Towards Developing Annual Records of Forest Change History Using Landsat Observations

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UMD: Samuel Goward (PI), Nancy Thomas, Karen Schleeweis, Ainong Li

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Forest Dynamics and Global Environmental Change

- Carbon
  - UN-REDD
- Climate modeling
- Hydrology
- Conservation and biodiversity

A CORE ELEMENT OF THE U.S. CLIMATE CHANGE SCIENCE PROGRAM

North American Carbon Program

CONTINENTAL CARBON BUDGETS, DYNAMICS, PROCESSES, AND MANAGEMENT

GOFC-GOLD GLOBAL OBSERVATION OF FOREST AND LAND COVER DYNAMICS

GCOS Global Climate Observing System
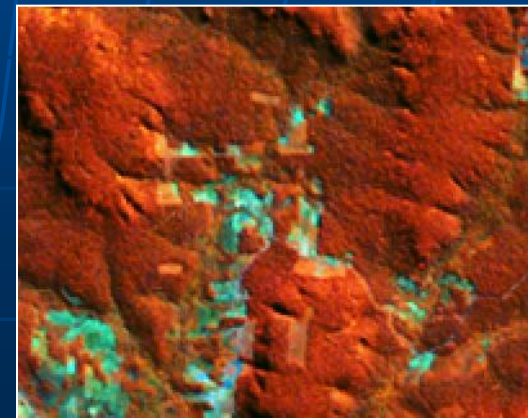Ensuring the Availability of Global Observations for Clim

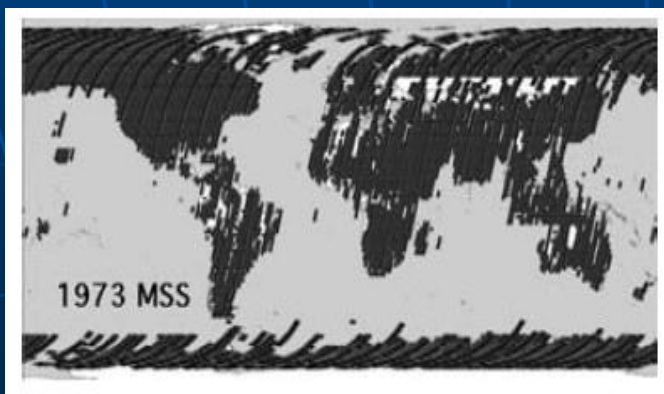**US Global Change Research Program**
www.usgcrp.gov

Landsat Unique for Monitoring Forest Change

- Fine spatial resolutions (sub-ha)
  - Necessary for detecting many anthropogenic changes
- Longest satellite record
  - 6 satellites
  - 1972 to future
- Comprehensive global coverage

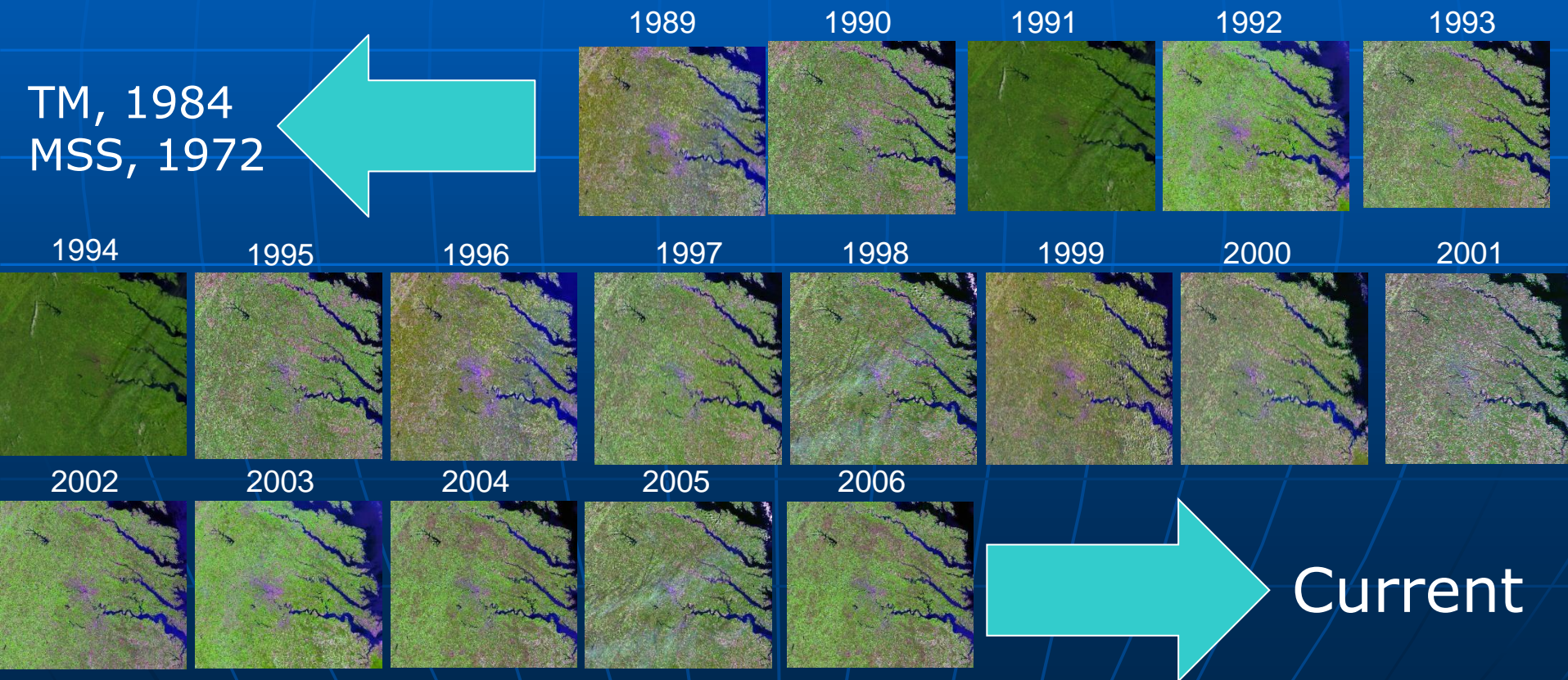

1973 MSS

Temporally Dense Observations Necessary

- Disturbance followed by rapid regrowth is a continuous process

  - Difficult to characterize using bi-temporal (or tri-temporal, quadri-temporal) observations
  - Time series observations necessary
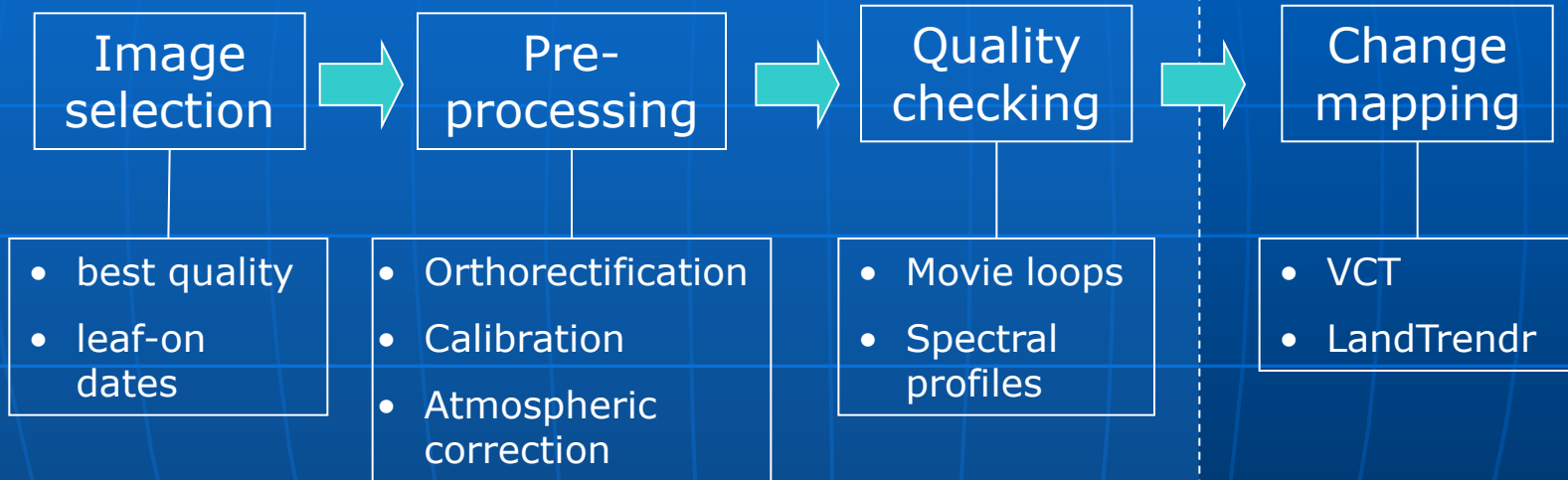
1990 Harvest difficult to detect by 1994

