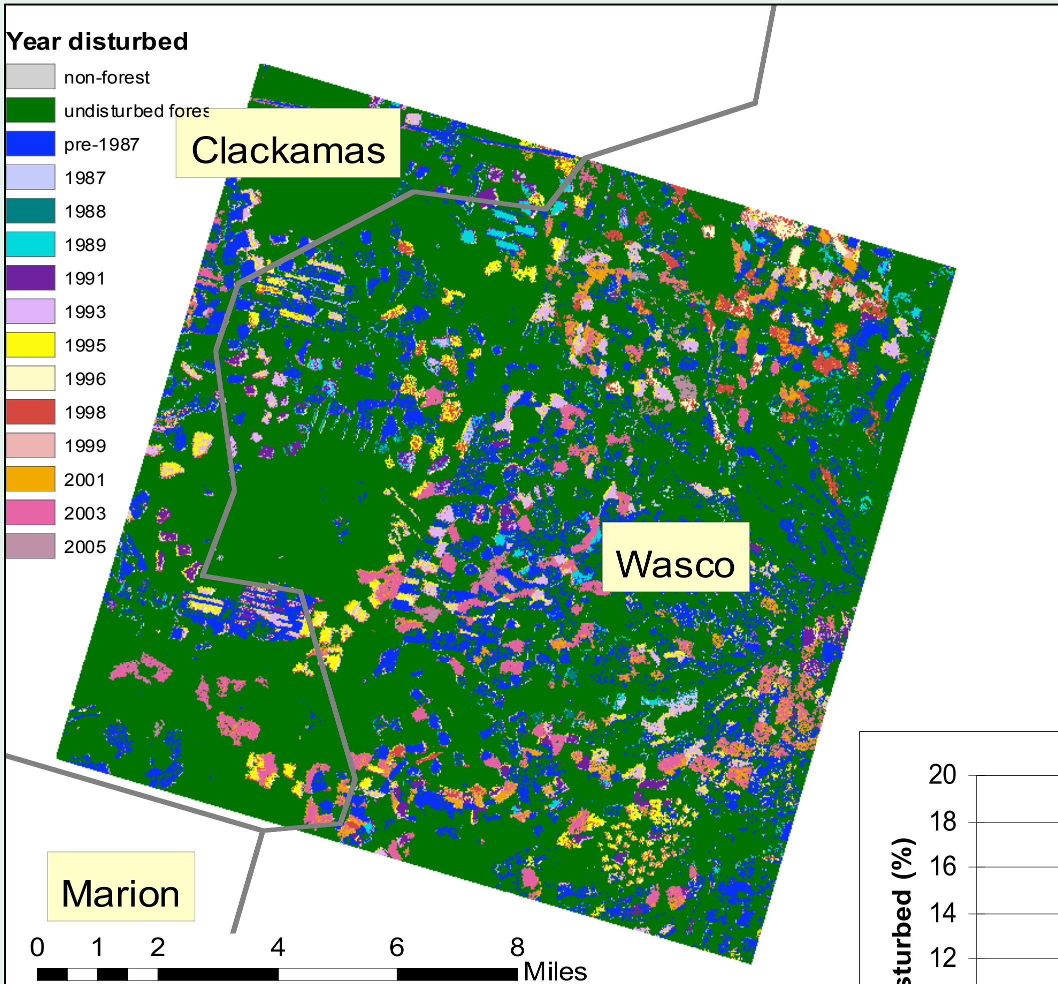

**Take advantage of temporal richness of Landsat data**

**Longer-term trends emerge above the noise of year-to-year variation and may be the most reliable signal**

# UMD Forestness Index (FI)

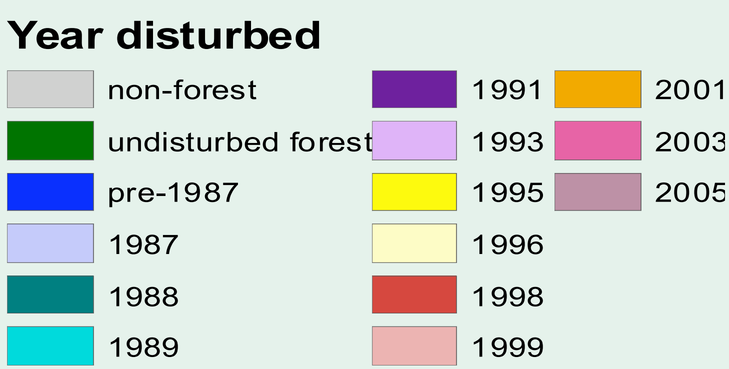
- Pixel-level multi-band reflectances normalized by known forest population
- FI measures how many standard deviations a given pixel is from forest population
- Used to map timing, magnitude of disturbance events

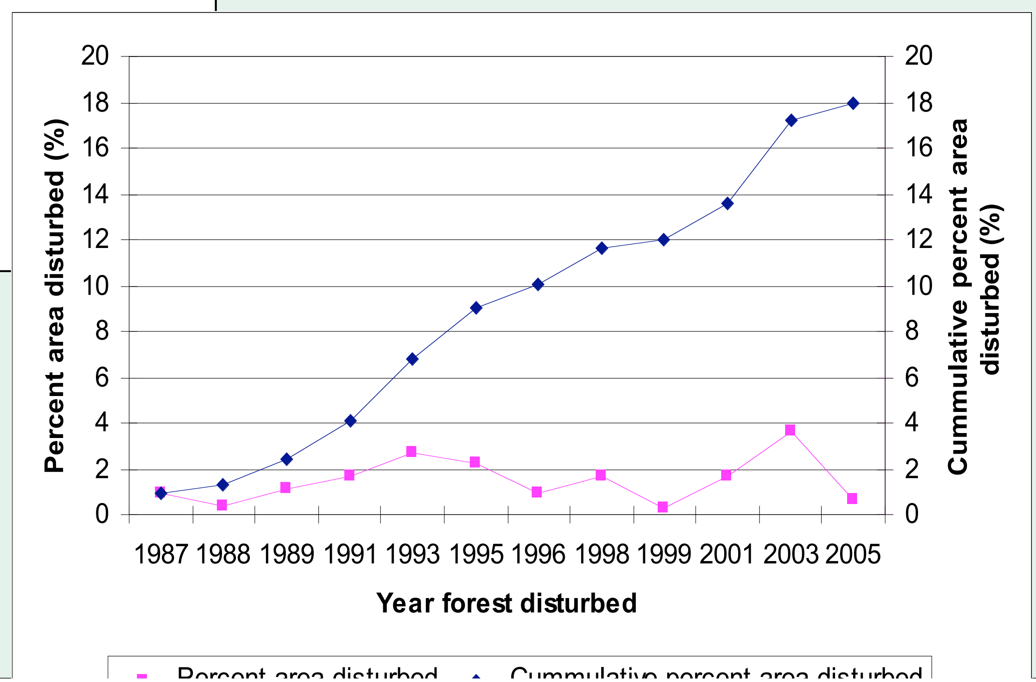





Landsat mapped forest change between 1987 and 2005 in western Oregon along the Clackamas County-Wasco County border (left)

