

# Ecological Applications of Landsat Data – USDA Forest Service Science and Operational Needs (with partners)

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*& many other amazing, talented people at USFS, USGS, OSU,  
BU, UMD, SUNY, HU-Berlin*

Landsat Science Team Meeting, 29-31 October 2013, EROS, Sioux Falls, SD

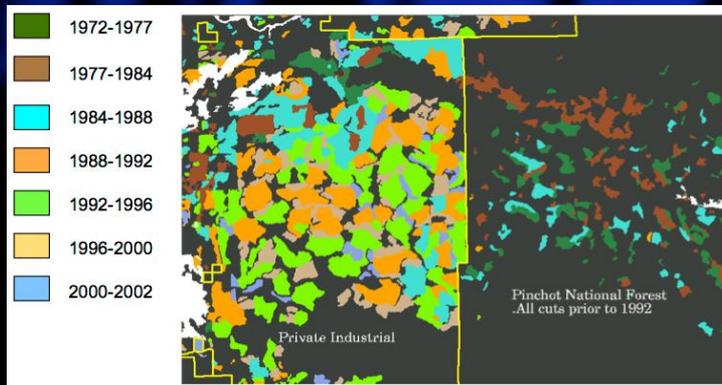
# Focal Point

- *Furthering a Landsat-based interagency (USFS, USGS) monitoring system for the US: Landscape Change Monitoring System (LCMS)*
  - Framework for integrating change and related information & data
  - All ownerships and cover types
  - Start with woody systems

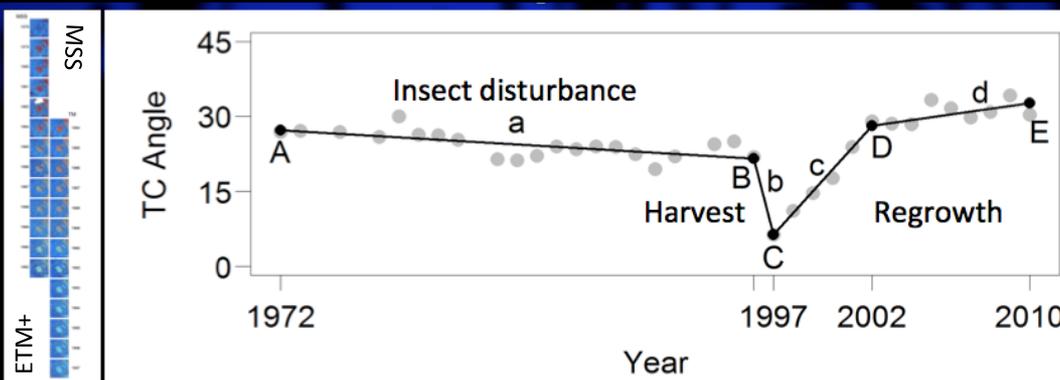


# Elements

- Integration across sensors from MSS→OLI
  - Long time periods of observation critical for understanding ecosystem resilience to historic management and policy decisions & to guide future decisions under the influence of climate change



- MSS-TM-ETM+ interval series integration has always been valuable for agency monitoring
- Recent integration over annual time-series

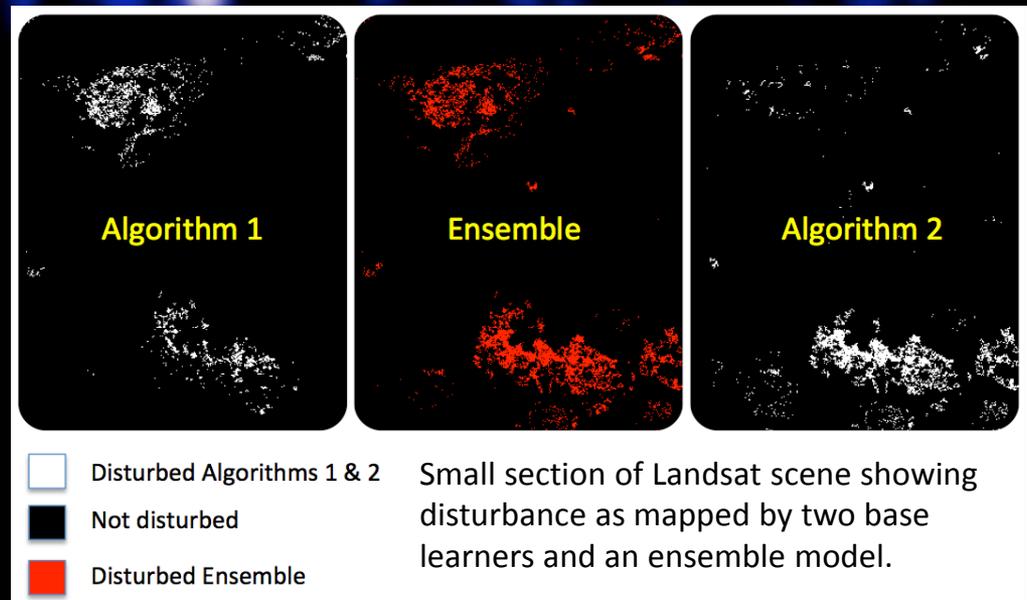


- Incorporate OLI, automate processing for large area mapping and related analyses

# Elements

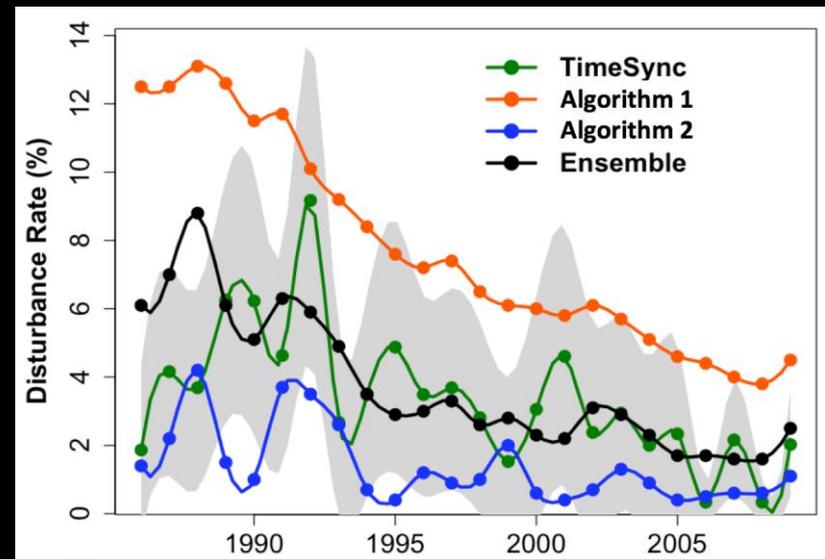
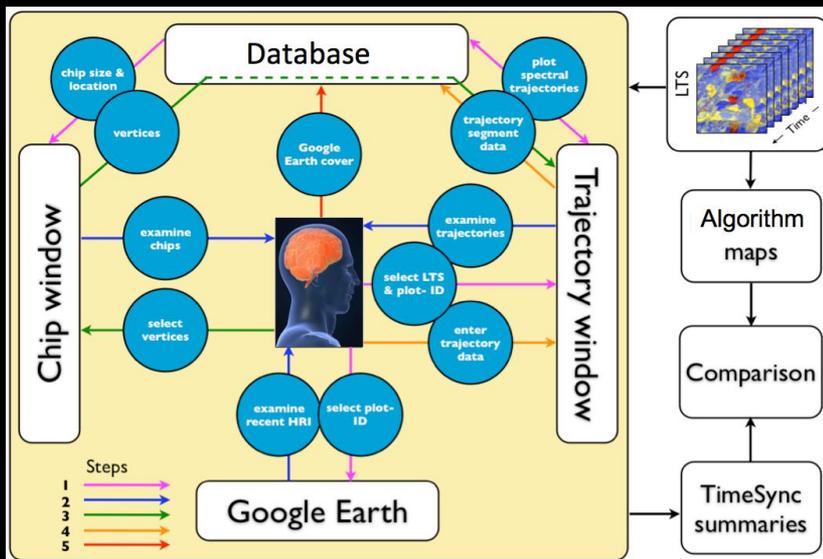
- Ensemble modeling integrates map output from multiple time series algorithms and other relevant data (will include causal agent)

- Recognizes that all algorithms formulated for specific purposes & map outputs have strengths and weaknesses across different systems