Use of Landsat Time Series Stacks (LTSS)

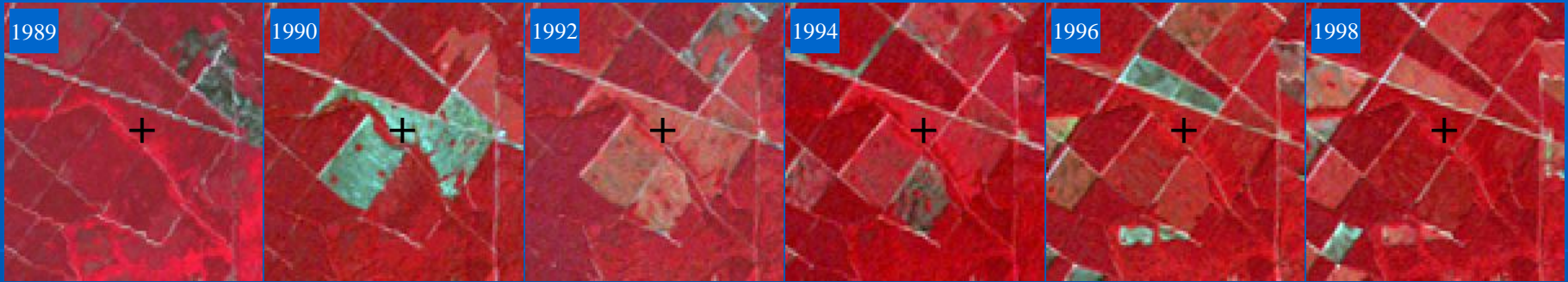- A sequence of images with a nominal temporal interval
  - Biennial
  - Annual

TM, 1984
MSS, 1972

1989 1990 1991 1992 1993

1994 1995 1996 1997 1998 1999 2000 2001

2002 2003 2004 2005 2006

Current

Major Steps for Forest Change Mapping using LTSS

Image selection	→	Pre-processing	→	Quality checking	→	Change mapping

Image selection
- best quality
- leaf-on dates

Pre-processing
- Orthorectification
- Calibration
- Atmospheric correction

Quality checking
- Movie loops
- Spectral profiles

Change mapping
- VCT
- LandTrendr

LTSS Production (Huang et al., 2009)

Vegetation Change Tracker (VCT)

$$FI_p = \sqrt{\frac{1}{NB}\sum_{i=1}^{NB}\left(\frac{b_{pi}-\overline{b_i}}{SD_i}\right)^2}$$
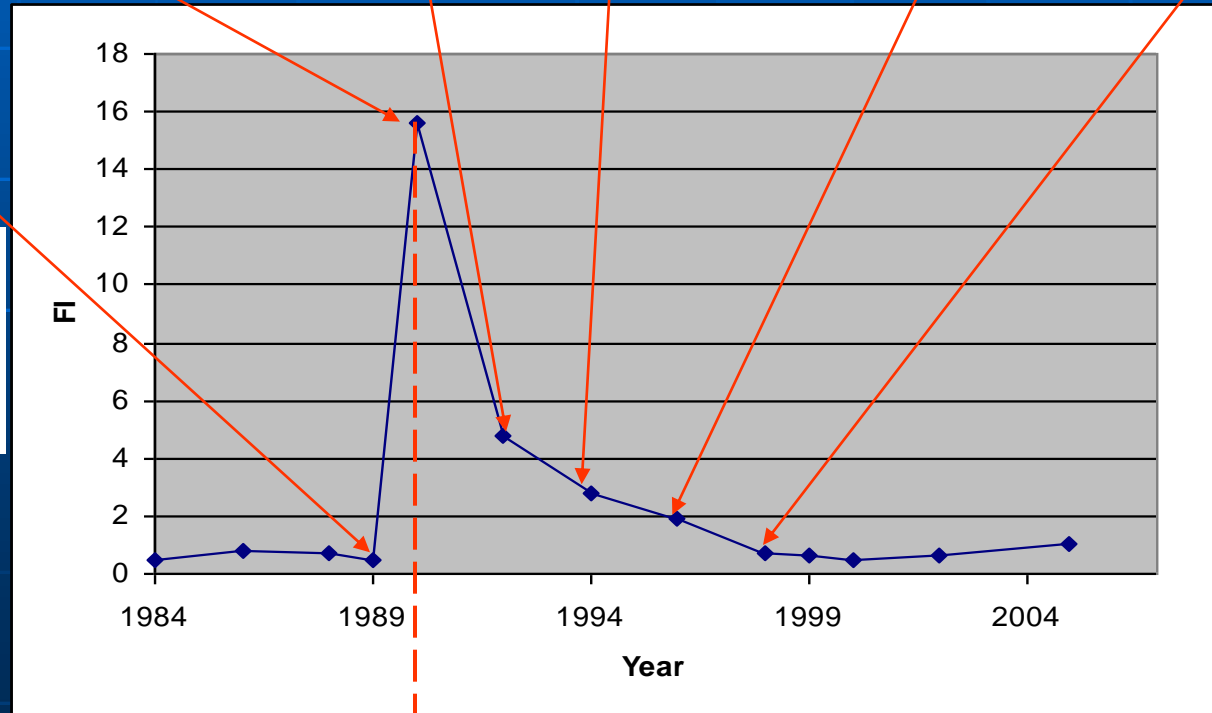
Year of disturbance

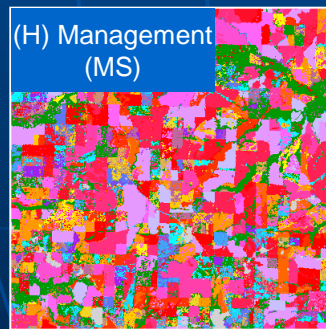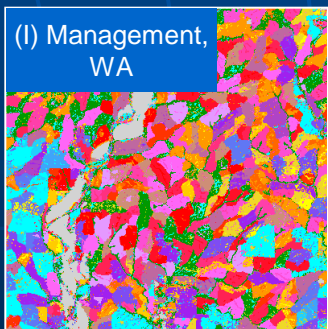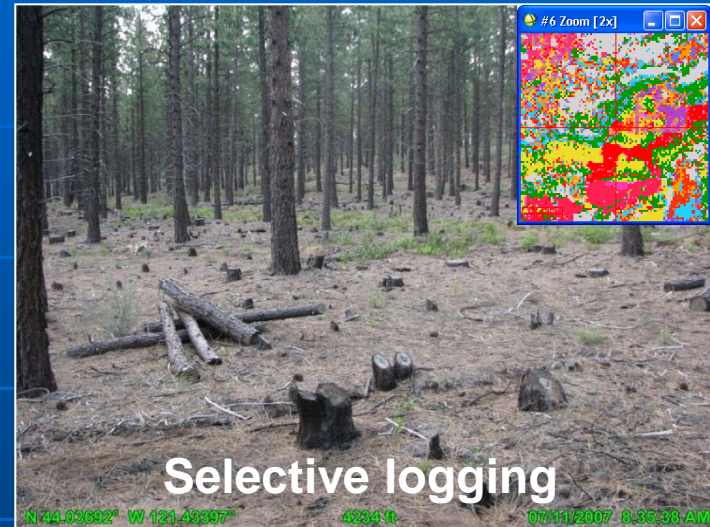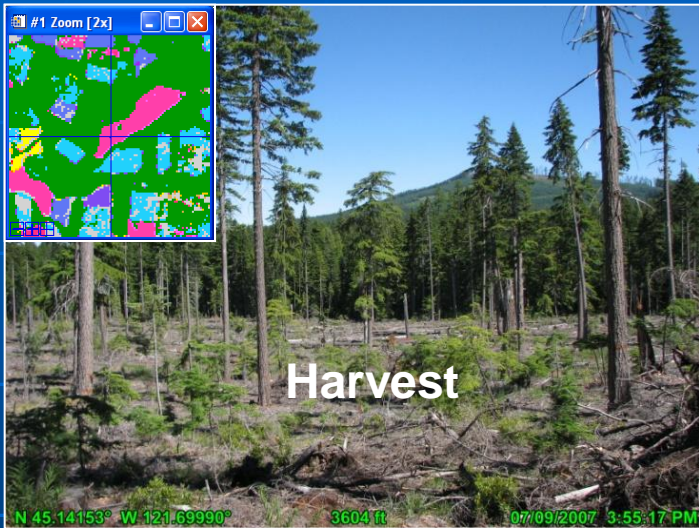Huang et al., 2010