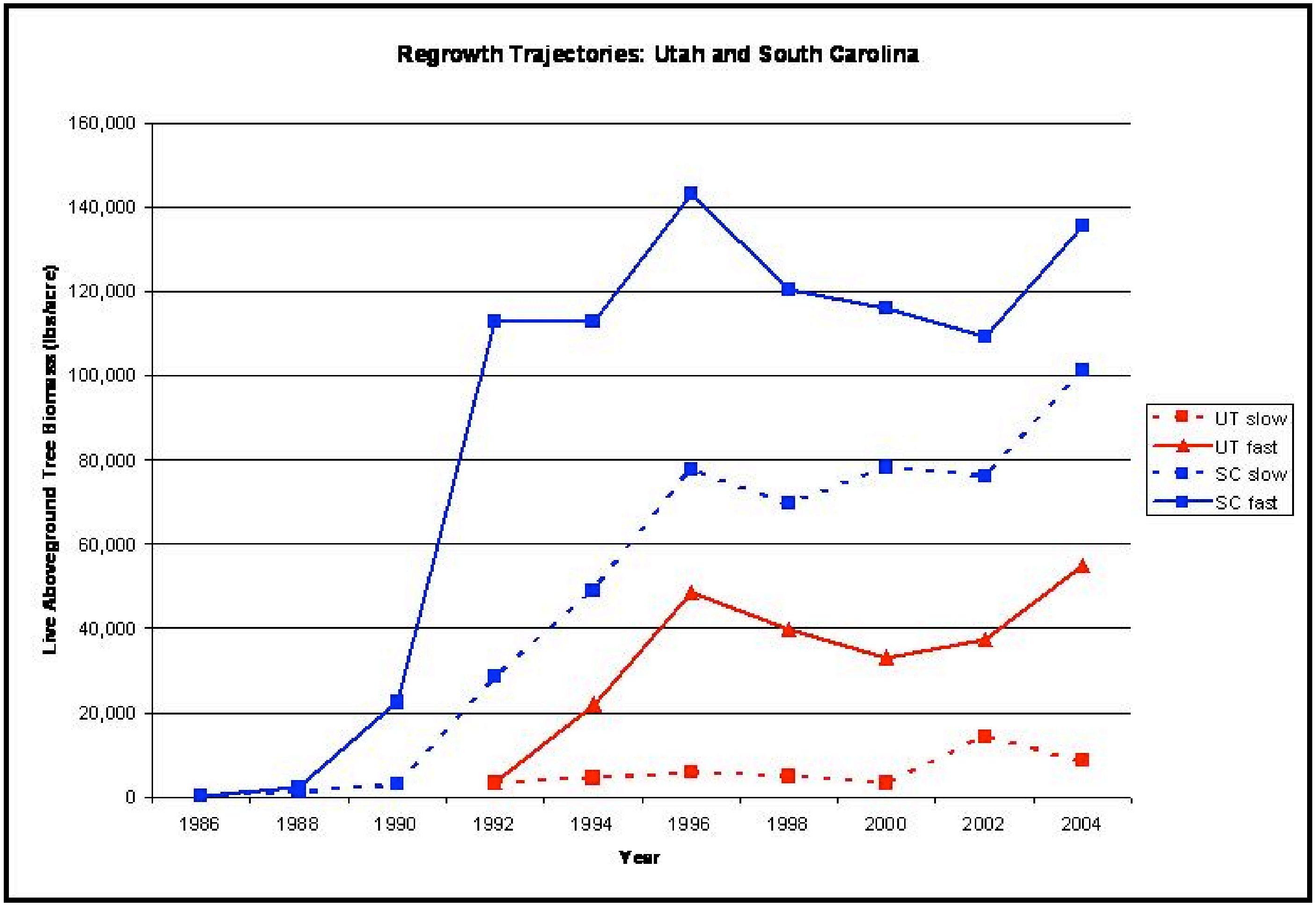
Temporal variation of the percentage of change area (below)



# Biomass Accumulation Following Disturbance

•Using FIA plot data, spectral reflectance can be related to observed biomass.
•Applying this regression relationship allows biomass trajectories of regrowing stands to be characterized.
•Here, stands from South Carolina (fast recovery) are contrasted with Utah (slow recovery). Note also there is variability in regrowth rate within each region.



LEDAPS

Landsat Ecosystem Disturbance Adaptive Processing System

Disturbance rates are critical for accurate modeling of carbon fluxes, but the Landsat archive has never been mined for this information

**LEDAPS Objective: Quantify rates of stand clearing disturbance (clear cuts, fire) across North America for the period 1975-2000, via Landsat Geocover product**

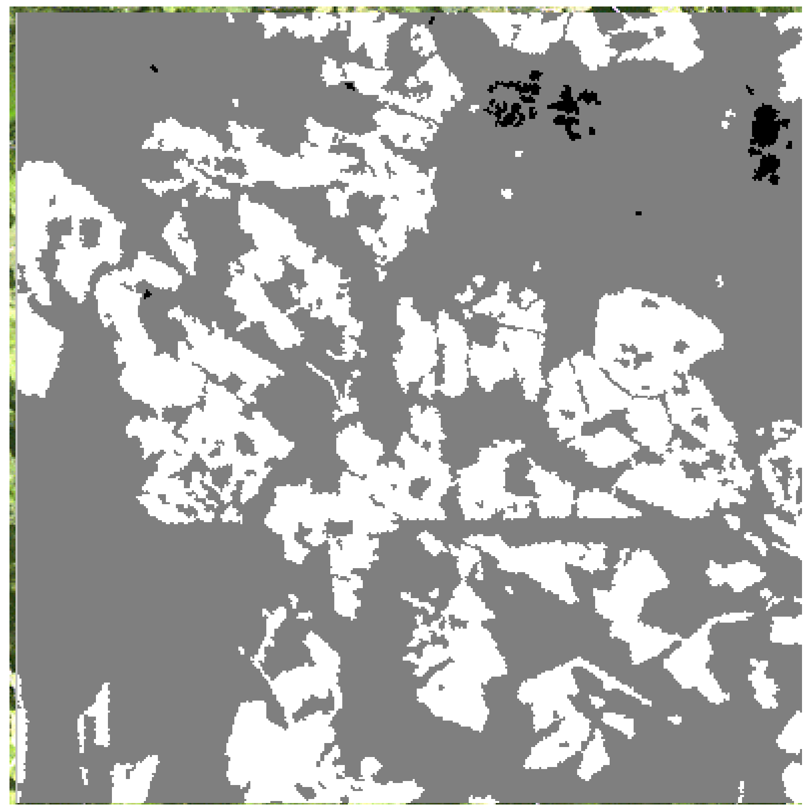
- process scenes to surface reflectance using MODIS/6S atmospheric correction approach
- use tasseled-cap “Disturbance Index” algorithm (Healey et al, 2005) to identify areas of significant disturbance (biomass loss) or regrowth (biomass gain) through time
- produce maps suitable for carbon modeling (30m, 500m, $1/20^{th}$ degree resolution

- **Continental reflectance product for 1990-2000 released in 2006**
- **Disturbance product for 1990-2000 to be released this summer**

