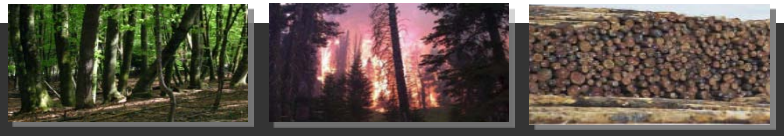
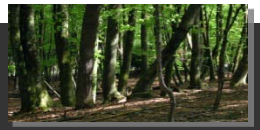


# Current Estimates of the US Forest Carbon Sink: Inferring Magnitudes and Mechanisms

Christopher A. Williams[1], G. James Collatz[2], Jeffrey Masek[2], Andrew R. Jacobson[3], Samuel N. Goward[4], Warren Cohen[5], Richard A. Houghton[6], Kevin Schaefer[7]

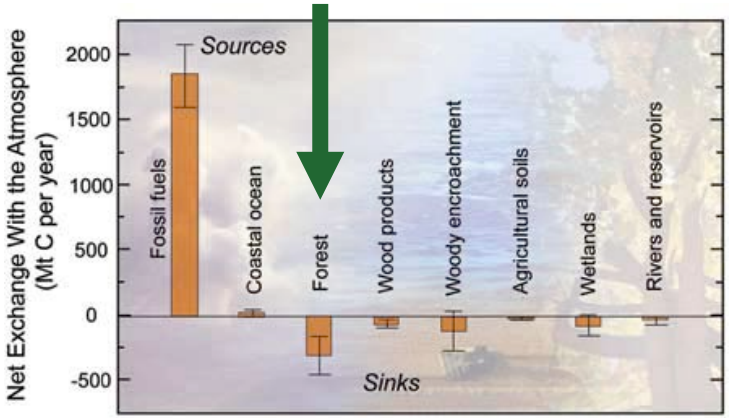
[1]Graduate School of Geography, Clark University
[2]NASA Goddard Space Flight Biospheric Sciences Branch
[3]Earth System Research Laboratory, NOAA
[4]Department of Geography, University of Maryland
[5]U.S.D.A. Forest Service, Pacific Northwest Research Station
[6]Woods Hole Research Center [7]National Snow and Ice Data Center

2011 NACP All-Investigators Meeting
4 February 2011

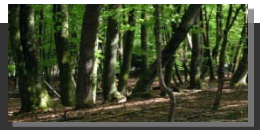


# Are Forests of U.S. Sinks and Why?

- thought to be the largest U.S. carbon sink
- causes remain ambiguous
- needed for better forecasts and to manage carbon




The First State of the Carbon Cycle Report (2007) King, Dilling, many others



# Mechanisms in Past Work

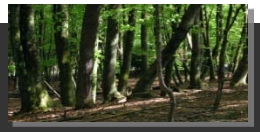
Houghton et al. ’99, ‘03
Book-keeping of carbon stocks with ***land use change accounts for less than half of the land sinks estimated from forest inventories***, implicating growth enhancements from environmental changes (e.g. $CO_2$, N, or climate change).

Schimel et al. ’00
Models suggest that ***$CO_2$ and climate growth enhancements account for only half*** of the observed forest sink (VEMAP).

Zaehle et al. ‘06
Modeled changes in ***age structure and harvest intensity account for about a half*** of the present-day forest C uptake in EU-25.

McMahon et al. ’10
***Modern growth rates exceed those predicted by inventory chronosequences*** of biomass regrowth with stand age.