Map records of forest disturbance and regrowth history
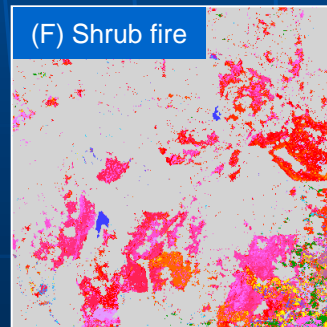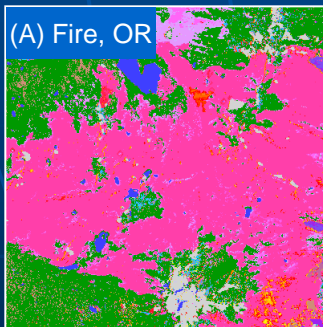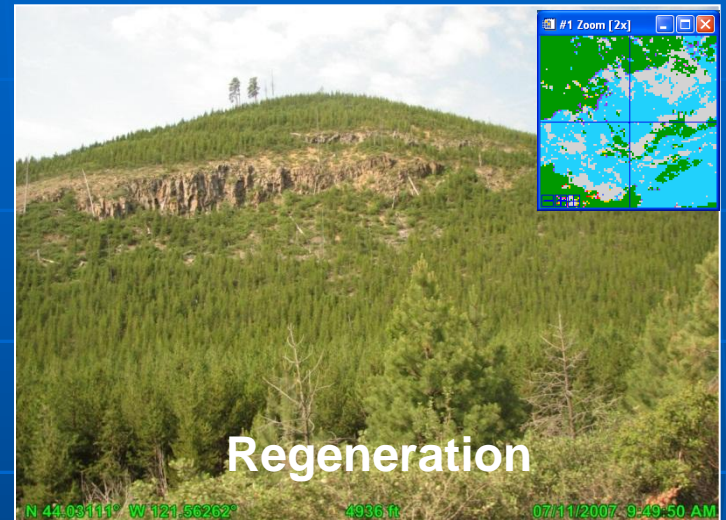
Disturbance History Map   Disturbance/regrowth Map for 2010
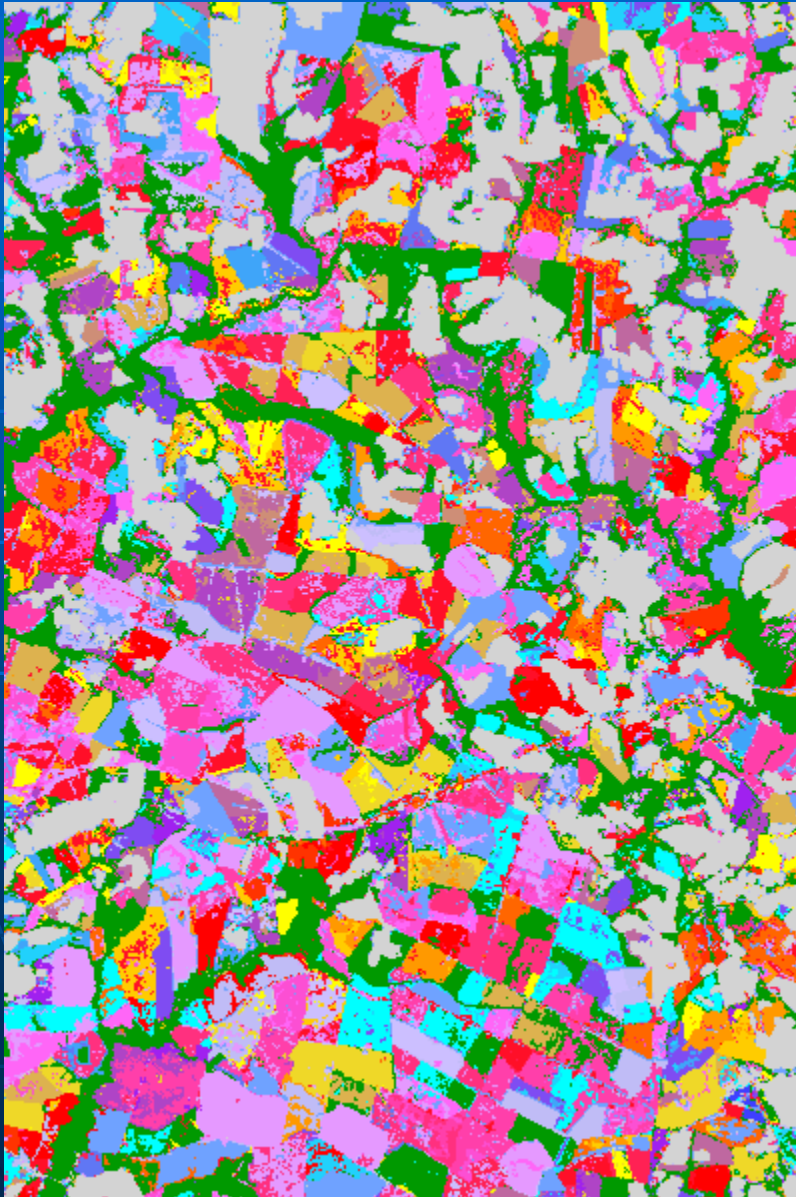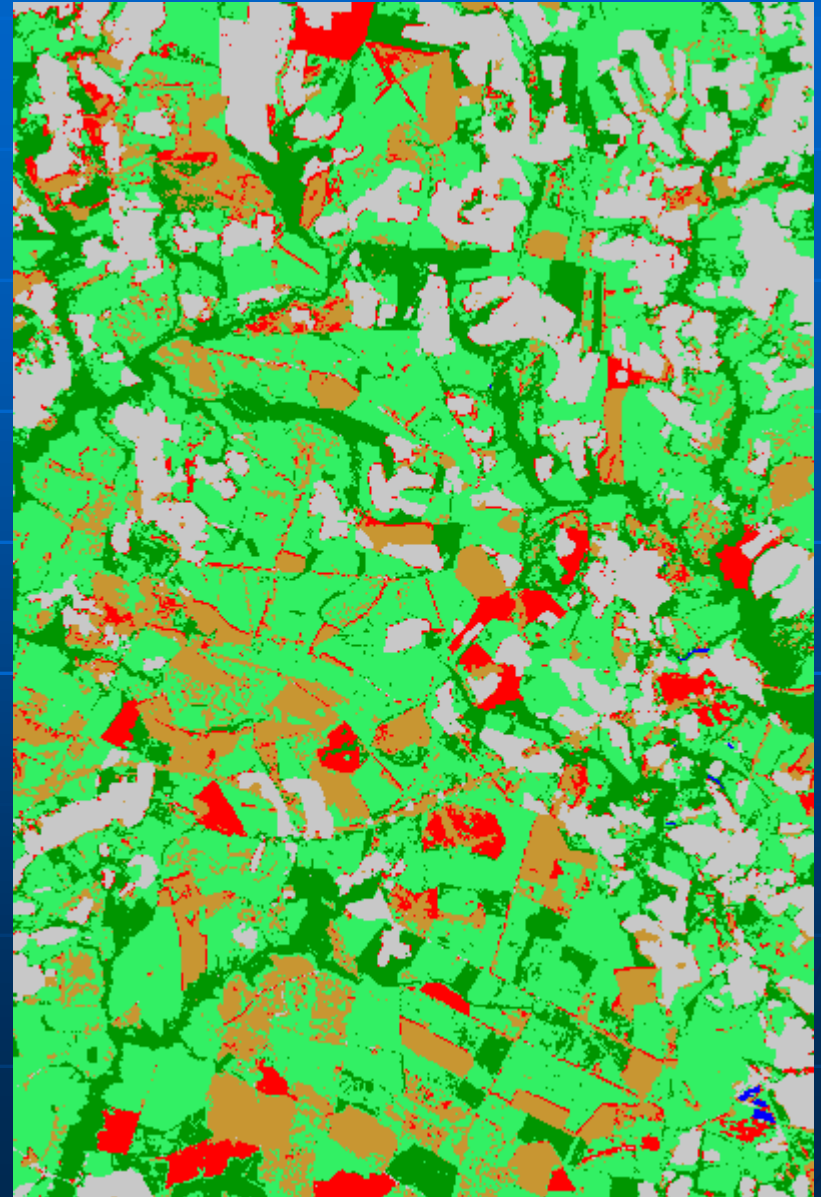
Disturbances Mapped by VCT – Harvest and Selective Logging
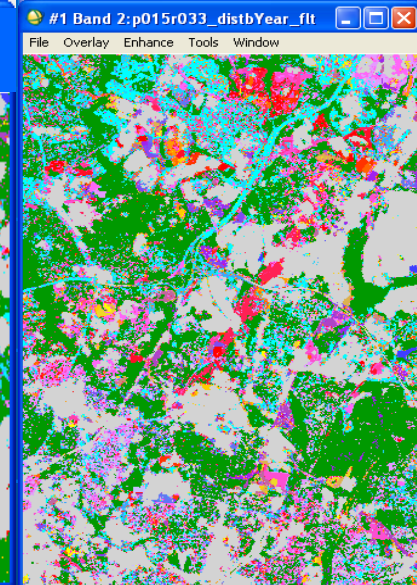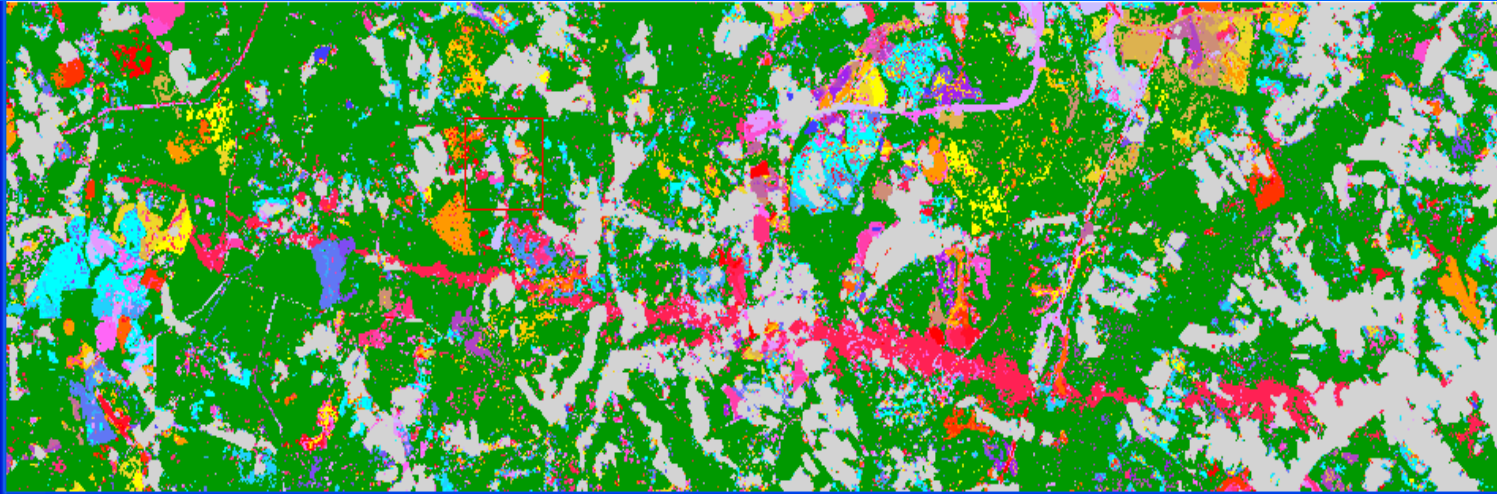