LEDAPS

# Northern Maine

Landsat Ecosystem Disturbance Adaptive Processing System



1986

2001

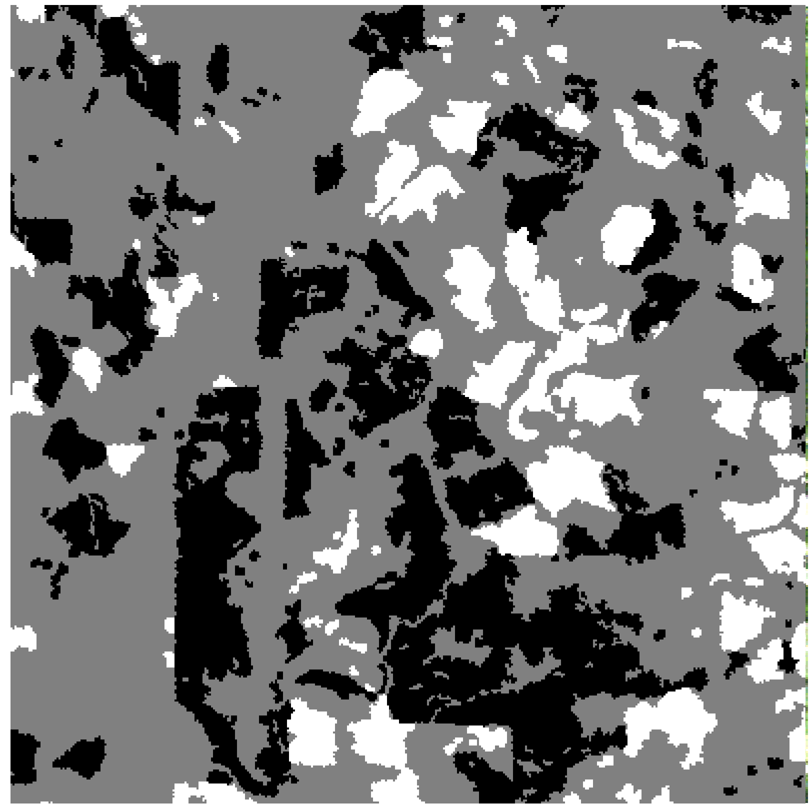
1986-2001 disturbed

1986-2001 regrowth

5km

# Western Oregon

September 1989



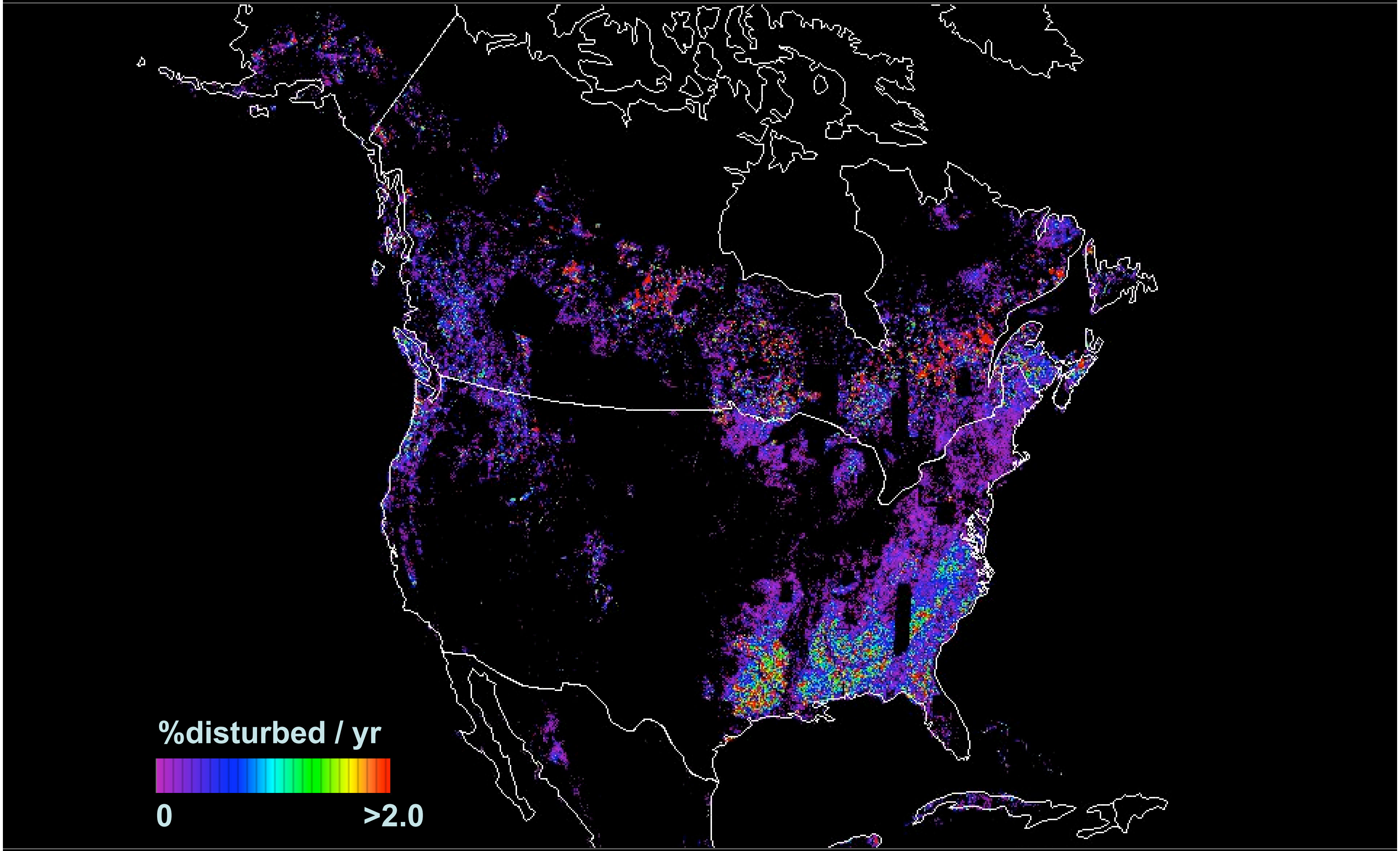
July 2001

1989-2001 disturbed

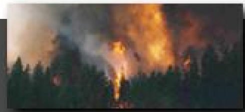
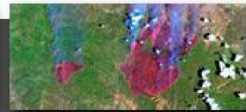
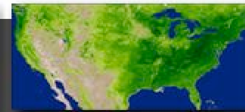
1989-2001 regrowth

5km

# LEDAPS Preliminary Map of Forest Disturbance, 1990-2000



LEDAPS

## Conclusions/Lessons Learned

**Disturbance rates vary widely**

- up to 3-4% per year in Southeast, PNW, Maine
- lower rates in Rockies, Mid-Atlantic, S. New England

**Regeneration of Eastern forests may be critical for long-term carbon sink, but current age structure strongly modified by land use**

**Omission errors (disturbance “missed”) are caused by the 10-year repeat interval associated with the Geocover products (see next slide)**

***…. In the future we need annual/biennial coverage***

LEDAPS

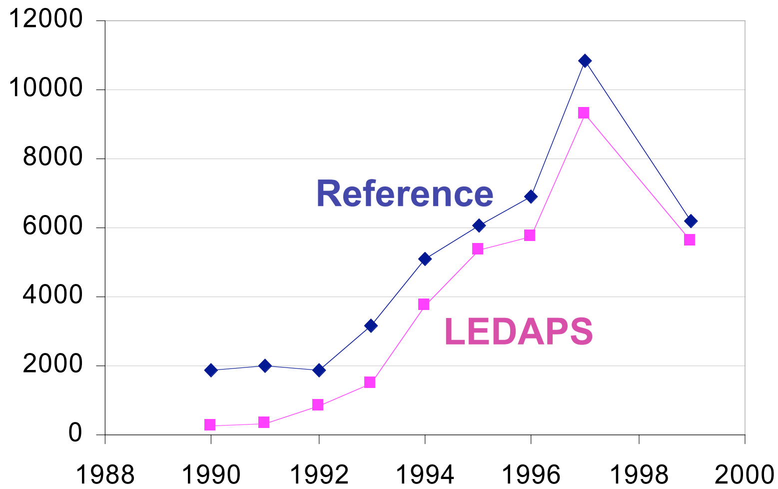
# Effect of 10-year Refresh

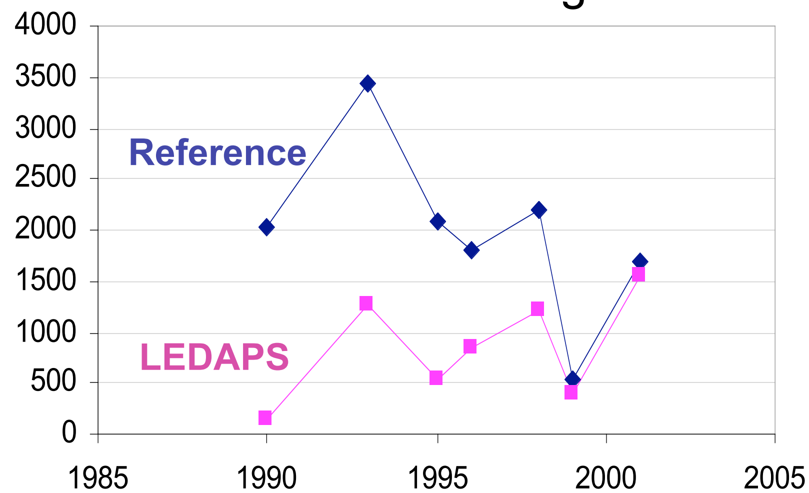
Landsat Ecosystem Disturbance Adaptive Processing System