Others e.g.: McGuire et al. ‘01;  Luyssaert et al. ’10

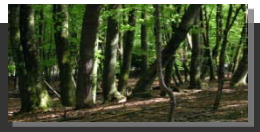


# Methods of Attack

**Two uses of inventory data:**

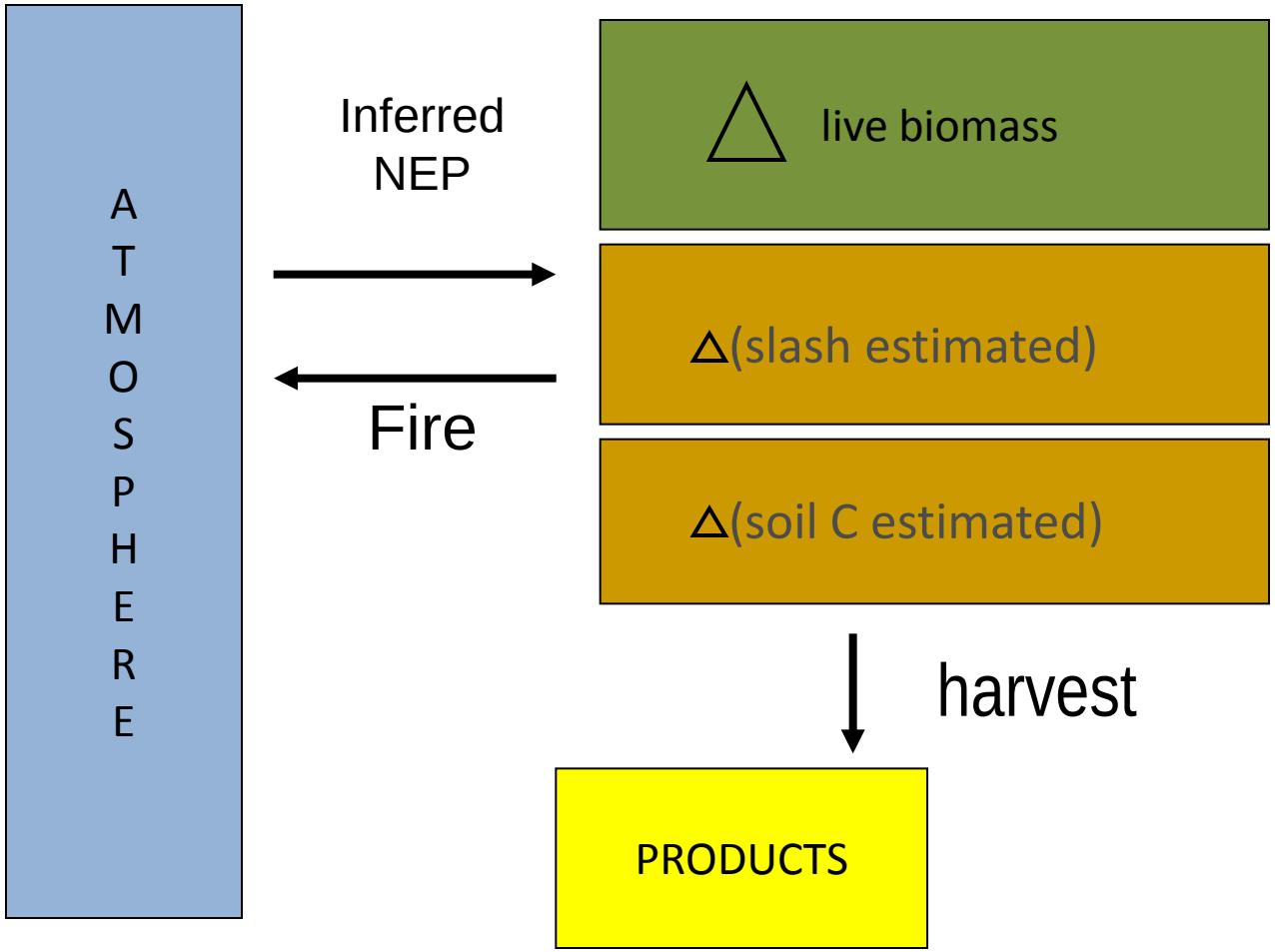
1) Stock Change Method

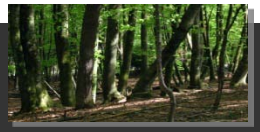
2) Constraint on Disturbance/Regrowth Modeling