Harvest

Selective logging

(I) Management, WA

(H) Management (MS)

(G) Selective logging
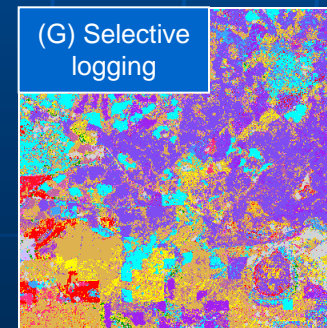
12 x 12 sq km

Disturbances Mapped by VCT – Fire, Insect, Regeneration

Fire

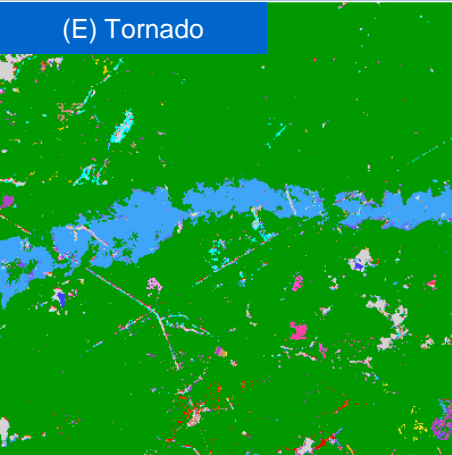Regeneration

Insect outbreak

(A) Fire, OR

(F) Shrub fire
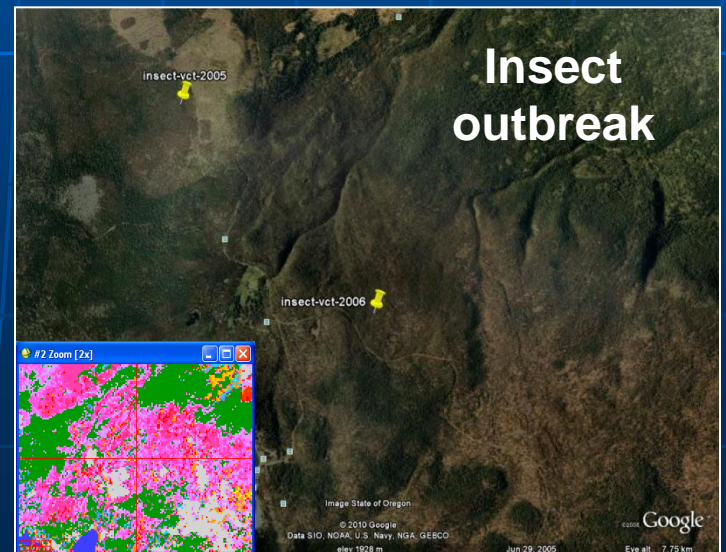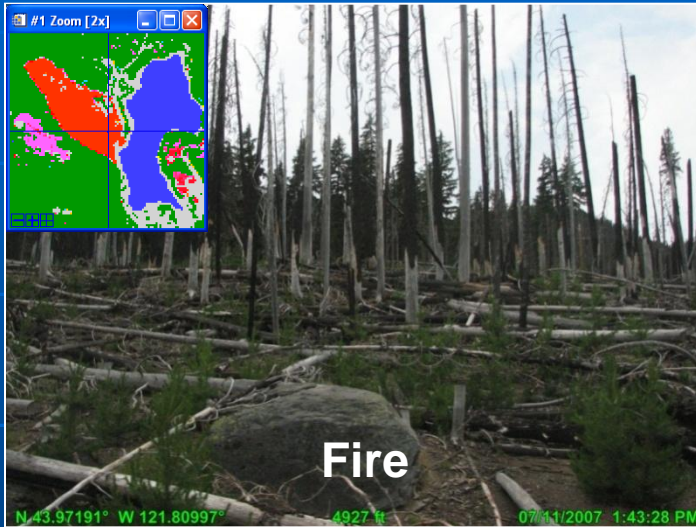
Disturbances Mapped by VCT – Hurricane, Tornado, Ice Storms