## Central Virginia

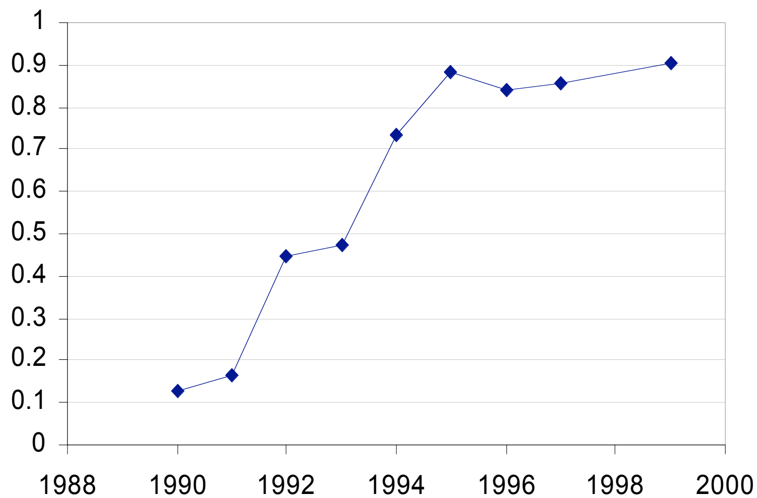
## Northern Michigan

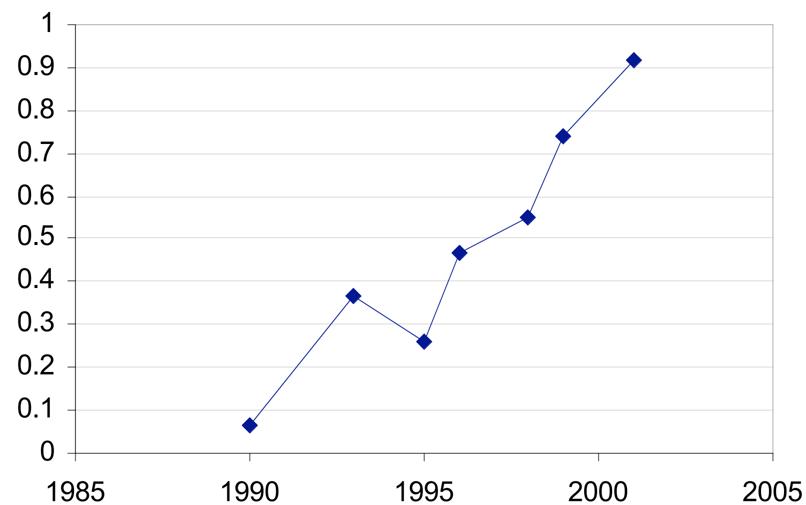
Pixels disturbed



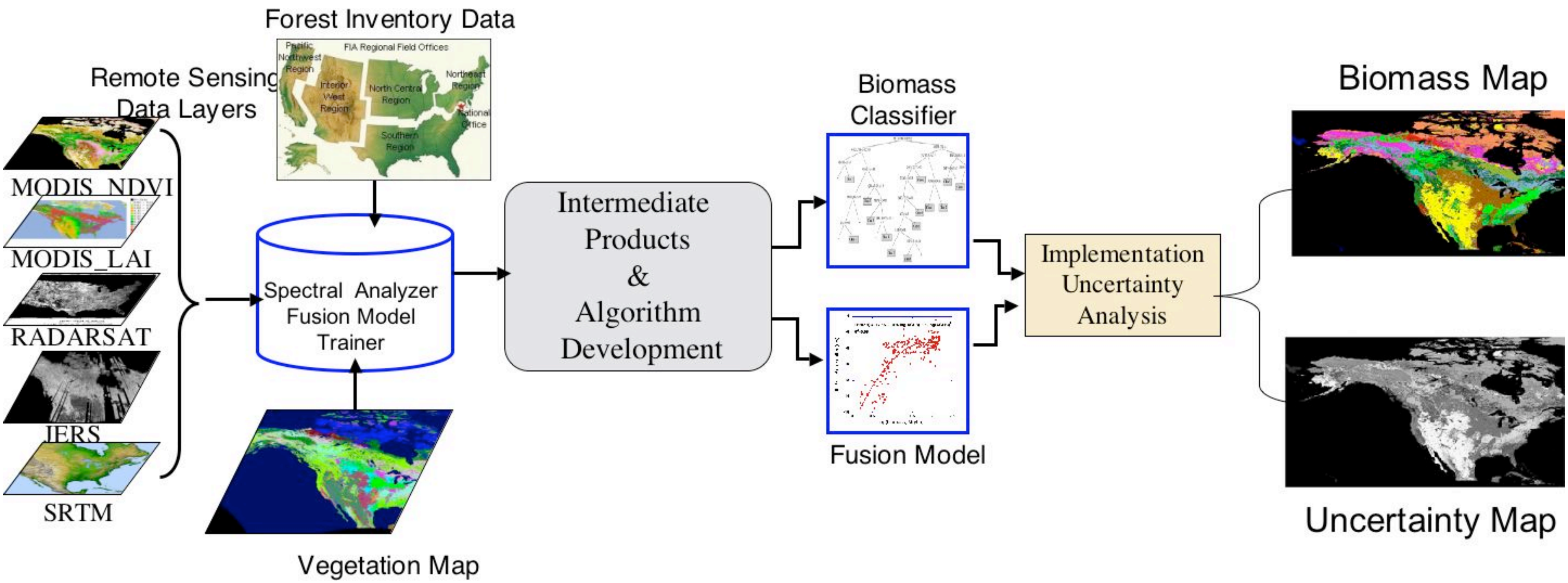




LEDAPS detection fraction

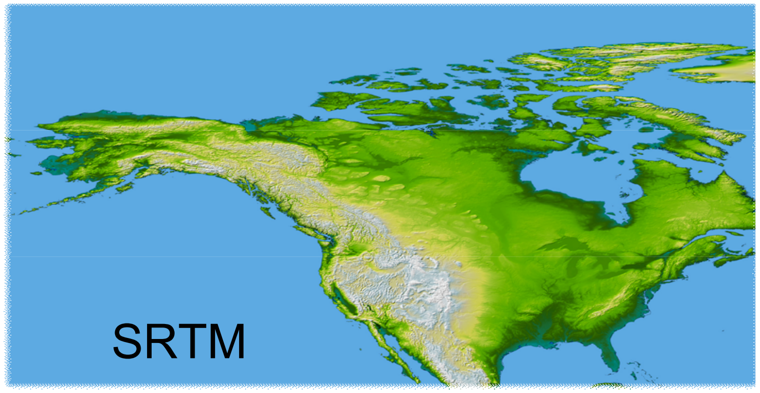


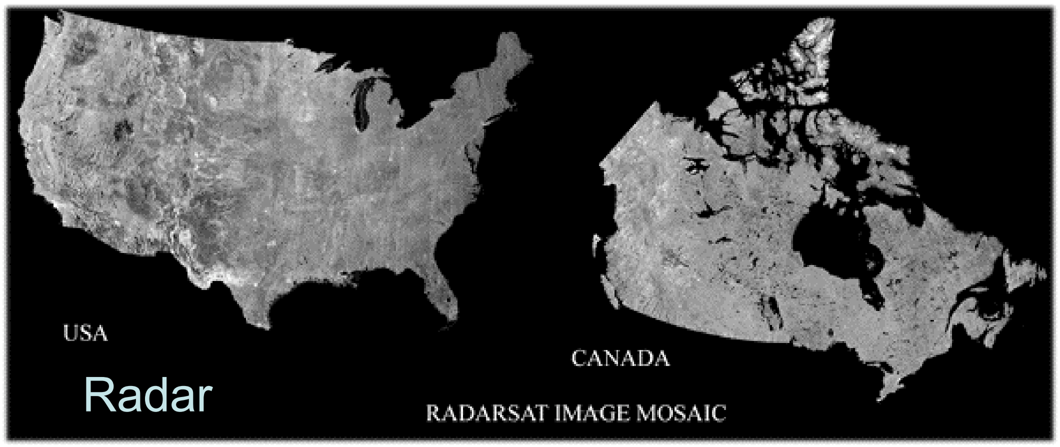
# Biomass Estimation Methodology

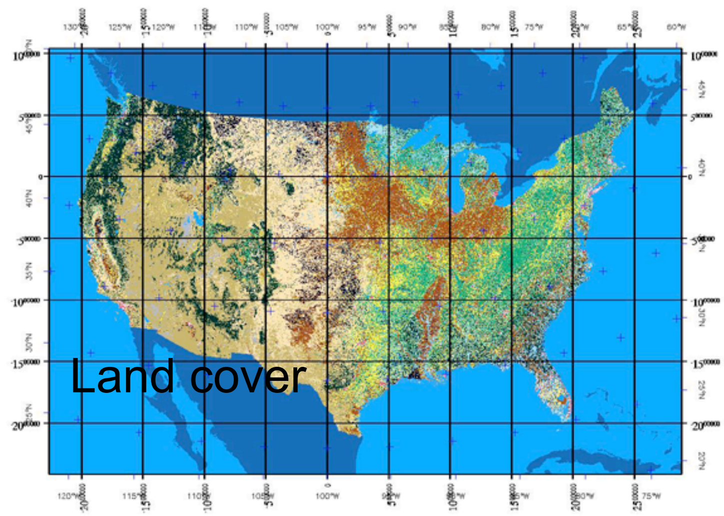


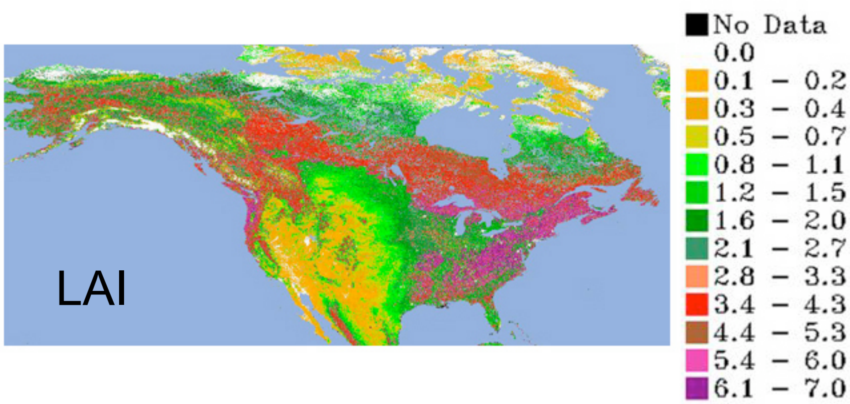
# Remote Sensing Data Fusion



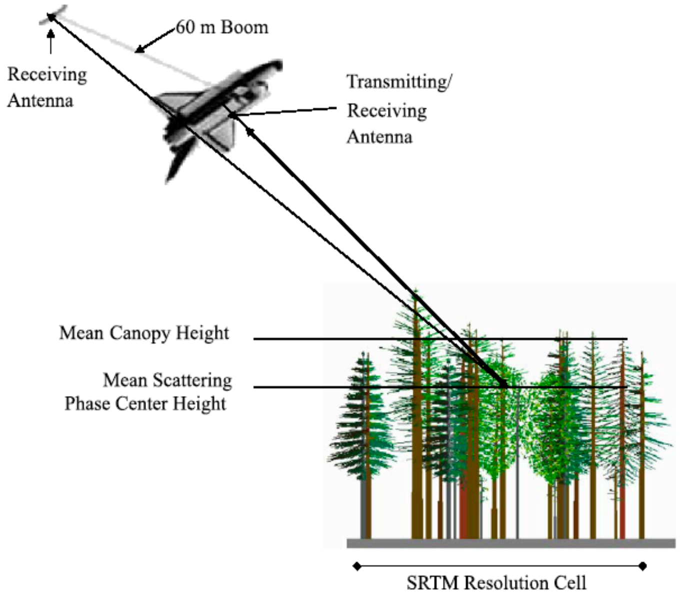