# Elements

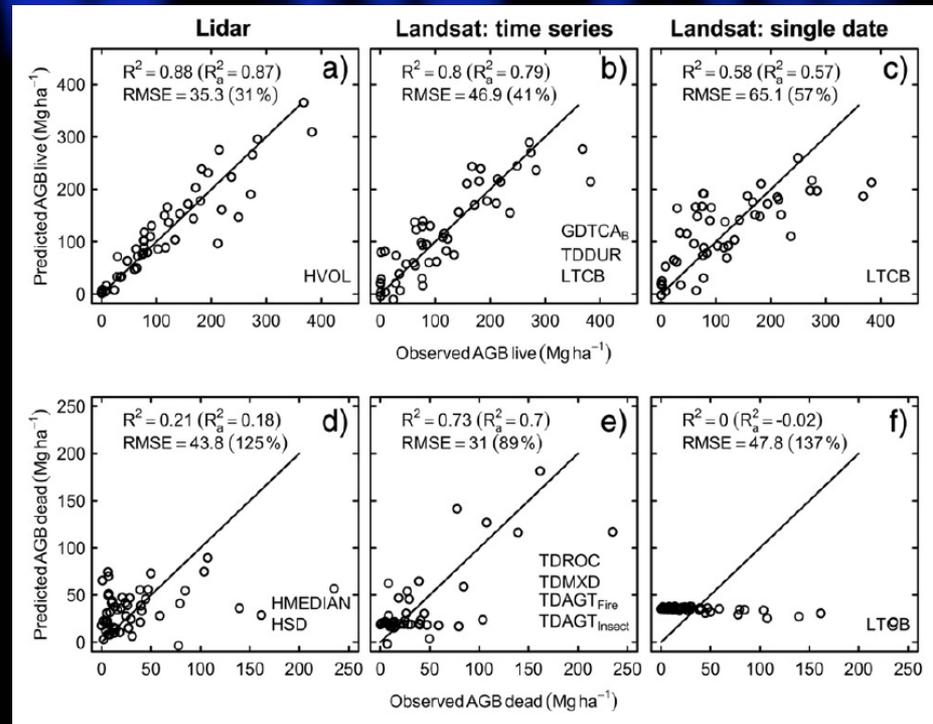
- Sampling component to provide map quality assessment (QA) and independent disturbance estimates
  - TimeSync Landsat time-series visualization tool



# Elements

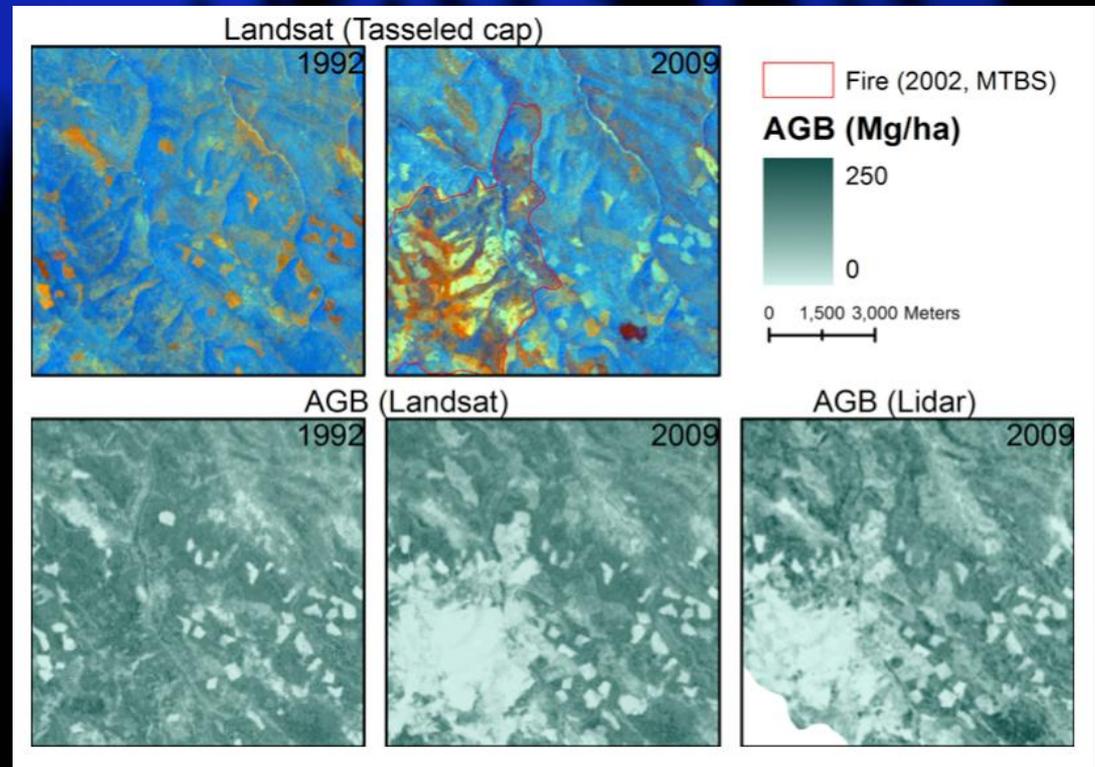
- Statistical modeling to predict current forest structure as a function of *disturbance history metrics*

- Recognizes that forest disturbance & recovery history strongly influence current forest structure
- Live and dead components



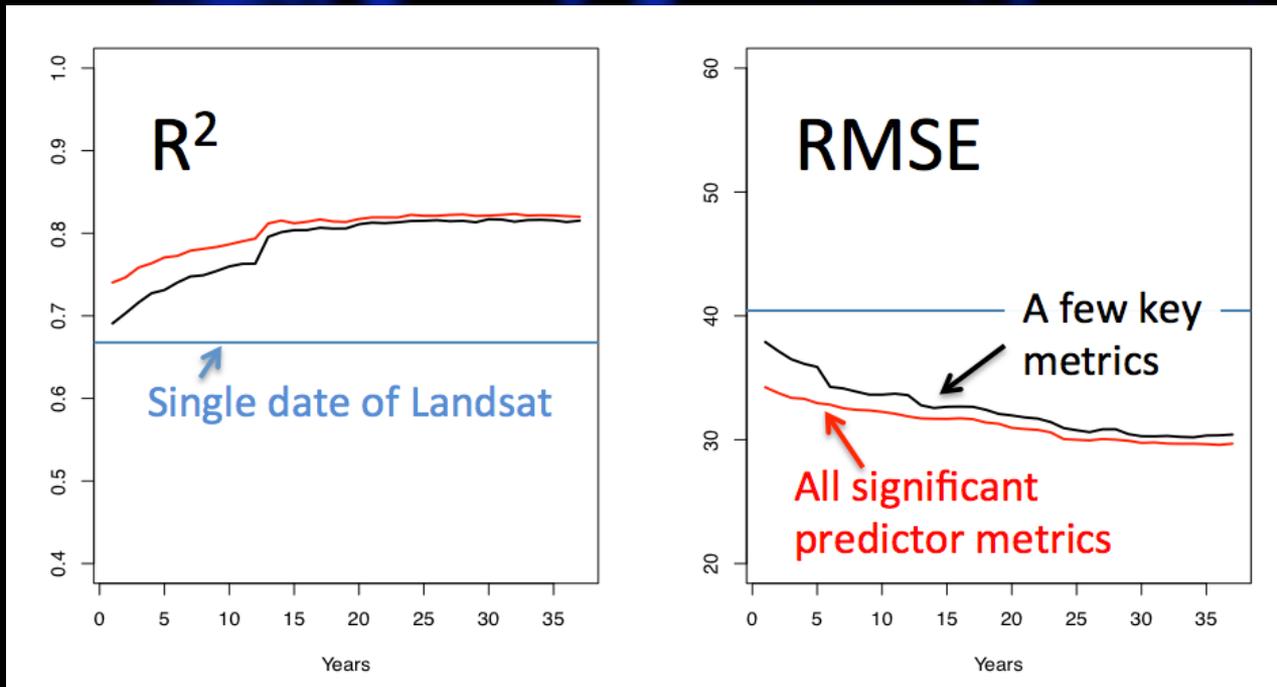
# Elements

- Application of statistical model to predict historic forest structure
  - Requires Landsat image for prediction date and Landsat-derived history metrics for period prior to prediction date