2002 Tornado in S Maryland
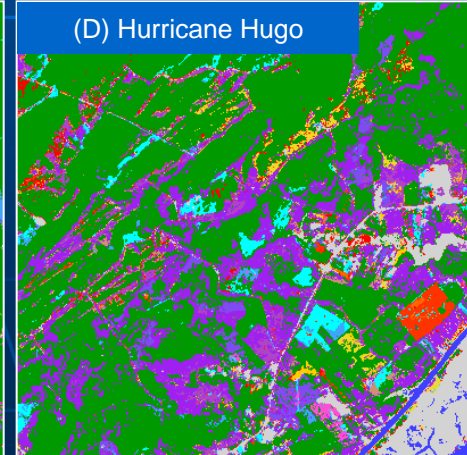
#1 Band 2:p015r033_distbYear_flt
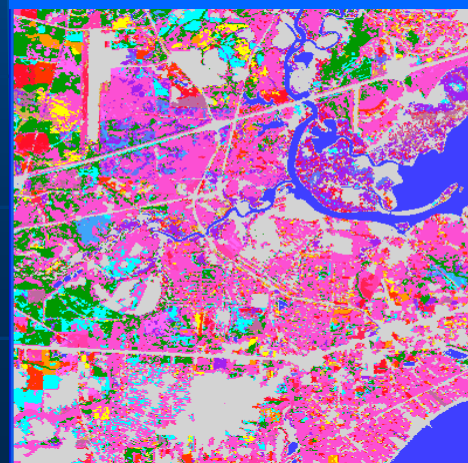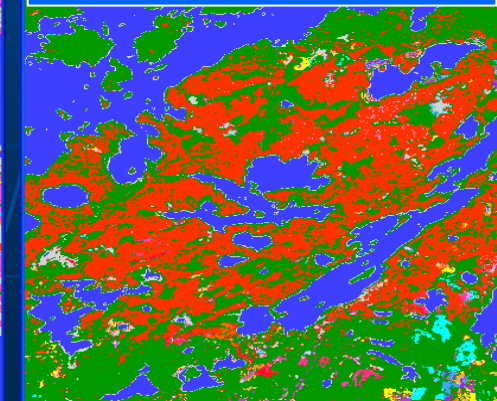File Overlay Enhance Tools Window

(E) Tornado

(D) Hurricane Hugo

Hurricane Katrina

1999 Ice Storm Damage
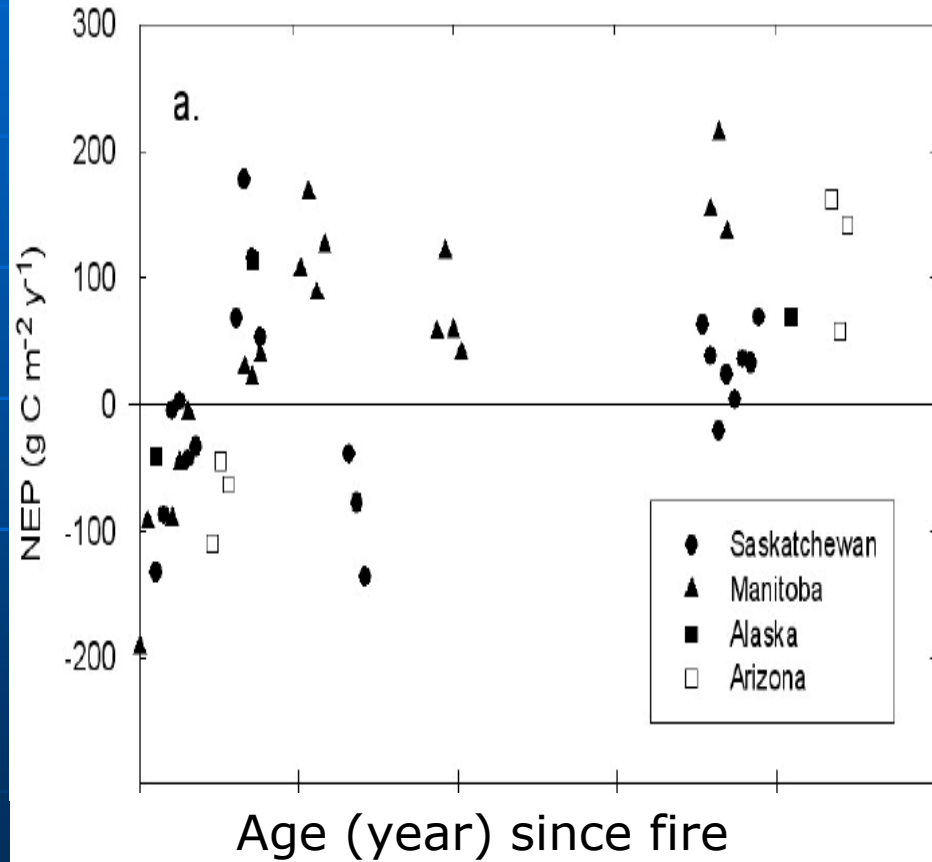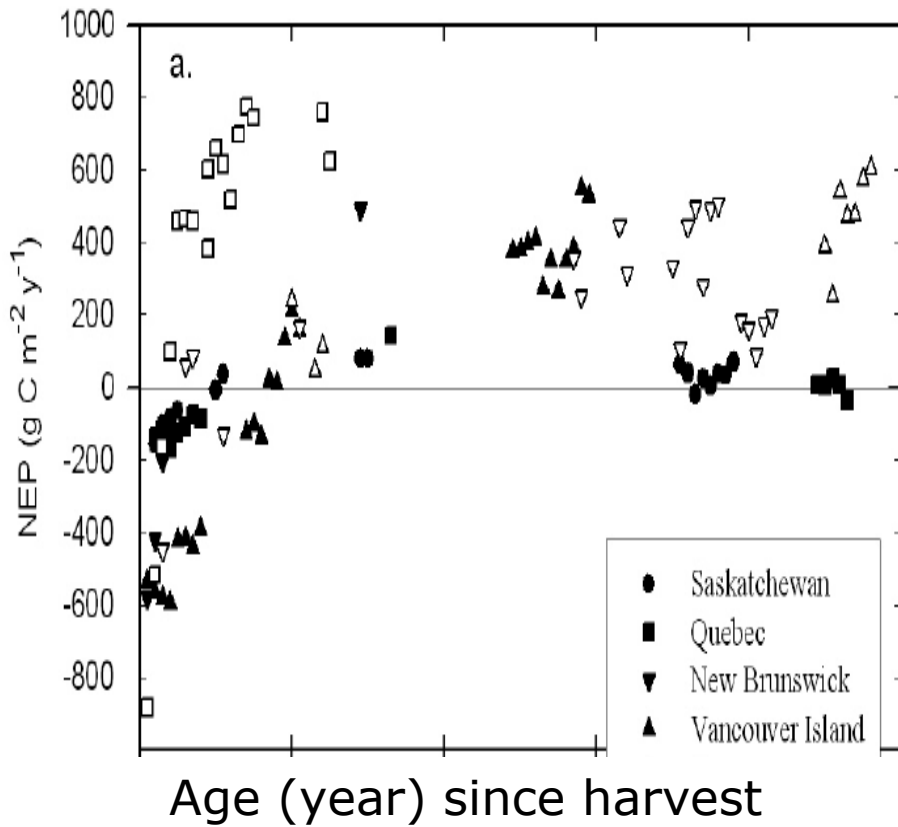
Accuracy of Age Since Disturbance

Table 5

Overall accuracy and Kappa Statistic are calculated for each site. We also include the average user's accuracy for the disturbed forest classes, calculated from the error matrices (Table 4). Average user's accuracy was also calculated from an additional set of error matrices, where ±1 time step is allowed as a correct match for each disturbance year. The pre-series disturbance class is not included here as a change class.