# Stock Change Approach

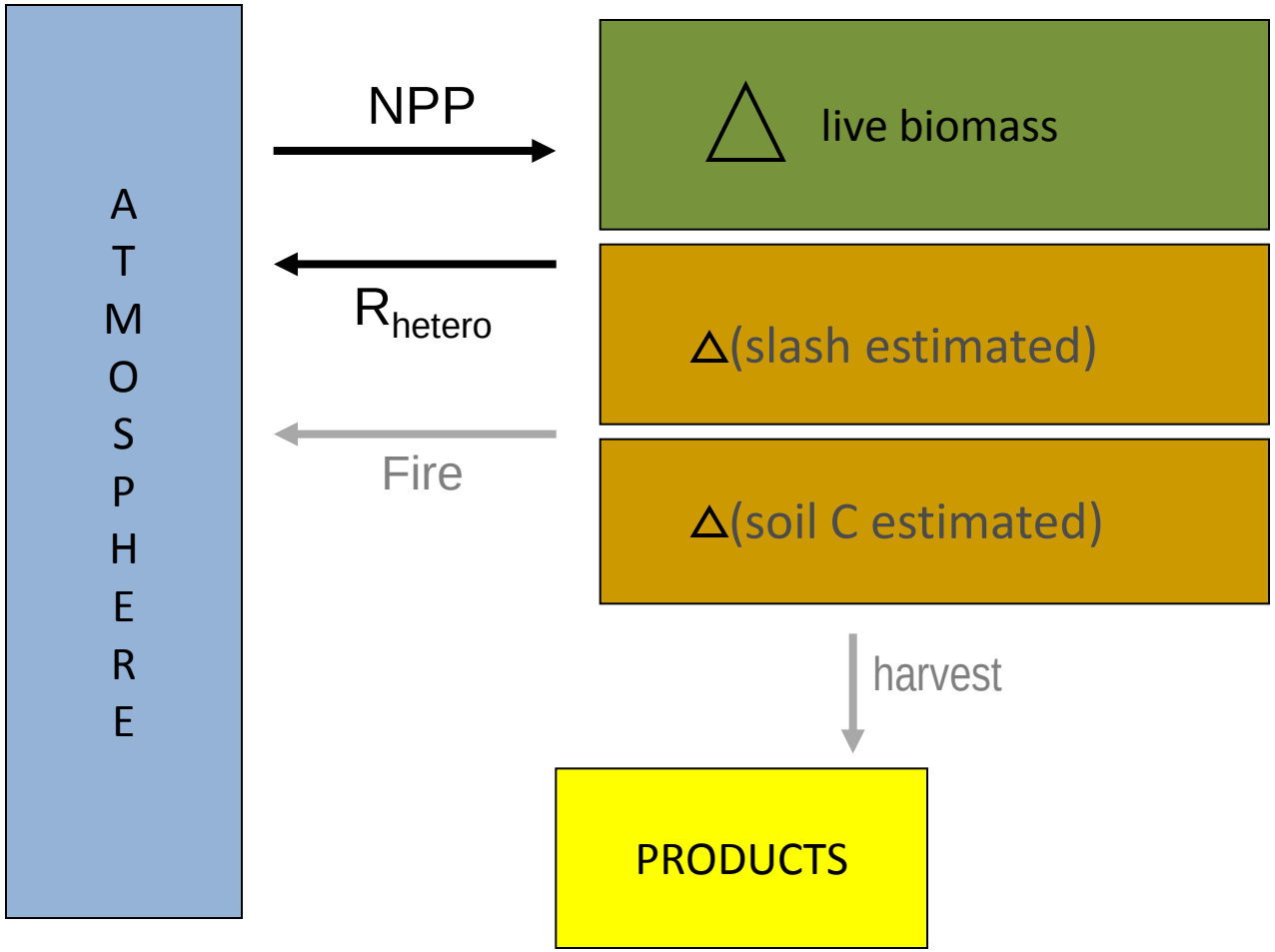
$$NEP_{stock\ change} = \Delta Forest\ Stock + Harvest\ Flux + Fire\ Flux$$