# Elements

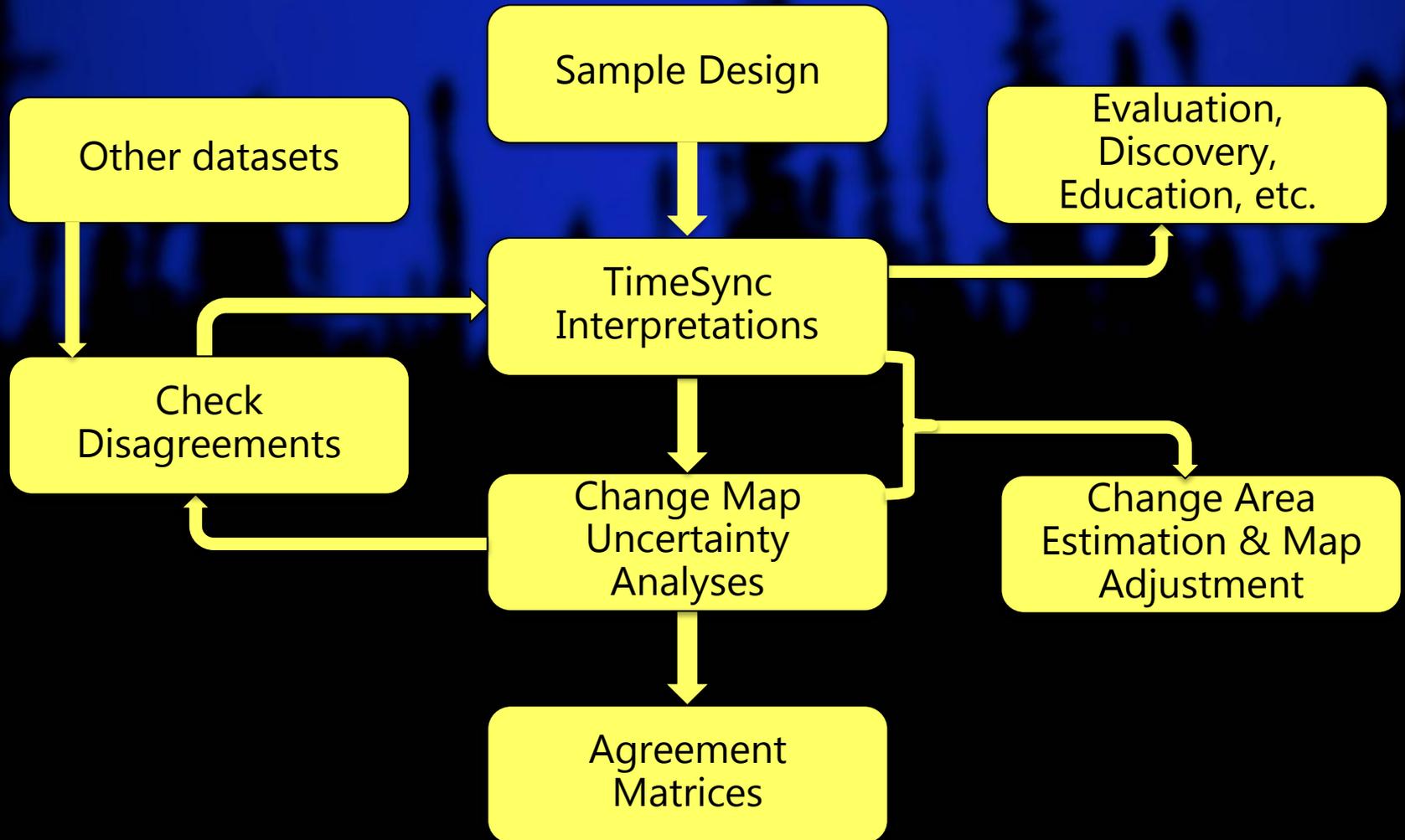
- Application of statistical model to predict current & historic forest structure
  - How many years required?
  - **Strong motivation for inclusion of MSS data**

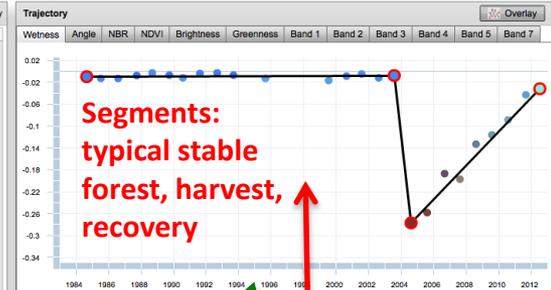
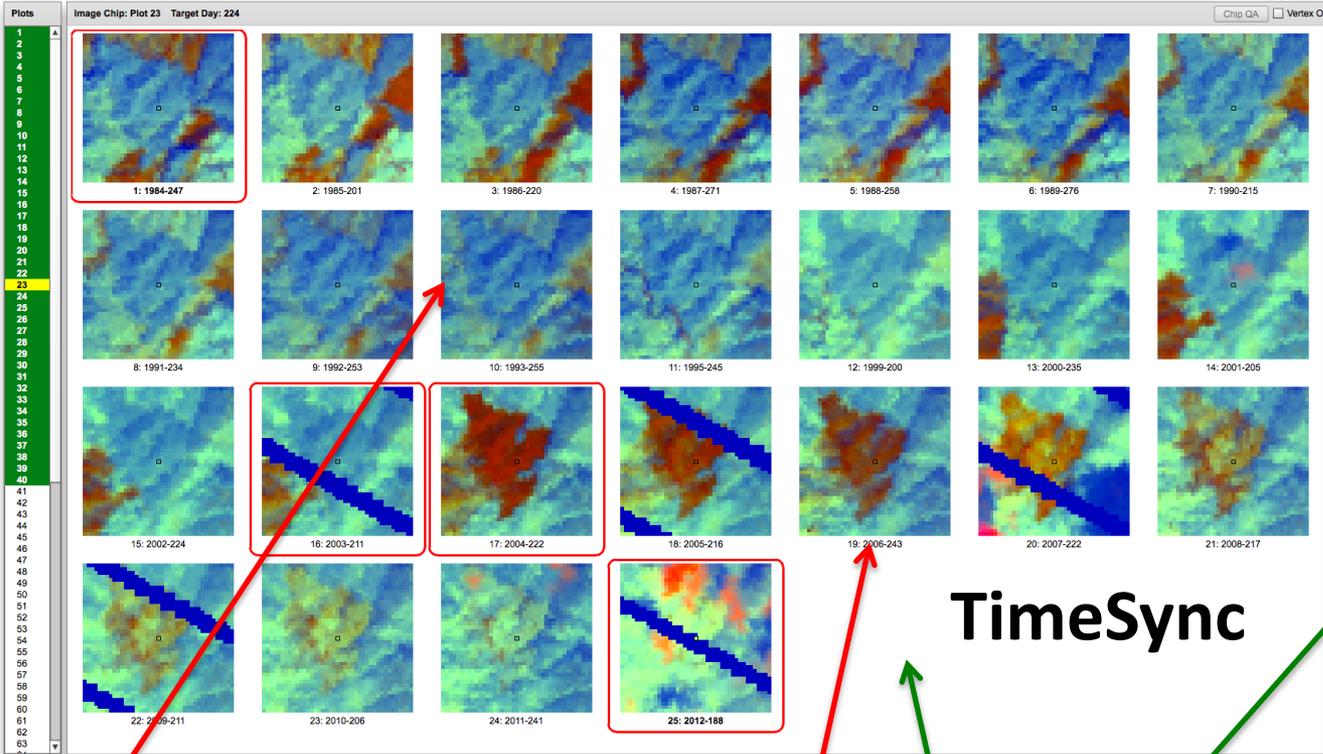


# Examples of Elements in Action

- Disturbance estimation and map QA for the North American Forest Dynamics (NAFD) project
  - VCT map QA context with traditional agreement matrices + area/rate estimation
  - MSS and OLI not included here, but same approach with MSS and OLI for LCMS...
- First MSS→OLI integrated dataset (analysis thus far, primitive)
  - One of six LCMS pilot scenes where ensemble modeling approach under development

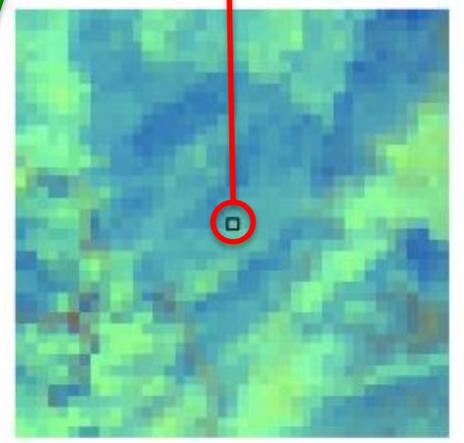
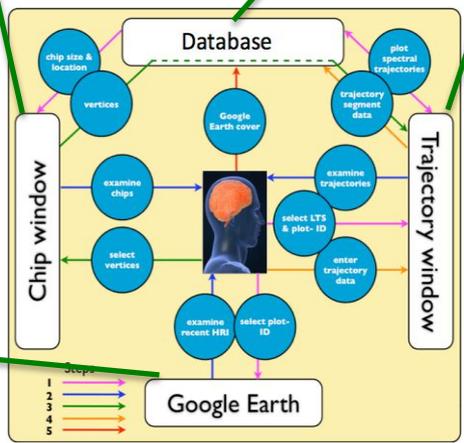
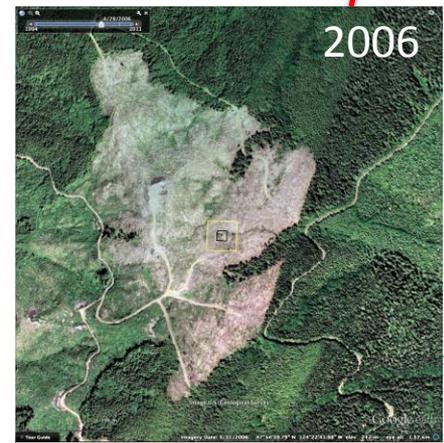
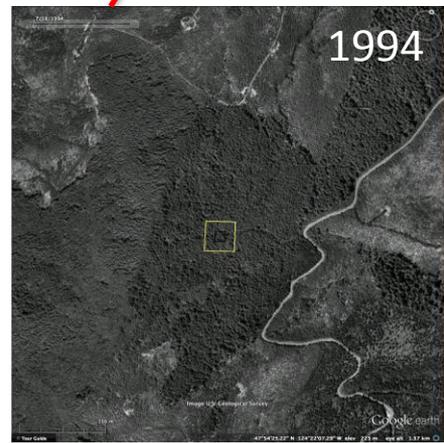
# Disturbance Estimation & Map QA Framework