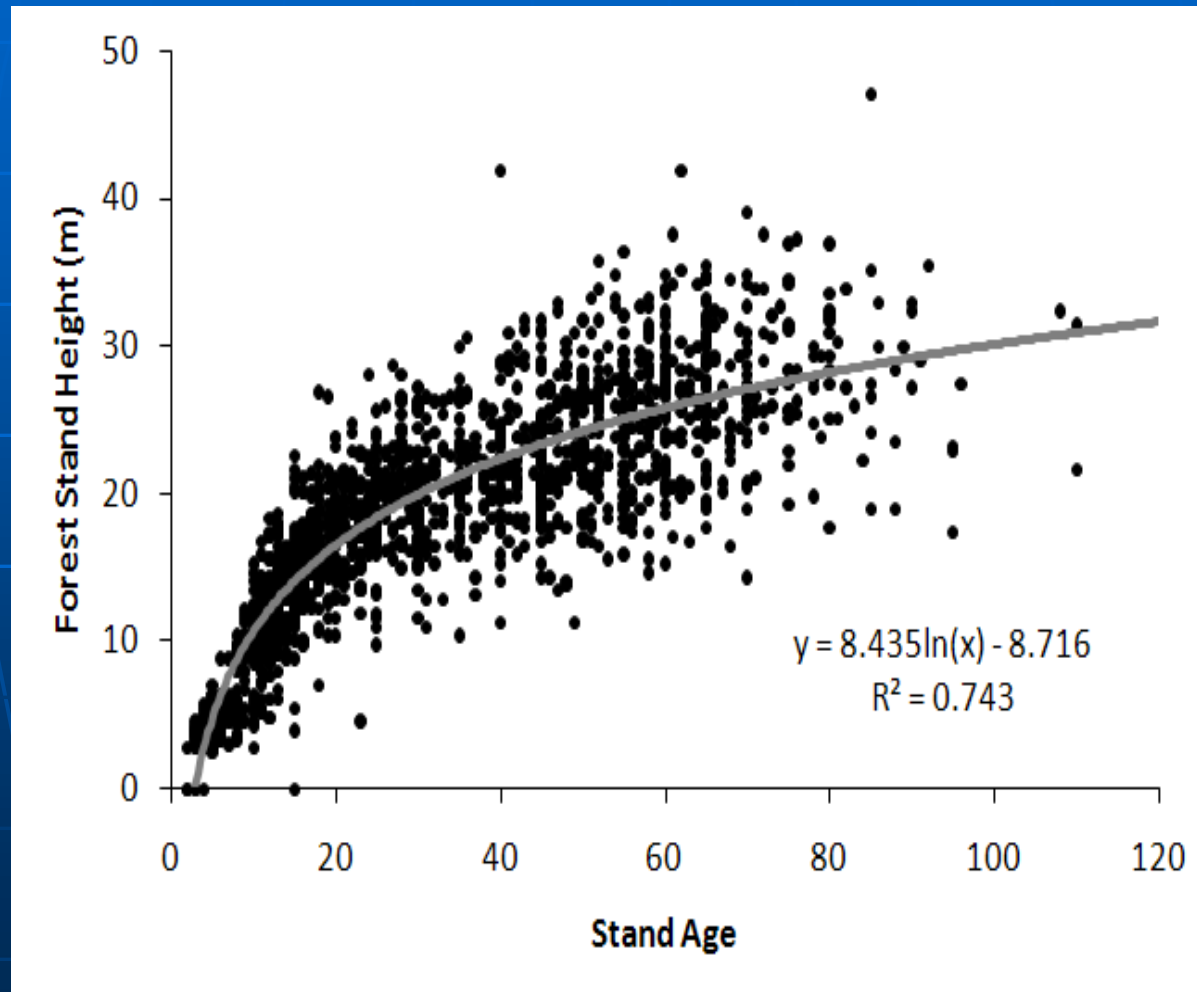| Path/row	Overall accuracy	Kappa	Average user's accuracy for forest change classes	Average user's accuracy for forest change classes ±1
12/31	85.16	0.76	66.49	75.84
15/34	80.28	0.75	78.21	85.56
21/37	77.83	0.74	77.61	81.08
27/27	76.71	0.67	79.1	86.67
37/34	85.83	0.43	55.37	64.27
45/29	83.8	0.73	71.05	85.74

(a) Virginia Site (15/34)

$R^2 = 0.742$

NAFD Year of Disturbance

FIA Plots

FIA Stand Establishment Year
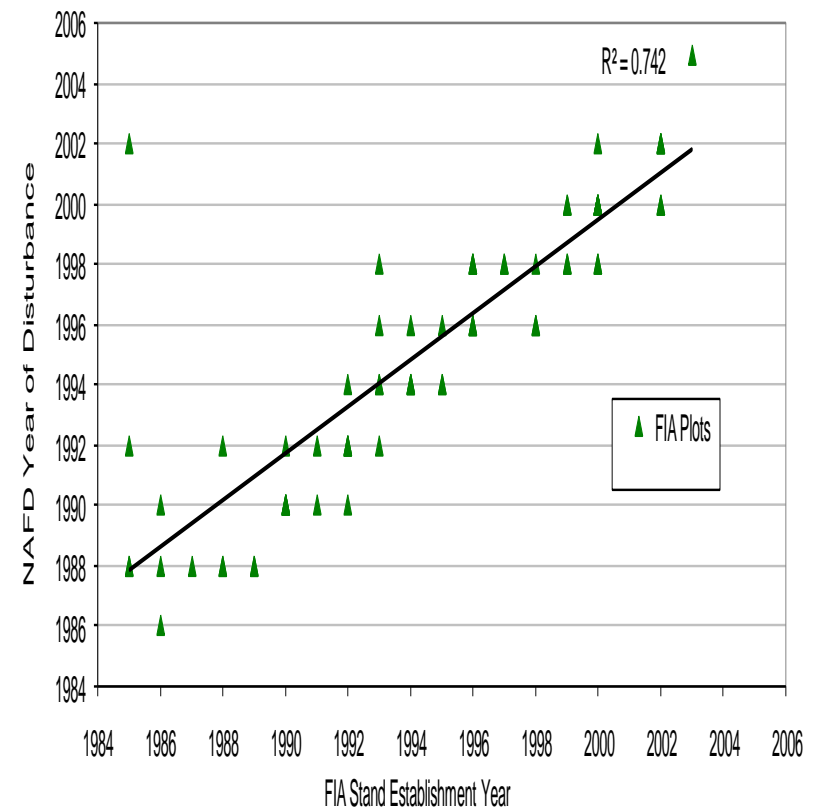
C Flux Varies with Age Since Disturbance