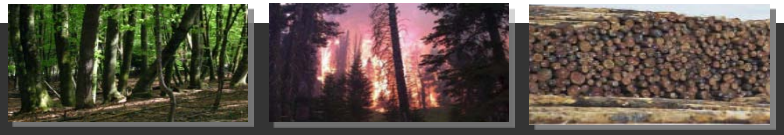




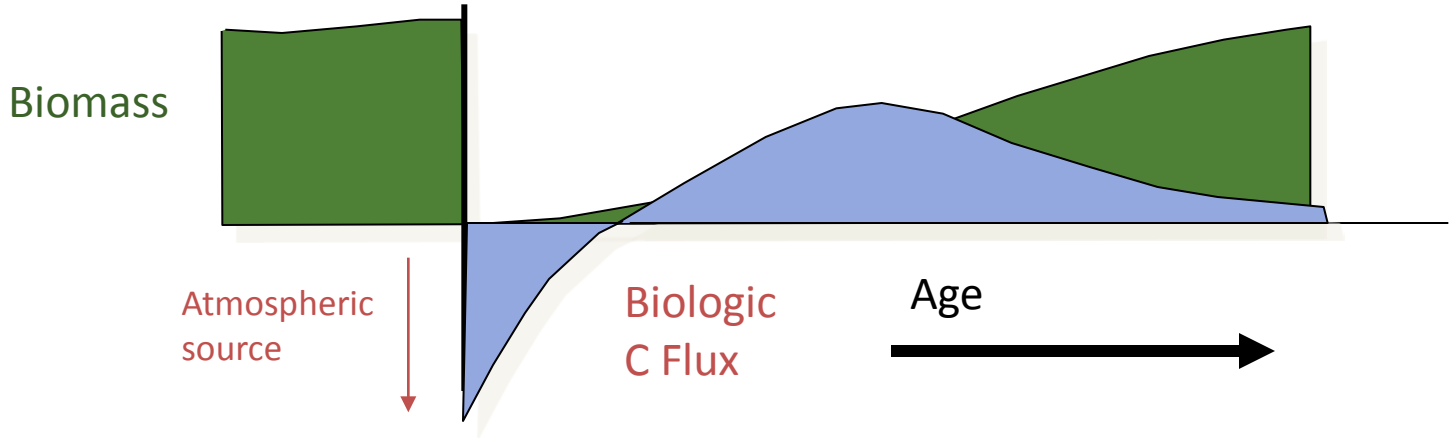
# Constrained D/R Model Approach

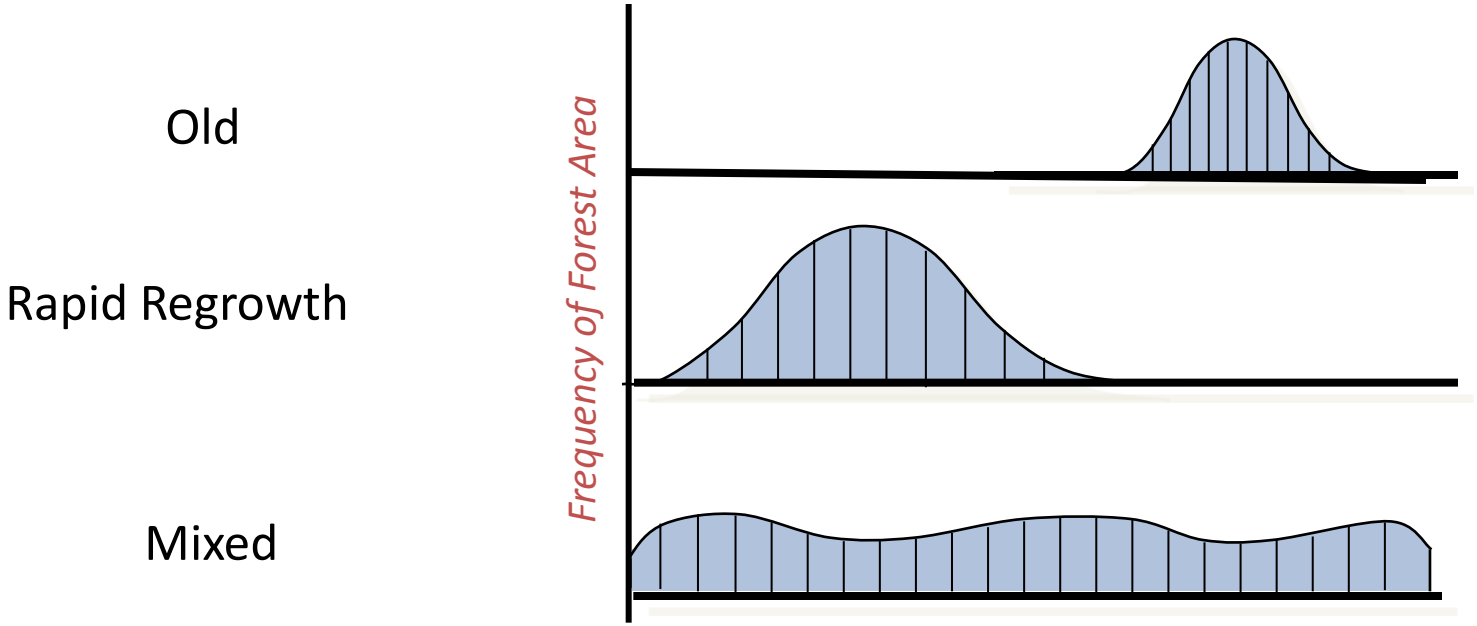
$$NEP_{regrowth} = NPP - R_{hetero}$$

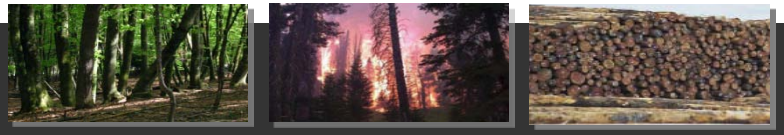




# Constrained D/R Model Approach

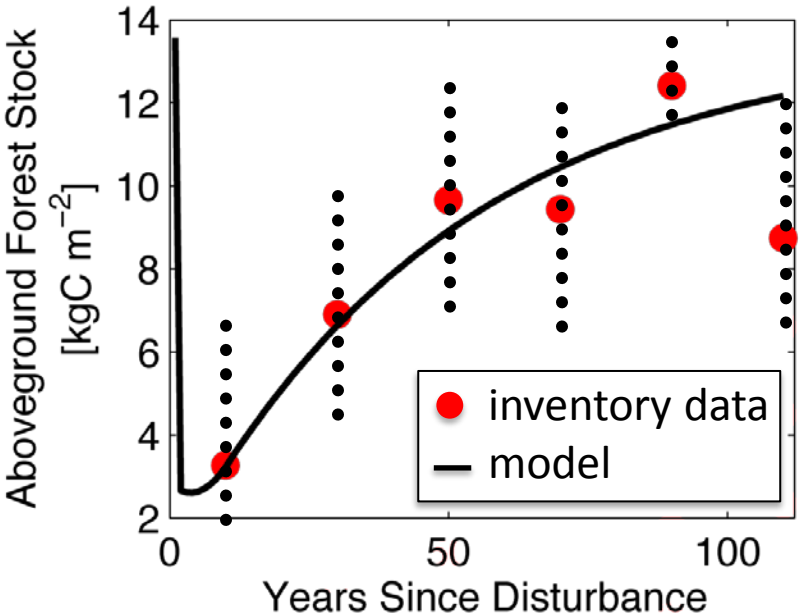


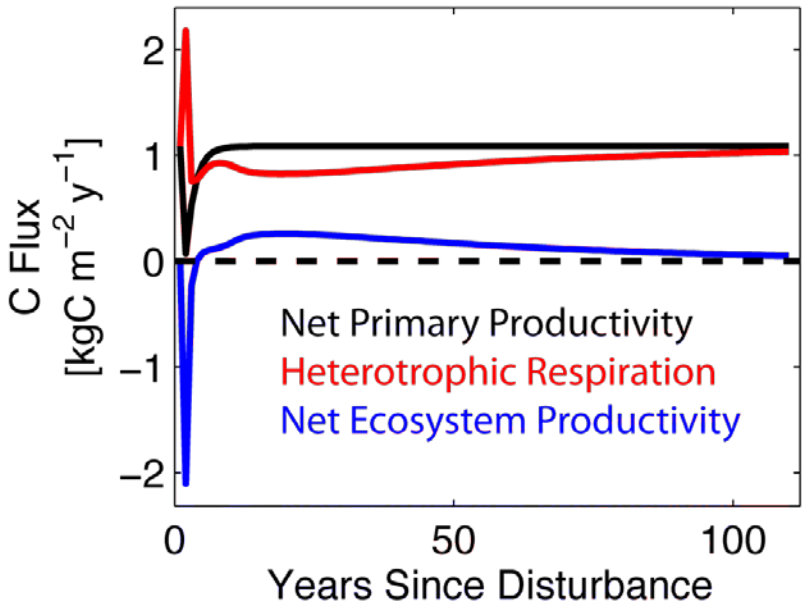





# Flux Trajectories

Unique trajectories for regional forest types, productivity classes, and climate settings

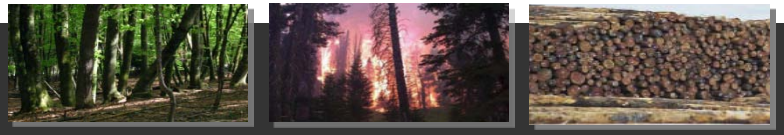



Uncertainty formally analyzed with Monte Carlo fitting

- biomass sampling error from FIA (+/- 10 to 100%)
- volume to carbon conversion (+/- 7%)

Williams et al. (in review)