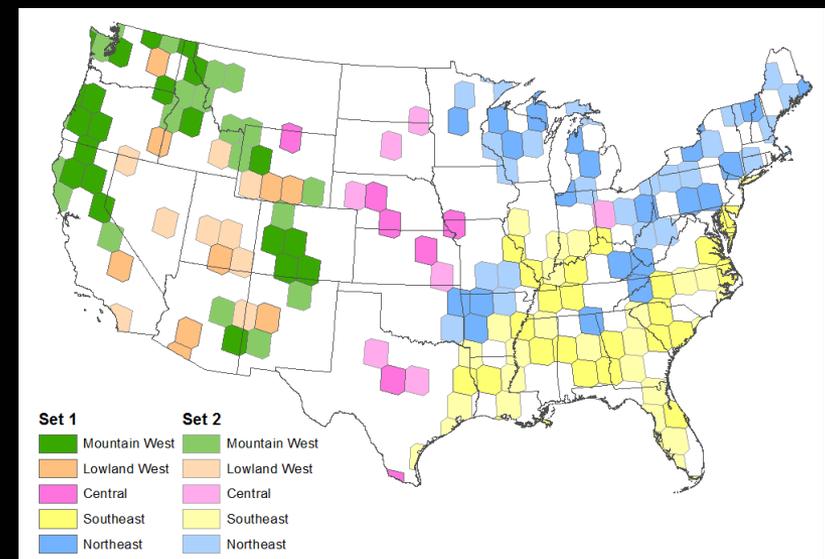
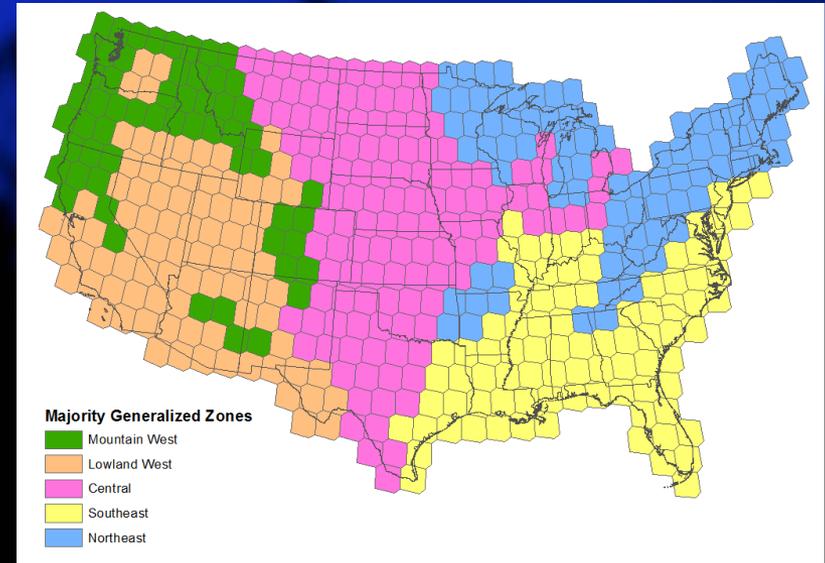
Start	End	Change Process	Ephemeral
1984-247	2003-211	Stable	<input type="checkbox"/>
2003-211	2004-222	Harvest	<input type="checkbox"/>
2004-222	2012-188	Recovery	<input type="checkbox"/>

# TimeSync



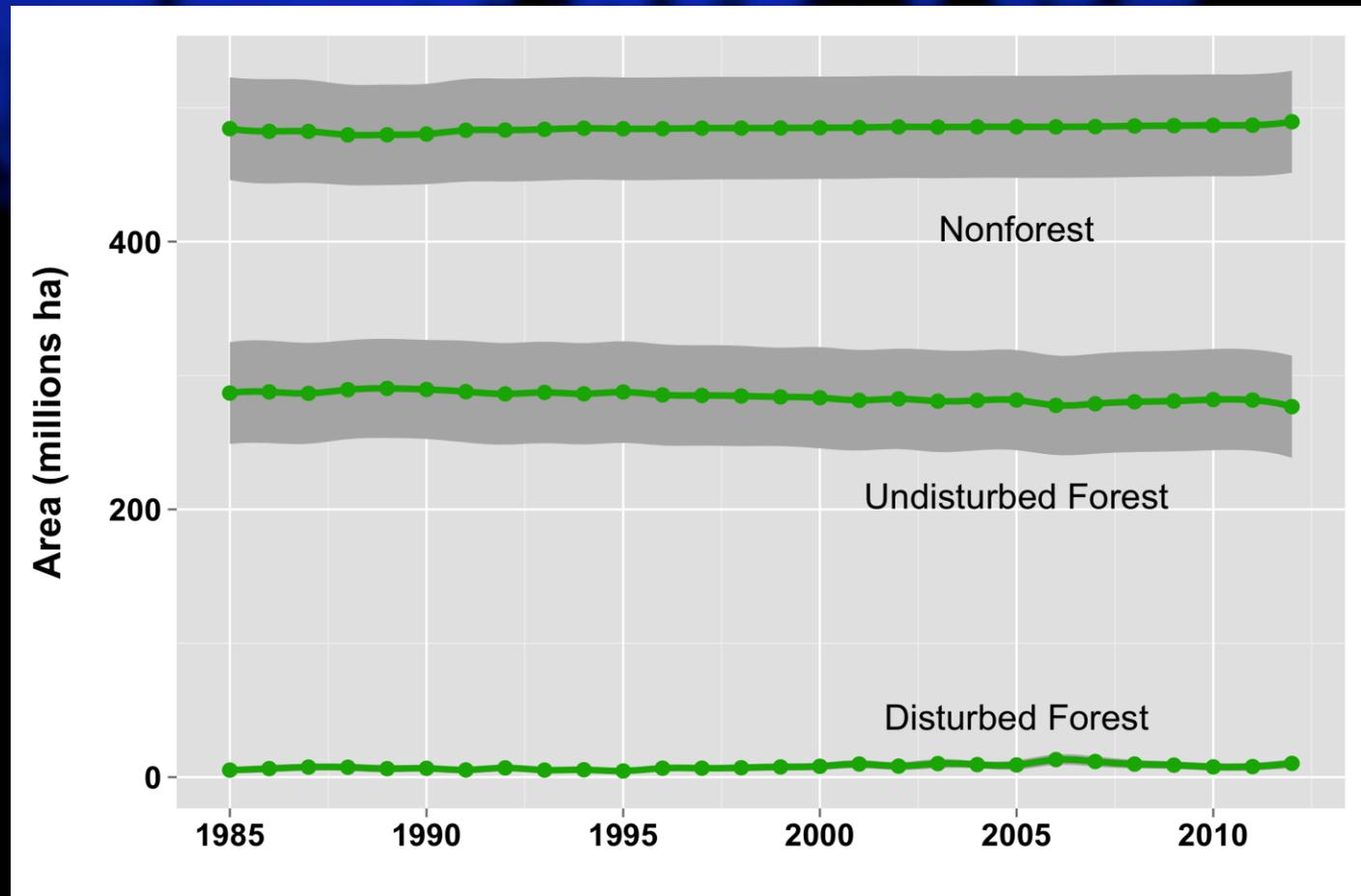
# NAFD Map QA Sample Design

- Two step process
  - (1) Select 180 sample scenes
    - Stratified by region to select proportionally more scene samples in forested areas
    - Proportion per region =  $f$  (region area, forest area per region)
  - (2) Random, within scene plot selection
    - 40 per sampled scene
    - 7200 plots total