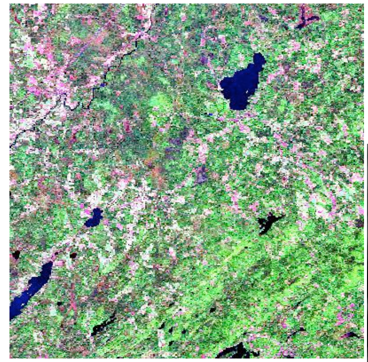


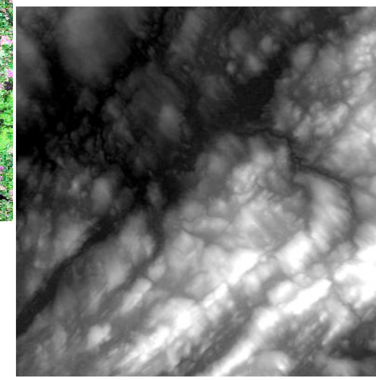




Final Product

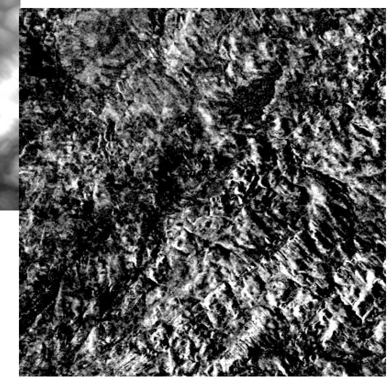


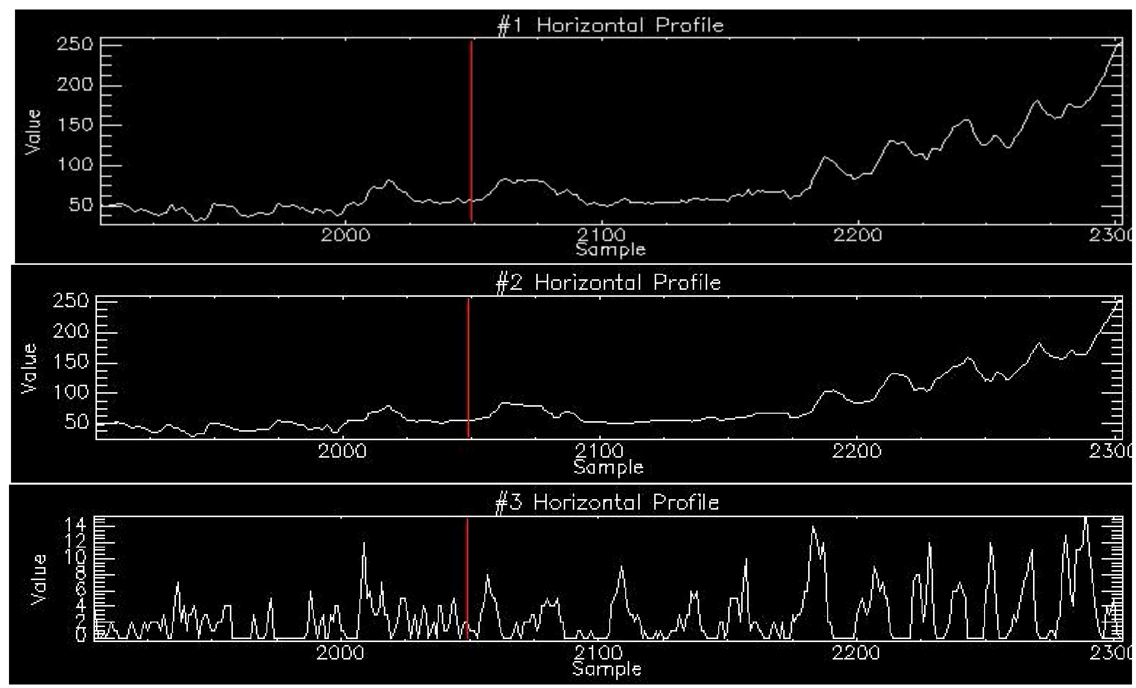
ETM



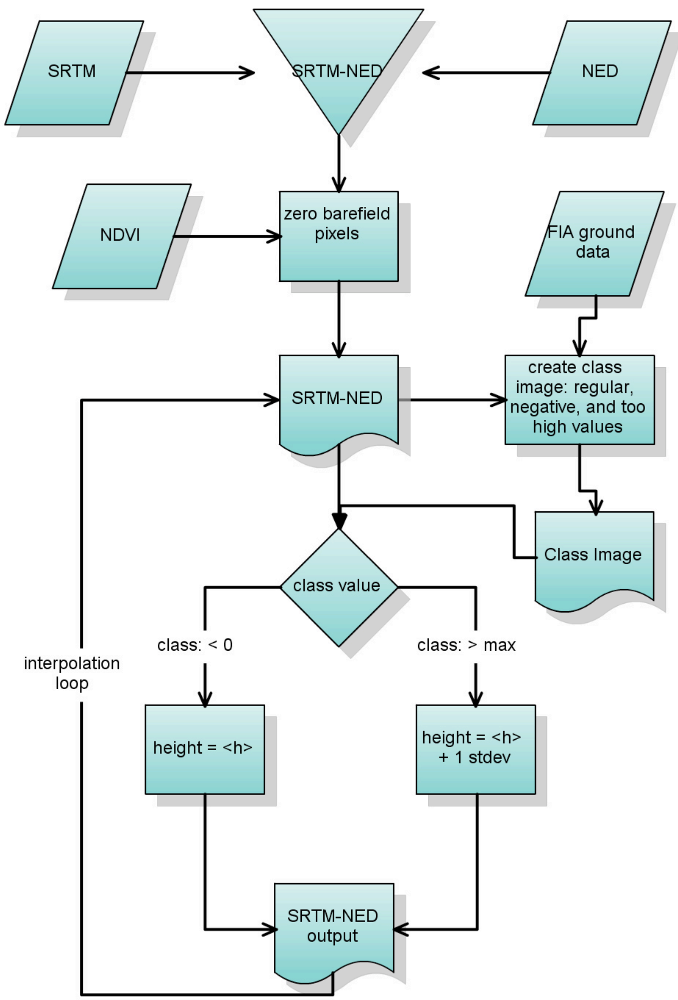
SRTM

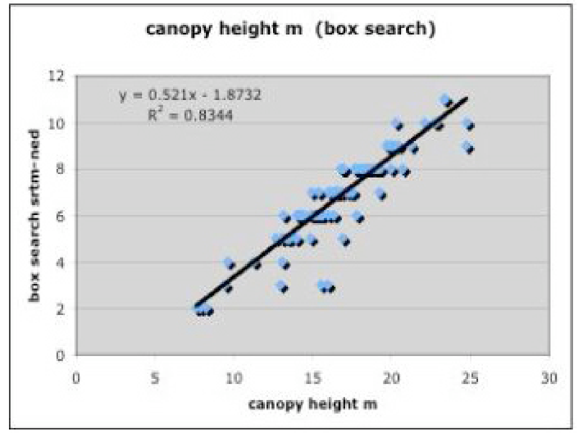


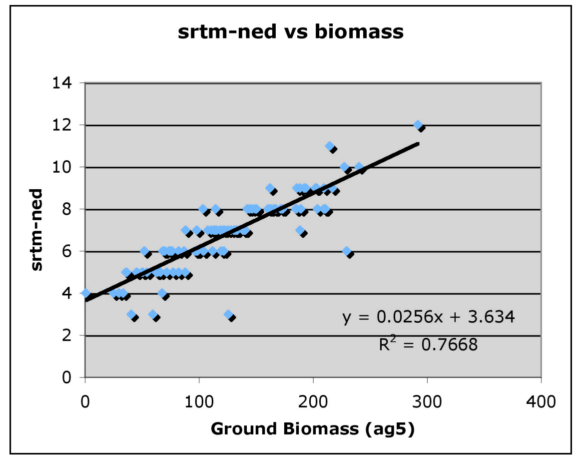
SRTM-NED

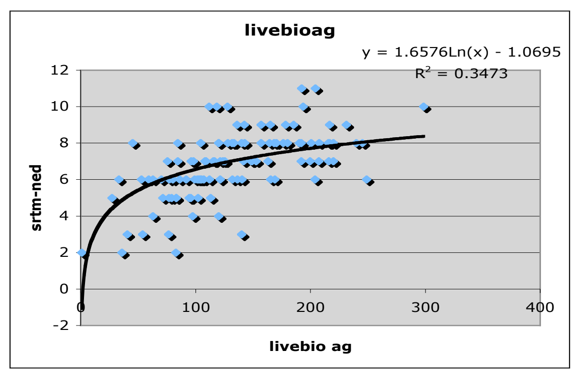


# Algorithm SRTM-NED Correction



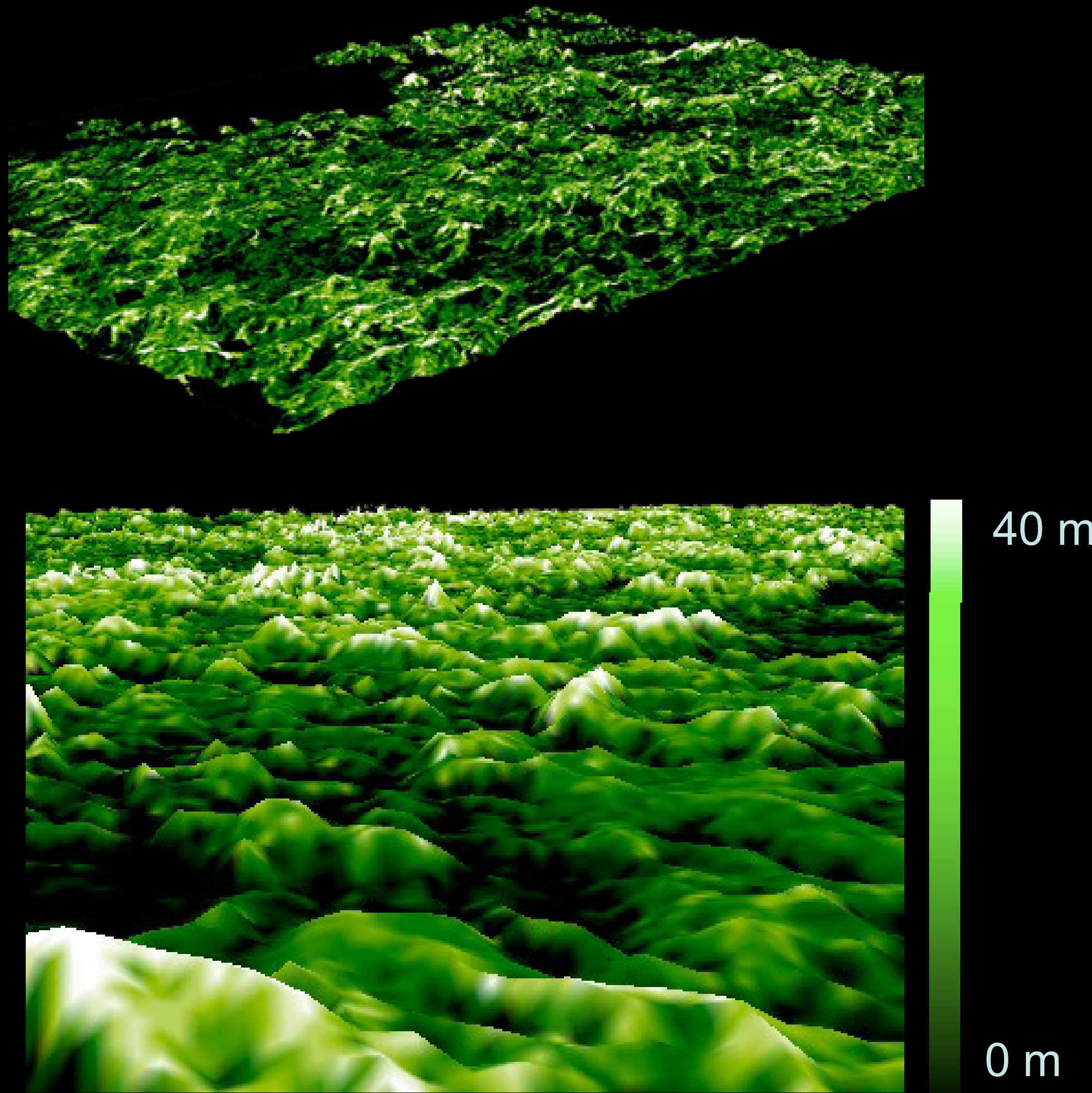



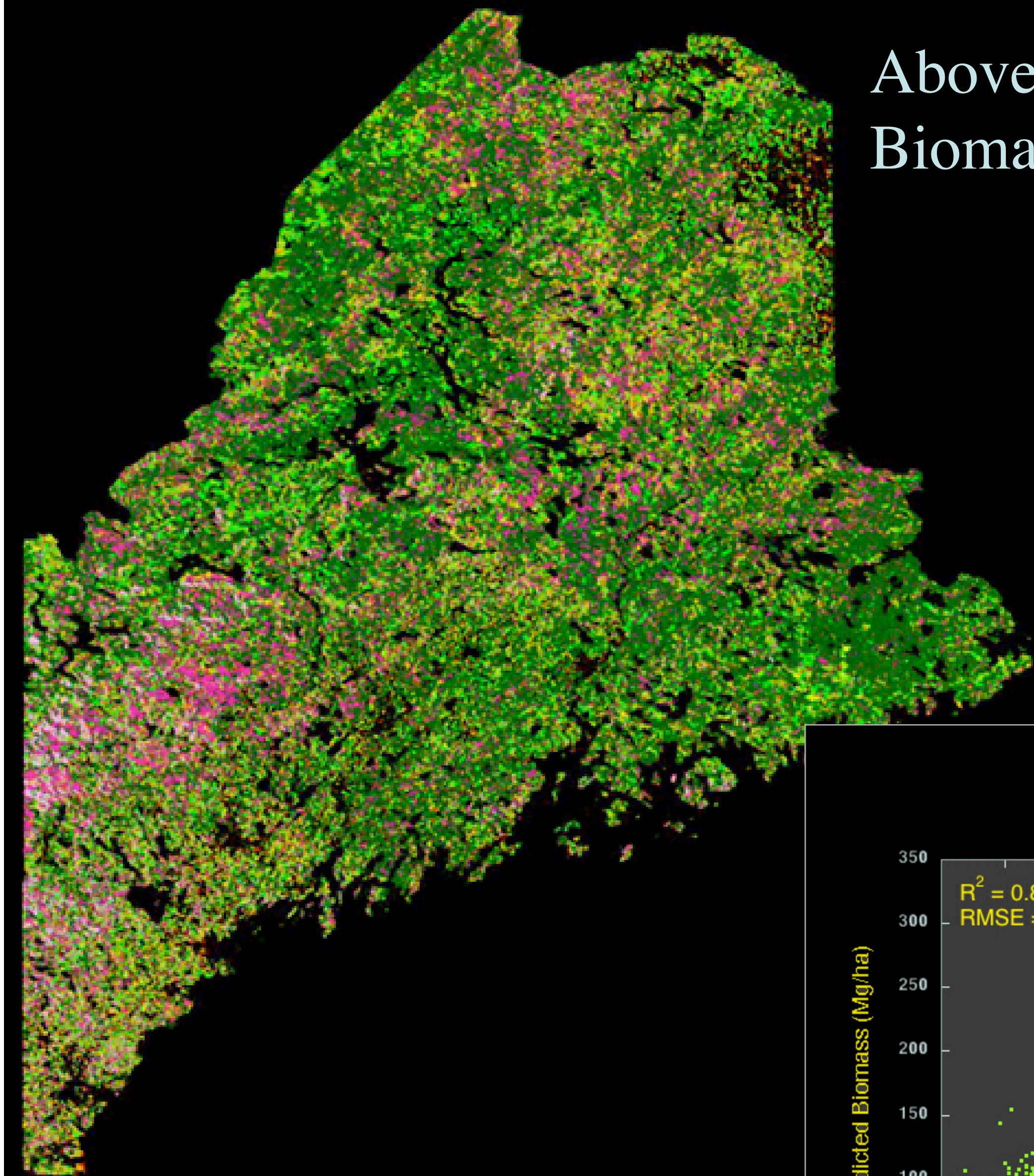