Age (year) since harvest

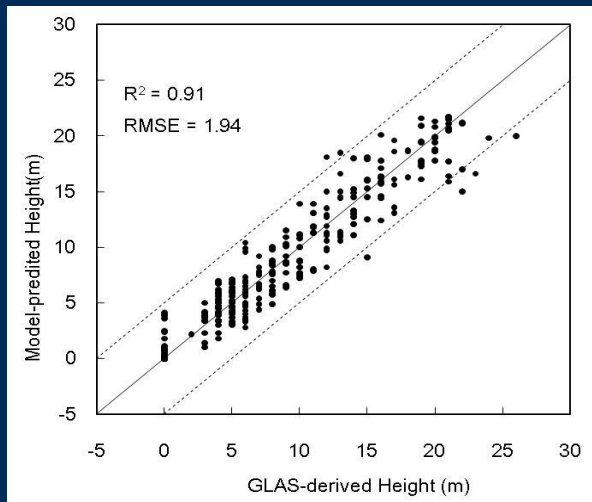Age (year) since fire

Amiro et al., 2010

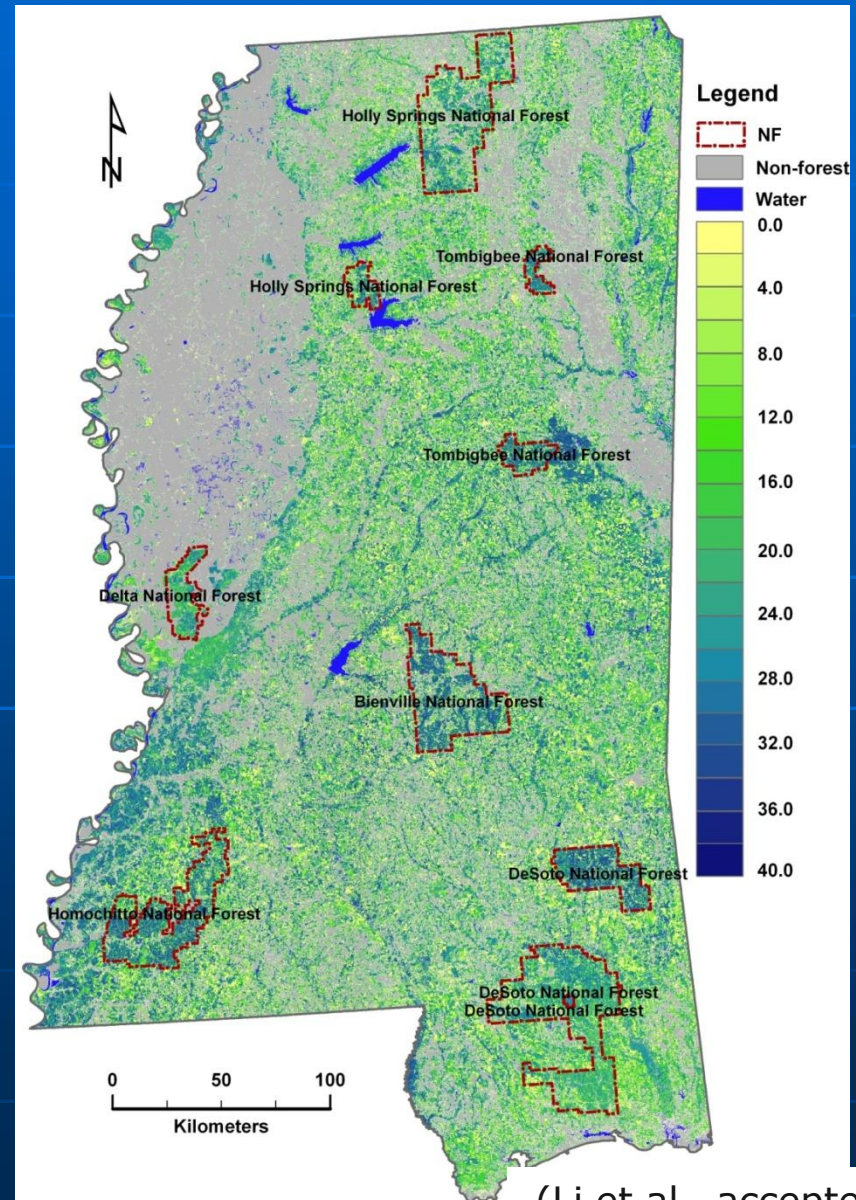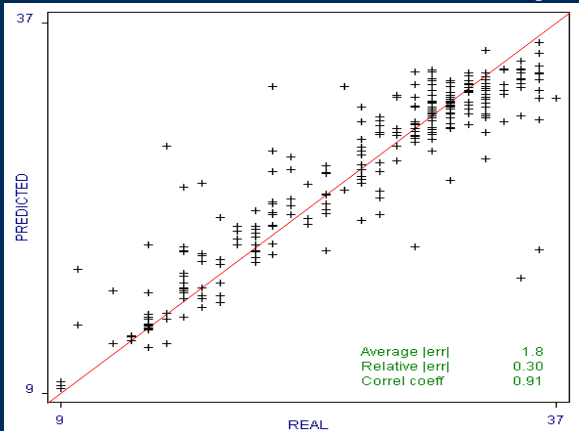# Forest Age is a Good Predictor of Height

Modeling Forest Height using VCT Products
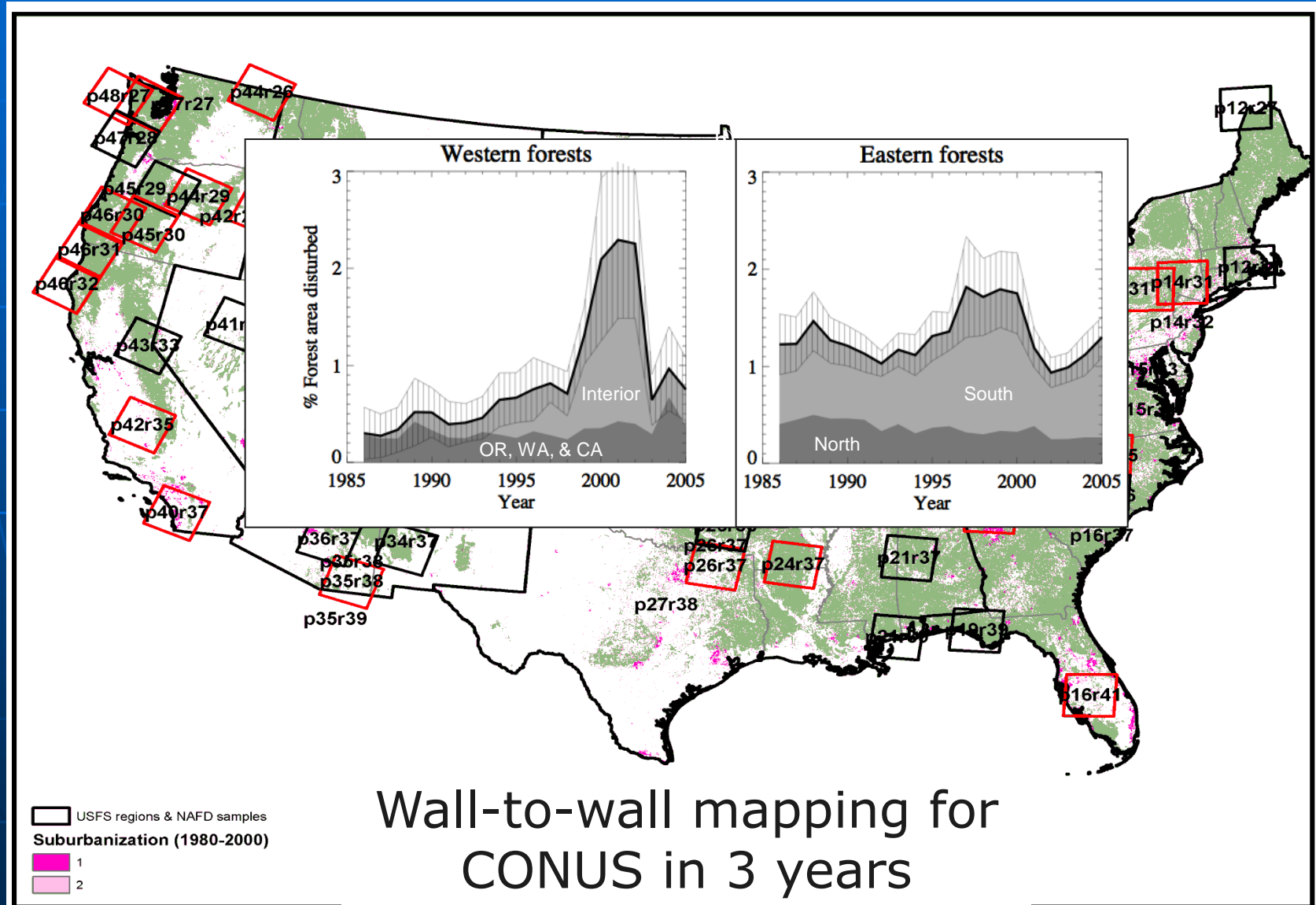
"Young" forest (disturbed after 1984)

"Old" forest (not disturbed after 1984)

(Li et al., accepted)

VCT Products Across the US
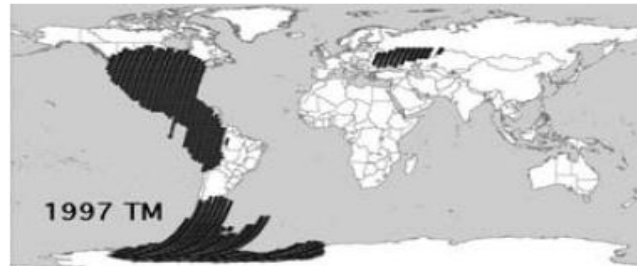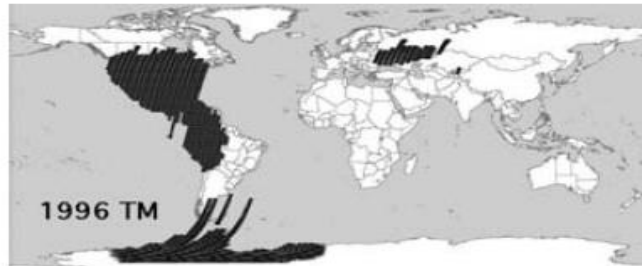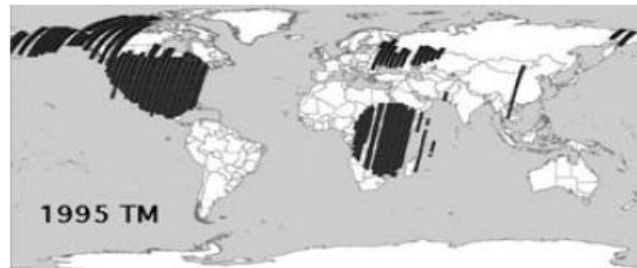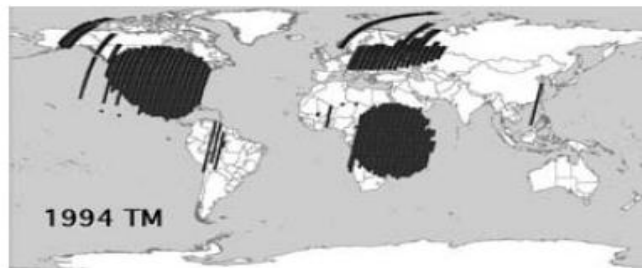

Wall-to-wall mapping for CONUS in 3 years

Global VCT Products?