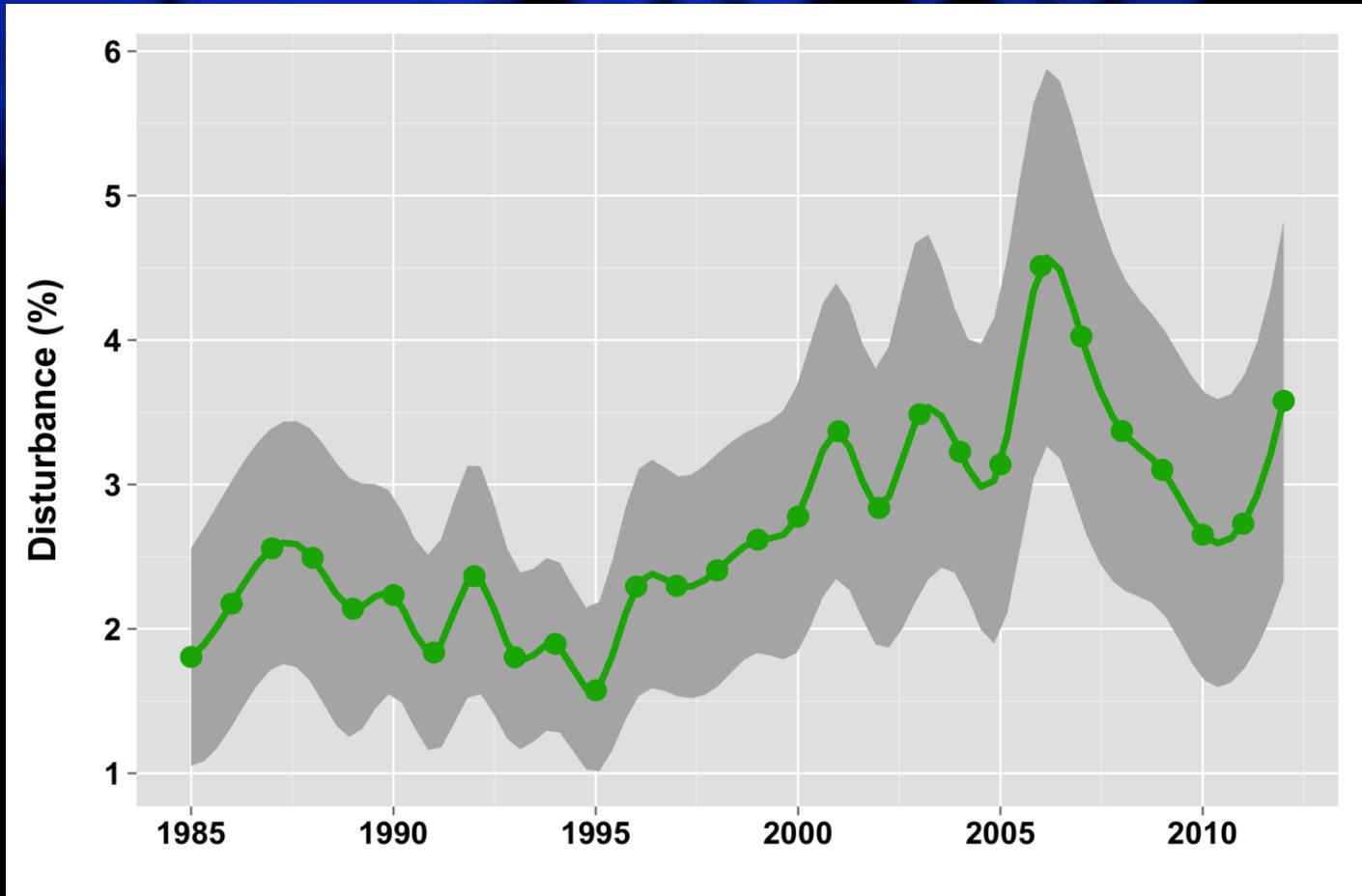
# Sampled v. Mapped Class Area

- Annual series, unbiased means with 95% CIs of true area per class (Set 1 only)
- Mapped estimates per class?



# Sampled v. Mapped Disturbance Rate

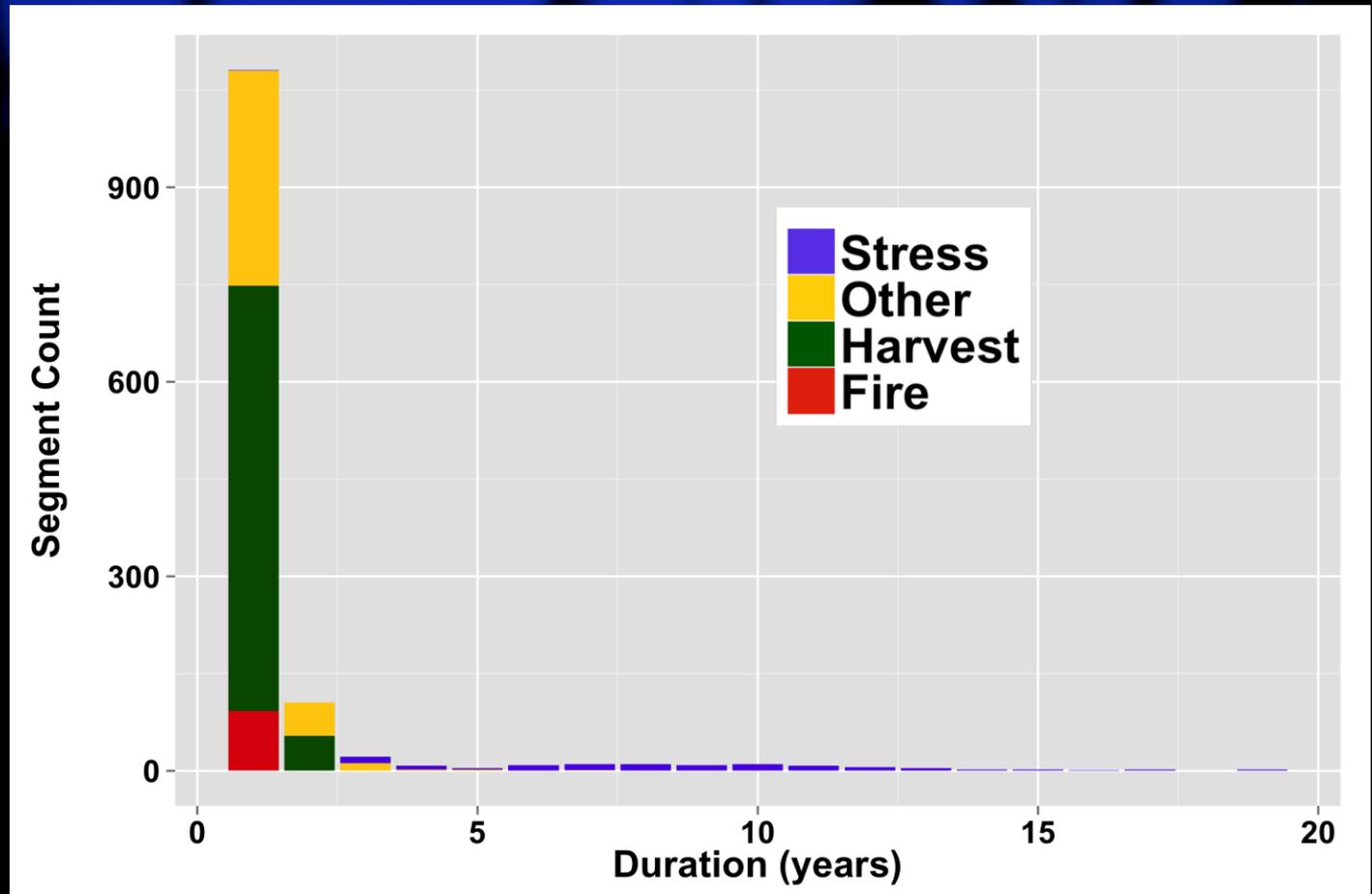
- Sampled annual rates (% / year, with CIs)
- Mapped annual rates?



# Disturbance Count v. Processes

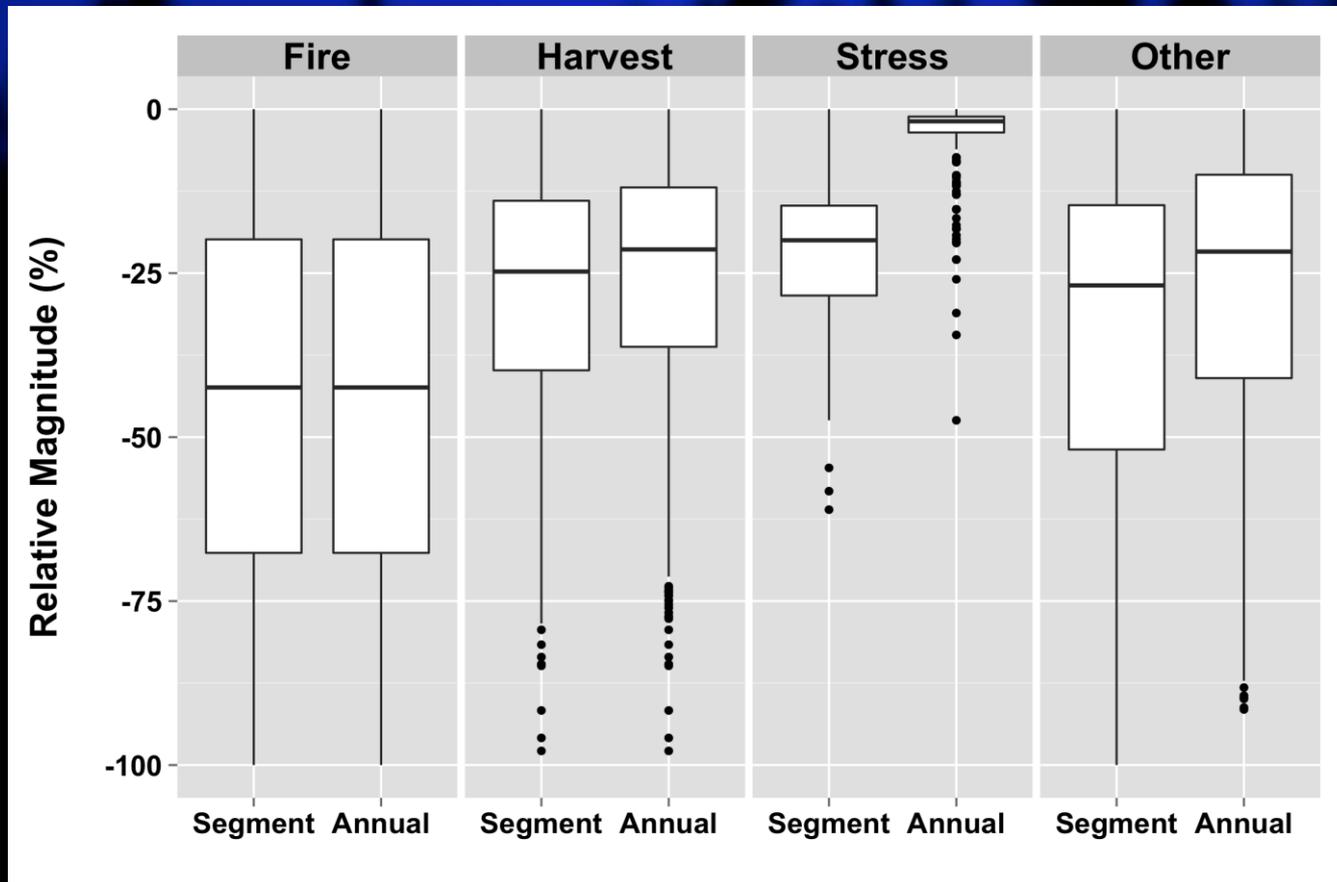
- Number of disturbance “segments” don’t tell whole story – duration important in an annual context

- Stress is insect, disease, LAI loss, mortality
- Other includes wind, water, forest loss, etc.