| Variables of Forest Structure | White /Red /Jack Pine | Spruce/Fir | Oak /Pine | Elm / Ash /Cottonwood | Maple /Beech /Birch | Aspen /Birch | Conifers | Deciduous |
|---|---|---|---|---|---|---|---|---|
| Height min/ mean/ max | 7.6 16.7 24.8 | 5.5 13.7 24.3 | 11.6 16.9 23.1 | 6.2 13.0 18.4 | 7.4 15.8 26.5 | 6.7 14.2 22.2 | 5.5 14.2 24.8 | 6.2 15.4 26.5 |
| Biomass min/ mean/ max | 0.5 122.3 291.8 | 0.6 80.4 260.9 | 27.6 118.5 225.4 | 5.5 76.7 188.2 | 1.2 105.3 341.8 | 0.8 66.5 209.1 | 0.5 87.6 291.8 | 0.8 96.6 341.8 |
| **Height** | **1.45** | **1.77** | **0.83** | **0.62** | **3.54** | **2.25** | **1.41** | **3.50** |
| Biomass (using height pixels) | 55.7 | 50.2 | 80.8 | 38.5 | 74.6 | 40.8 | 49.7 | 68.3 |
| Biomass (using biomass pixels) | 31.4 | 31.0 | 44.2 | 8.8 | 62.6 | 23.5 | 28.2 | 56.6 |

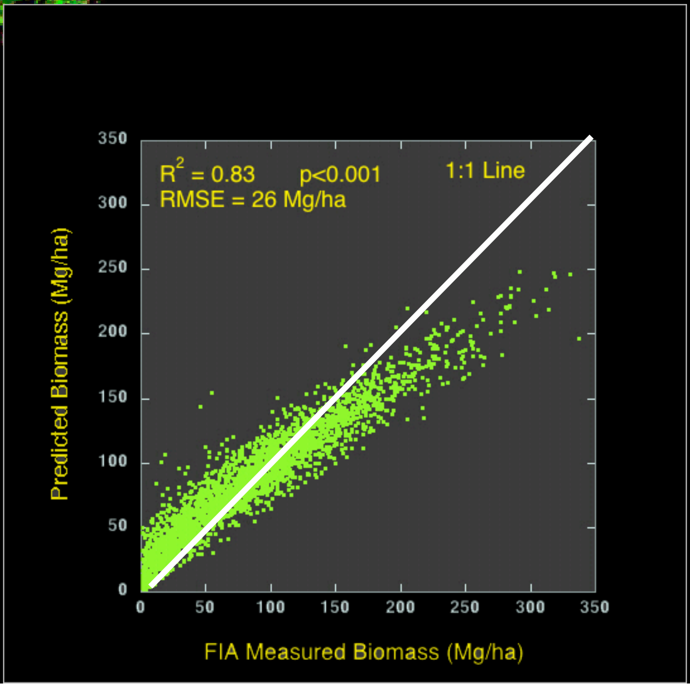
Height RMS values are units of meters. Biomass RMS values are in units of tons per hectare. The min/max values are from the ground data.