- Technically feasible
  - VCT highly automated
  - Computing and storage requirements manageable
- Landsat Data Availability the Biggest Challenge

Goward et al., 2006
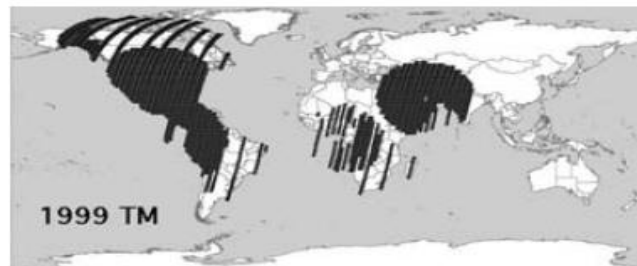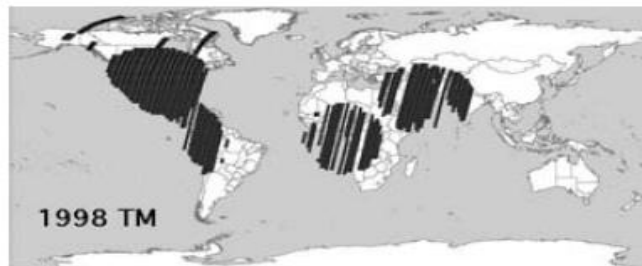
Data Inadequacy Exacerbated by Cloud

Image No.	Acquisition date	Cloud%	Image No.	Acquisition date	Cloud%
1	p013r029_1984162L50	14	30	p013r029_1996211L50	17.3
2	p013r029_1985196L50	48.7	31	p013r029_1996243L50	9.7
3	p013r029_1985244L50	18.8	32	p013r029_1997165L50	85.8
4	p013r029_1986215L50	50.5	33	p013r029_1997245L50	71
5	p013r029_1987154L50	68.2	34	p013r029_1998184L50	19.8
6	p013r029_1987170L50	77	35	p013r029_1998232L50	24.6
7	p013r029_1987186L50	15.9	36	p013r029_1999155L50	21.8
8	p013r029_1987218L50	16.1	37	p013r029_1999203L50	14.1
9	p013r029_1988173L50	22.9	38	p013r029_1999235L50	0.9
10	p013r029_1988189L50	60.9	39	p013r029_1999243L71	0
11	p013r029_1988205L50	37.7	40	p013r029_2000190L50	22.2
12	p013r029_1988253L50	7.8	41	p013r029_2000206L50	29.1
13	p013r029_1989207L50	13.2	42	p013r029_2000238L50	16.4
14	p013r029_1989231L40	11.6	43	p013r029_2000254L50	0.7
15	p013r029_1990178L50	79.7	44	p013r029_2001160L50	13.9
16	p013r029_1990194L50	22.5	45	p013r029_2001176L50	7.9
17	p013r029_1990210L50	4.5	46	p013r029_2001200L71	16.8
18	p013r029_1990242L50	15	47	p013r029_2001216L71	28.1
19	p013r029_1991229L50	18.1	48	p013r029_2001240L50	24.3
20	p013r029_1991245L50	0.7	49	p013r029_2001248L71	30.8

Global VCT Products?

- **Looking back**
  - Good Landsat records likely available for
    - U.S.
    - Brazil, China, Europe, Canada, Australia
    - Repatriation necessary for non-USGS data
      - Remove data cost
      - Best preprocessing
  - Other areas unknown
    - Africa problematic
  - Incorporation of other Landsat class data helpful:
    - SPOT, since 1980s
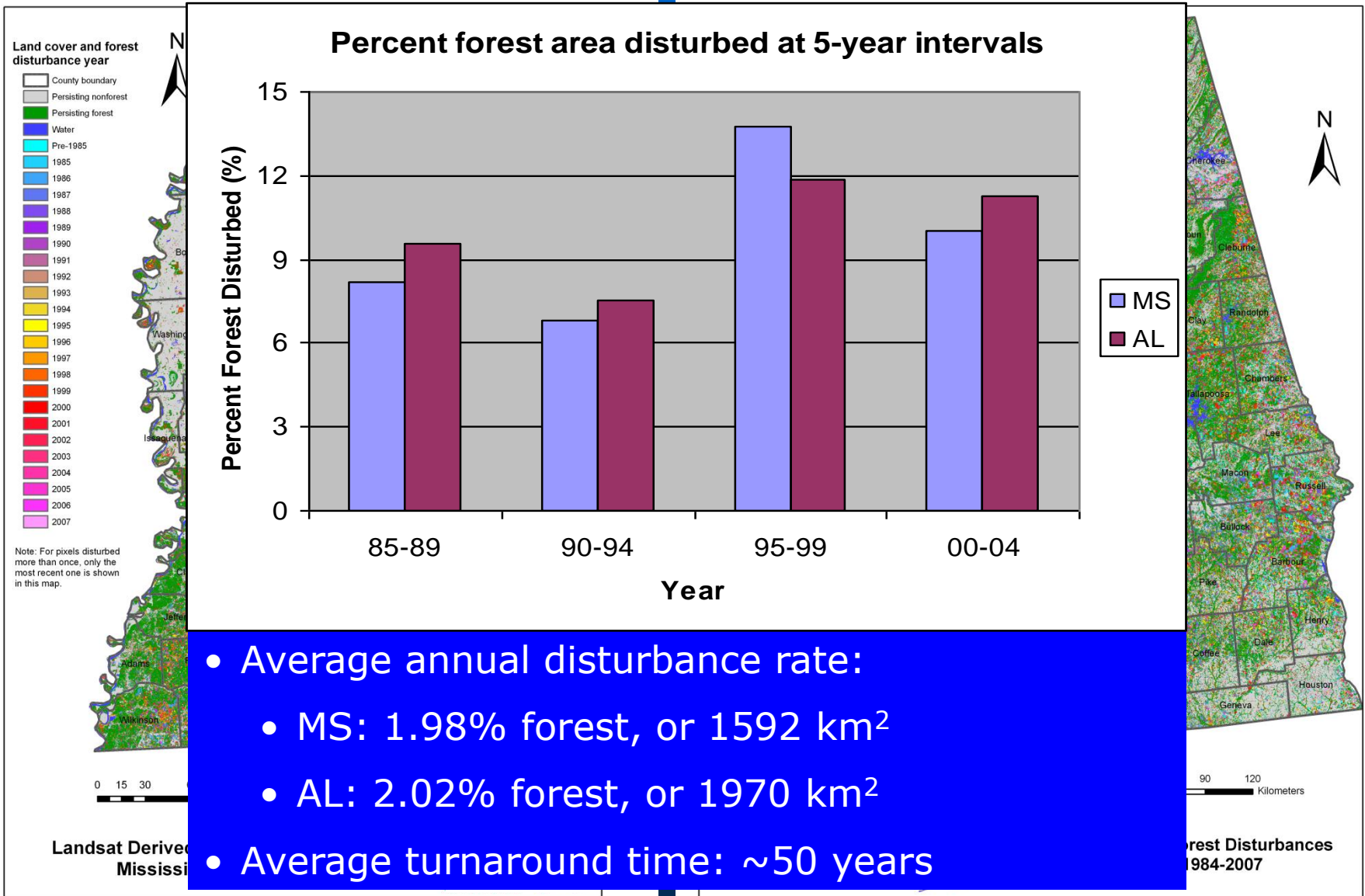   - IRS: LISS, AWIFS
    - CBERS, since 2000s
- **Future missions**
  - Global, daily 30 m observations necessary

Projects and Funding Agencies

- NASA
  - North American Forest Dynamics (NAFD) projects
  - LEDAPS

- USGS
  - LANDFIRE O&M
- USFS

Statewide VCT Products

- Average annual disturbance rate:
  - MS: 1.98% forest, or 1592 km^2
  - AL: 2.02% forest, or 1970 km^2
- Average turnaround time: ~50 years

Li et al., 2009a,b