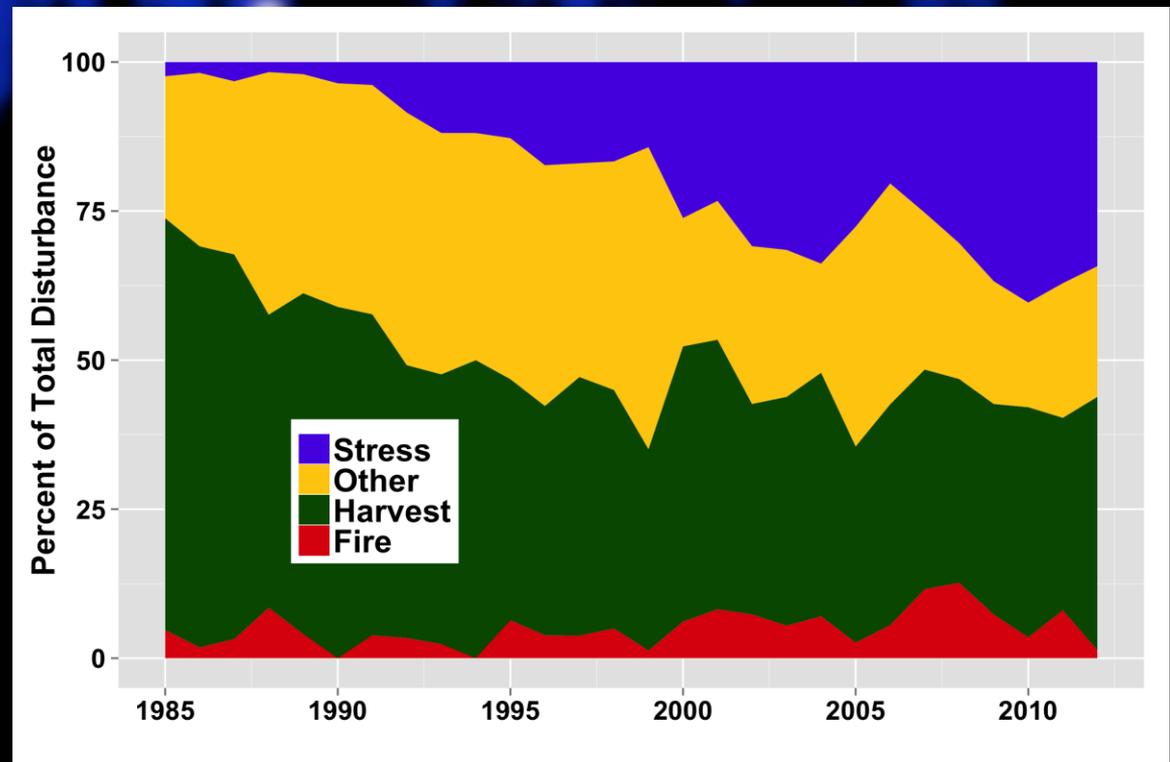
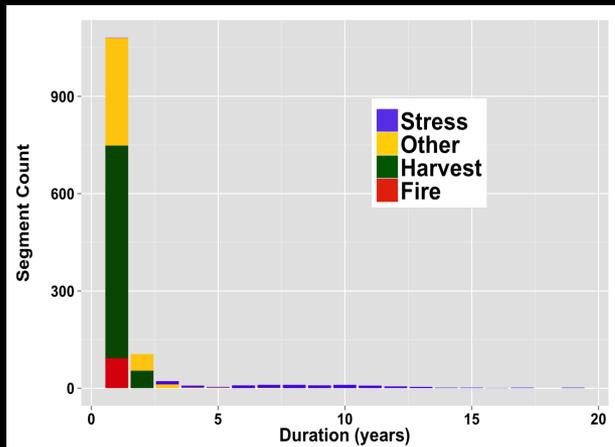
# Segment v. Annual Magnitude by Agent

- Segment magnitude and annual magnitude can be quite different, especially for stress



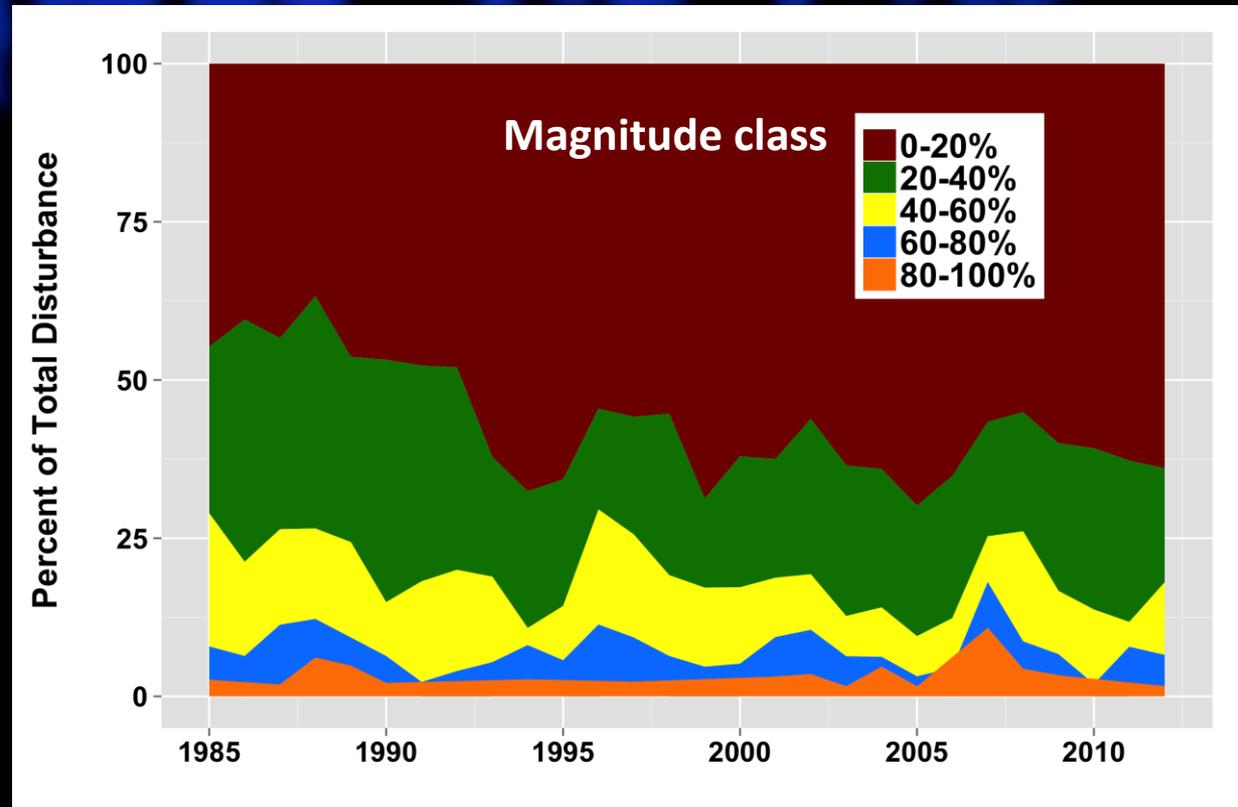
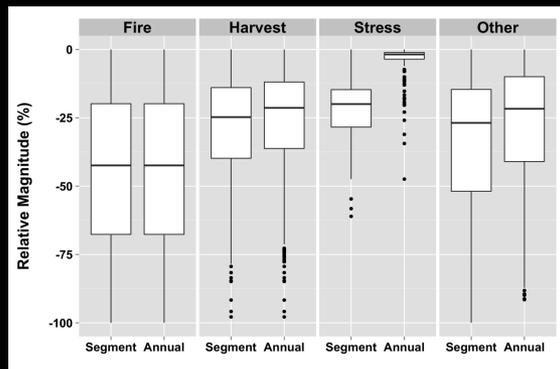
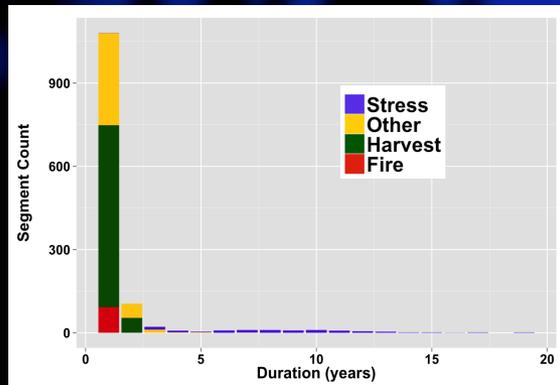
# Annual Disturbance by Agent