# 90 m Resolution Forest Height Distribution



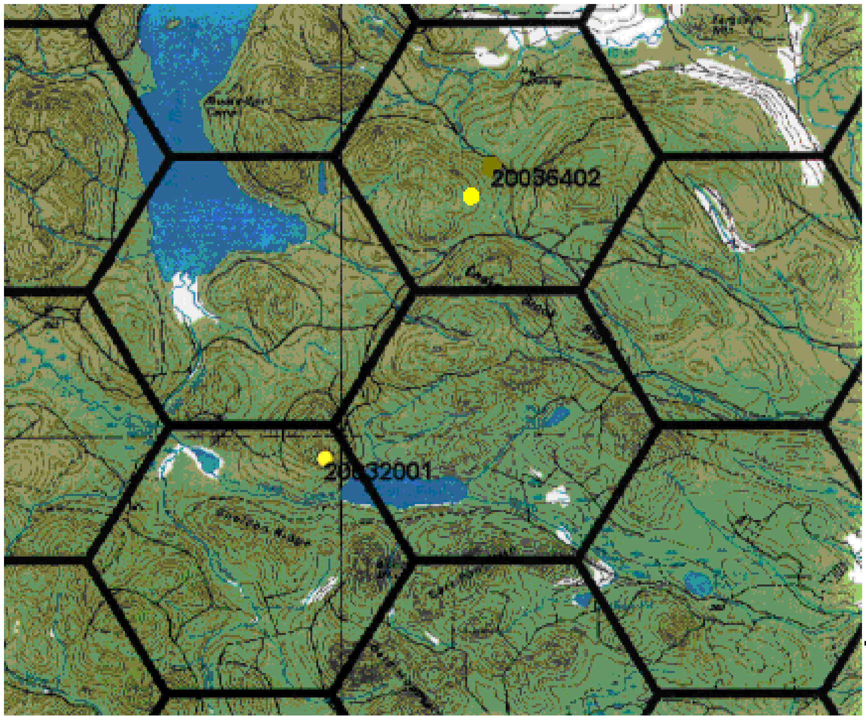
# Aboveground Biomass Map of Maine



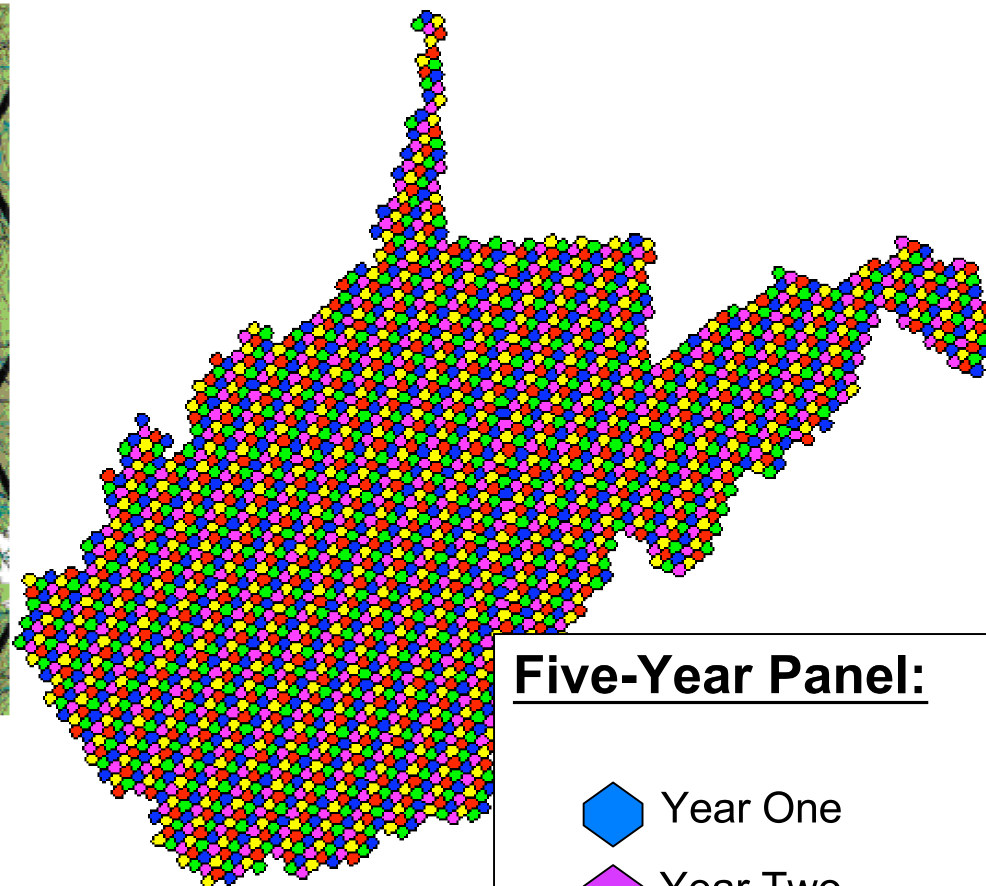



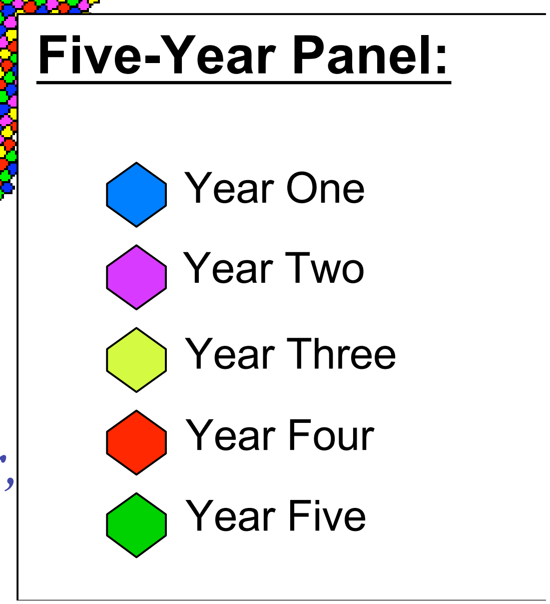
# USDA Forest Service FIA Plots

## a gift to the NACP



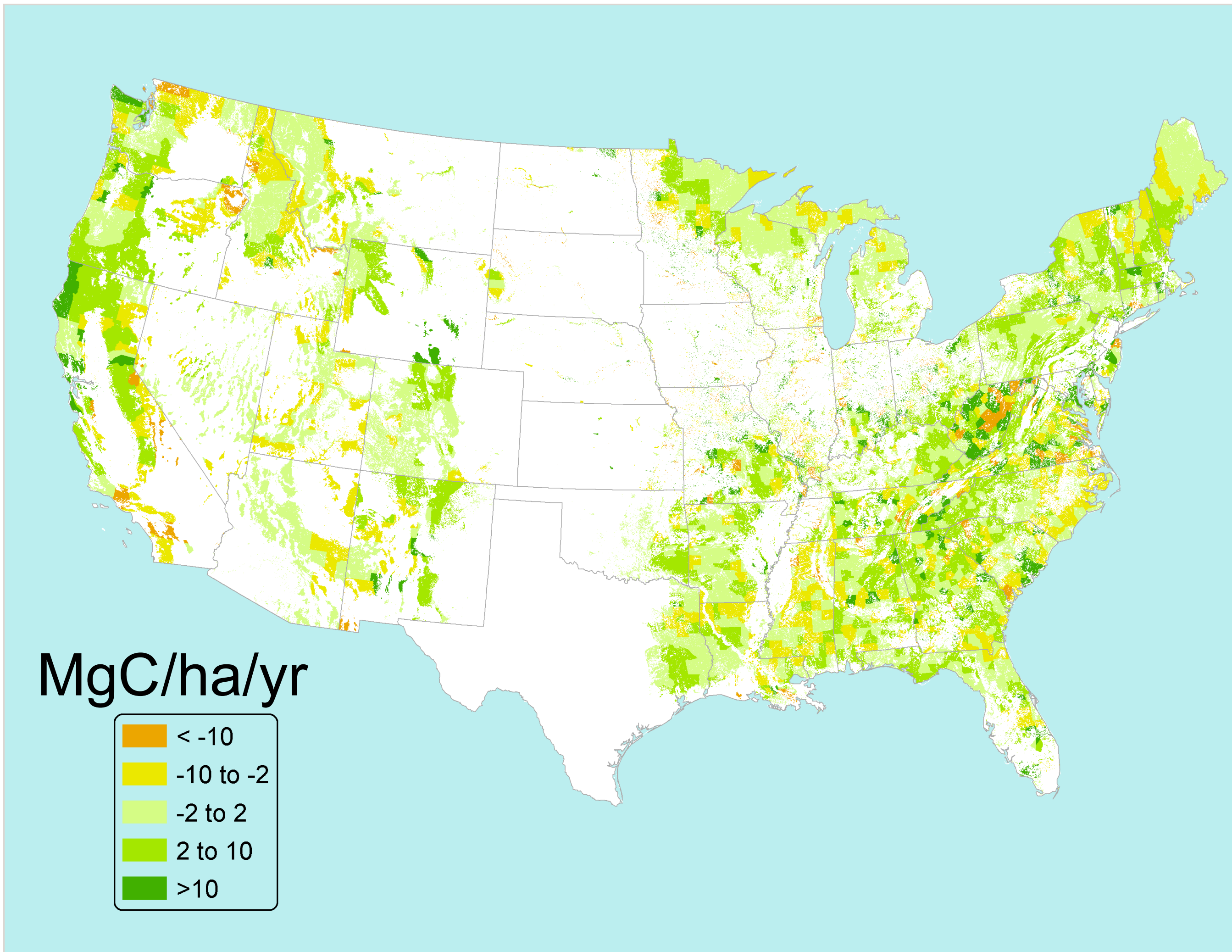

- 6000 acre grid cells
- 1 plot per grid cell
- >800K plots
- each plot visited every 5 (east) or 10 (west) years






*Courtesy Dave Hollinger, USFS*

# Average annual live tree C stock change by county, estimated from FIA data




Courtesy of Linda Heath, USFS

# Summary

**LCLUC Contribution to NACP**

1. Distribution of Aboveground Biomass Distribution of North America including Canada and Mexico
2. Land cover and Land Use change on decadal scale
3. Extent of natural disturbance and monitoring on decadal scale with selected regions for annual products

**Missing Elements**

1. Uncertainty analysis and products
2. Monitoring agricultural Sector
3. Annual land cover and Land Use change
4. Urban settlements
5. Monitoring changes in vegetation (forest) carbon stock