- Annual sample observations over time by agent when duration considered
  - Harvest and Other decrease as proportion of total
  - Stress small proportion of segment counts, but accumulates over time



# Annual Disturbance by Magnitude

- Most observed disturbances had low spectral magnitude
  - Especially at an annual time step
  - *Low magnitude disturbance should be challenging for an automated algorithm to detect relative to temporal “noise”*

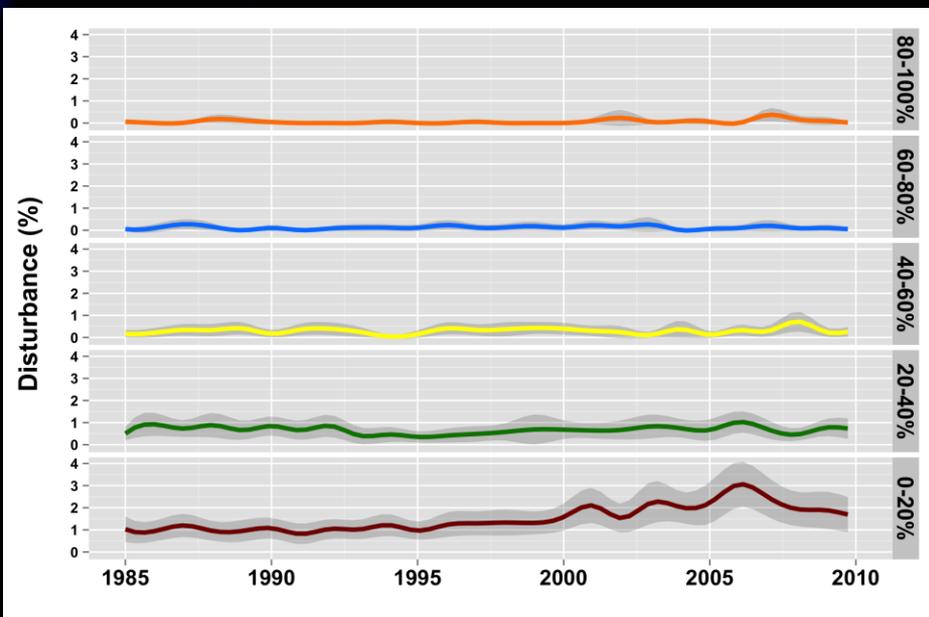
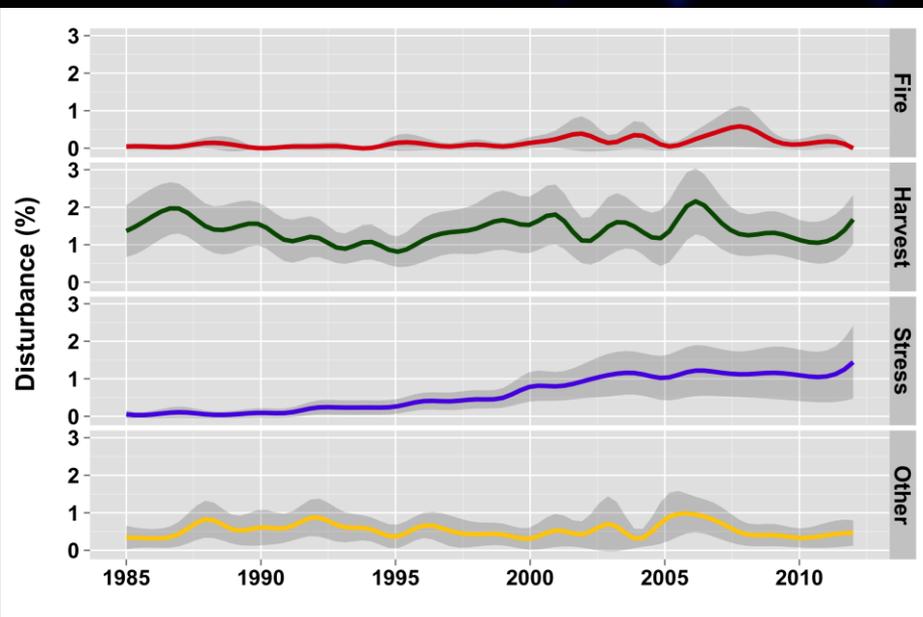
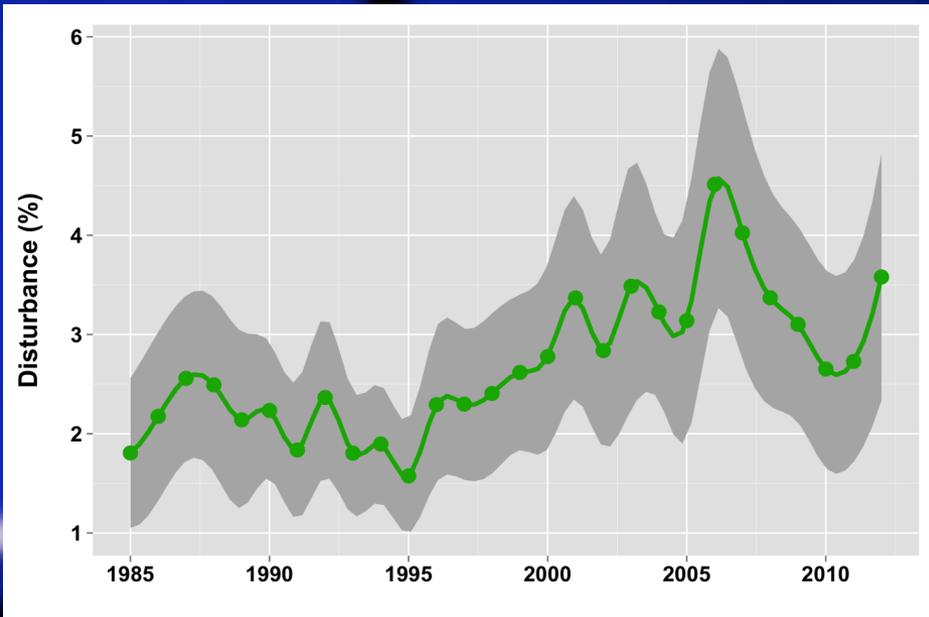


# Disturbance Rates by Agent & Magnitude

- Why is this important.....
  - Not all disturbances are equal: different agents have different ecological effects and variations in magnitude can have a profound effect on post-disturbance forest condition and recovery
- So we need to construct unbiased estimates (with CIs) at agent, magnitude class-level
  - Only possible with the proper sample design and toolset for gathering reference data

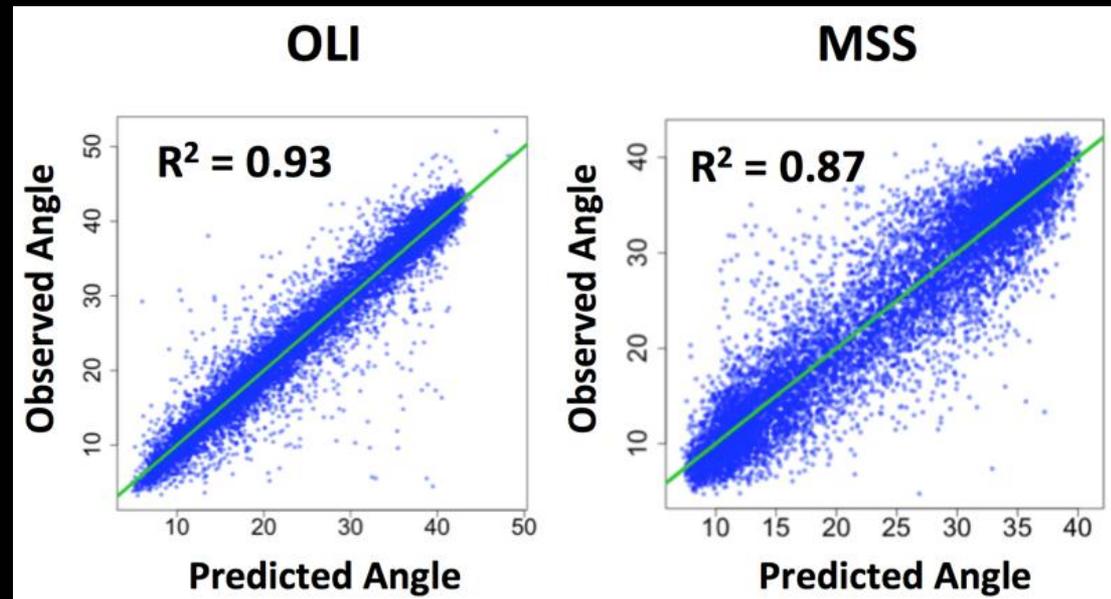
# Partitioning disturbance rate estimates

- $\Delta$  tree/woody cover = f (magnitude)



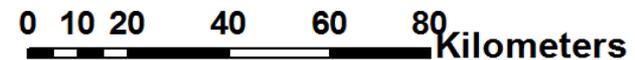
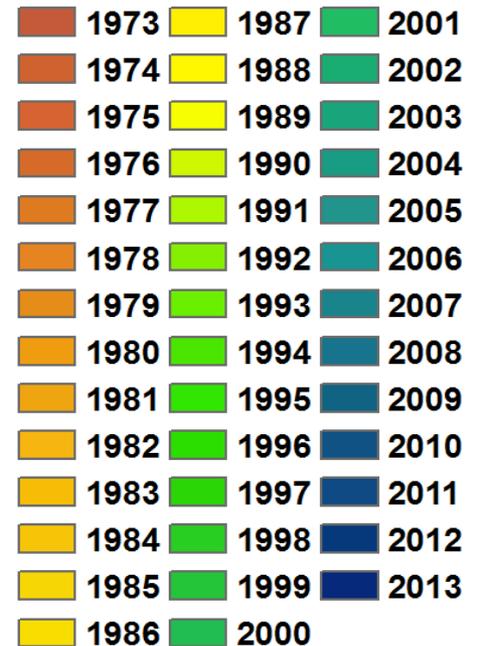
# MSS → OLI Integration

- Somewhere in Oregon...45/30
  - LIT data, cloud cleared, atmospherically corrected/normalized across stack, quick and dirty (Q & D) extension of TM Tasseled Cap and related backwards to MSS, forwards to OLI, change detection
  - Lots more work to do this correctly and with automation

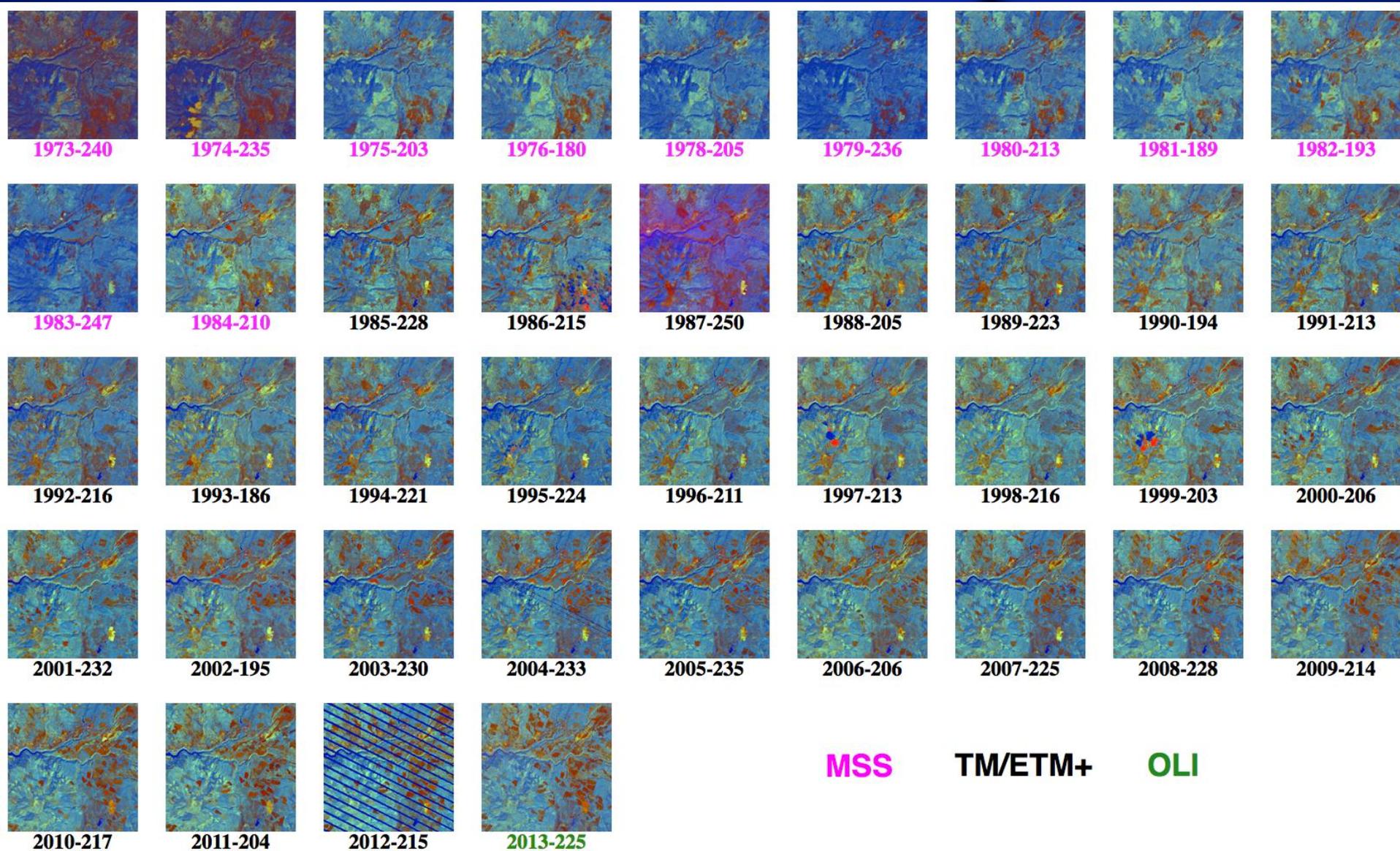


**Q & D result for  
annual disturbance  
mapping with  
integrated dataset:  
MSS→OLI**

**Year of Disturbance**



# Q & D Integrated Dataset



# New Landsat Revolution

- Availability of free, high-quality Landsat data has dramatically accelerated the creative process for using dense time series over long periods to map forest and other disturbances over large areas
- The USFS and USGS with multiple university partners committed to the development of an all-lands monitoring system as a centerpiece of the New Landsat Revolution:
  - Landscape Change Monitoring System (LCMS)

# LCMS

- Key elements of the system currently include
  - Integration across sensors from MSS→OLI to provide an historic perspective for future land policy and management decisions
  - An ensemble modeling approach that explicitly recognizes the value of all change algorithms and associated maps for crafting a comprehensive, accurate picture of change (including timing, agent, magnitude, duration)
  - A time-series reference data collection sampling approach to provide both map QA and an independent disturbance estimation framework for understanding map errors and helping to accurately partition disturbances into agent and magnitude classes for more intelligent use in ecological modeling

# LCMS

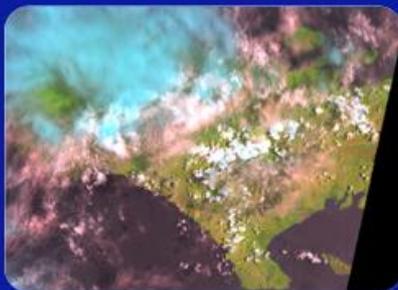
- Current elements of the system (cont.)
  - Statistical modeling to predict forest structure now and in the future, as a function of current (and future) Landsat data and disturbance history metrics derived from the full depth of the archive
  - Model hindcasting to predict historic forest structure
    - Understand effects of past forest policy and management decisions on forest resiliency
    - Guide future decision making in the era of forest vulnerability
    - NGHGI reporting for greenhouse gases back to 1990 (US, REDD)

# What LCMS Needs & Offers

- Need to bring ideas, approaches, and algorithms to the data (à la Hostert)
  - Inhibitive to rapid use & adoption to port large datasets, and store them and manipulate them locally
- Offer a change monitoring framework that will include all lands & cover types and could be applied globally



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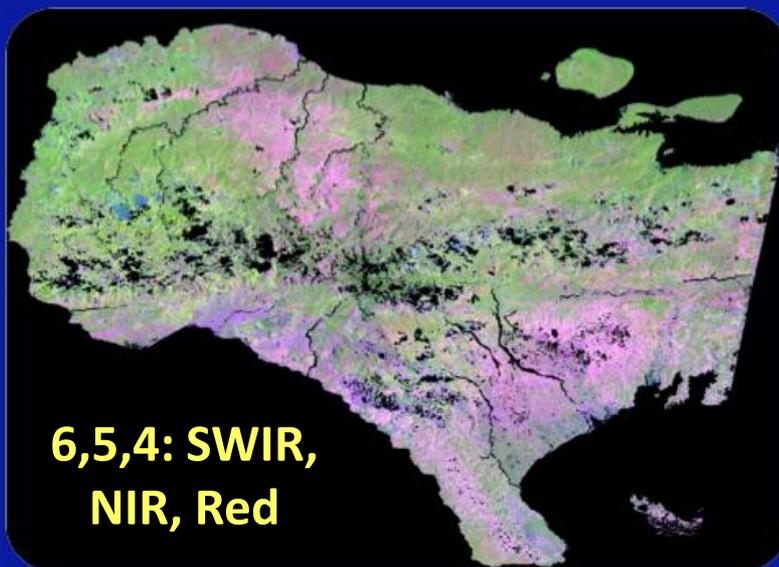
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236



188



6,5,4: SWIR,  
NIR, Red



252



172

**Composite Image for 2013**  
**OLI – Haiti, SW peninsula**



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# Primary Collaborators

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Robert Kennedy, Curtis Woodcock, Zhe Zhu [*Boston University*]