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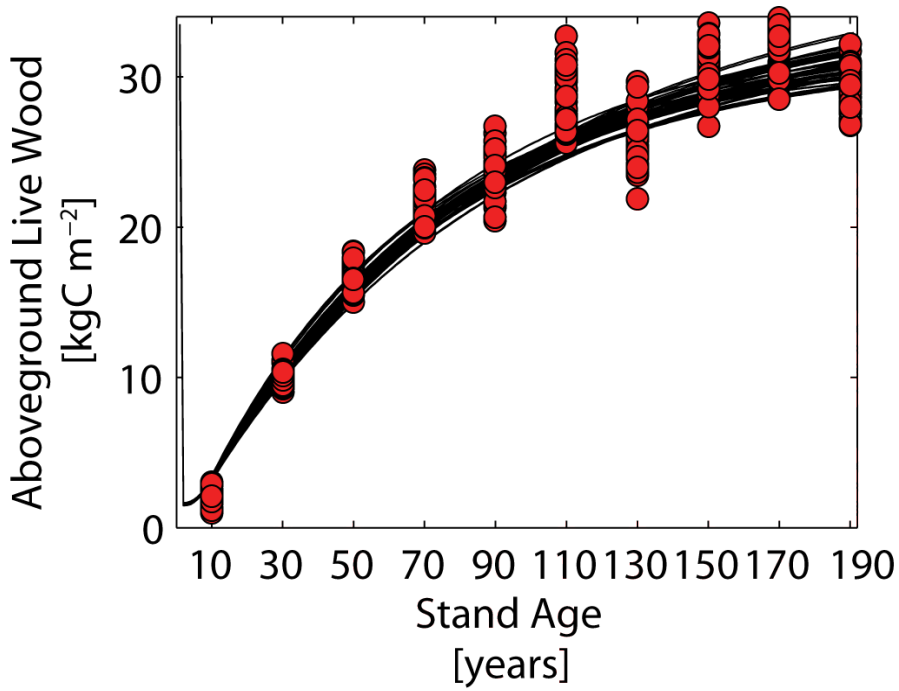


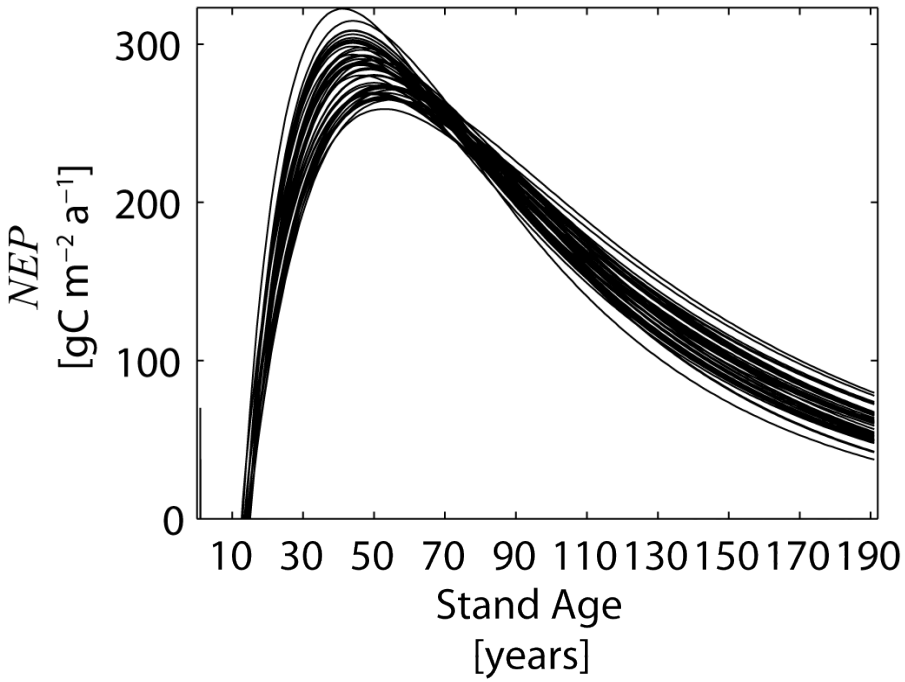


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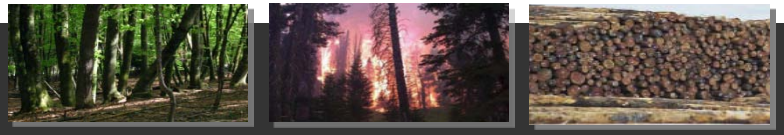
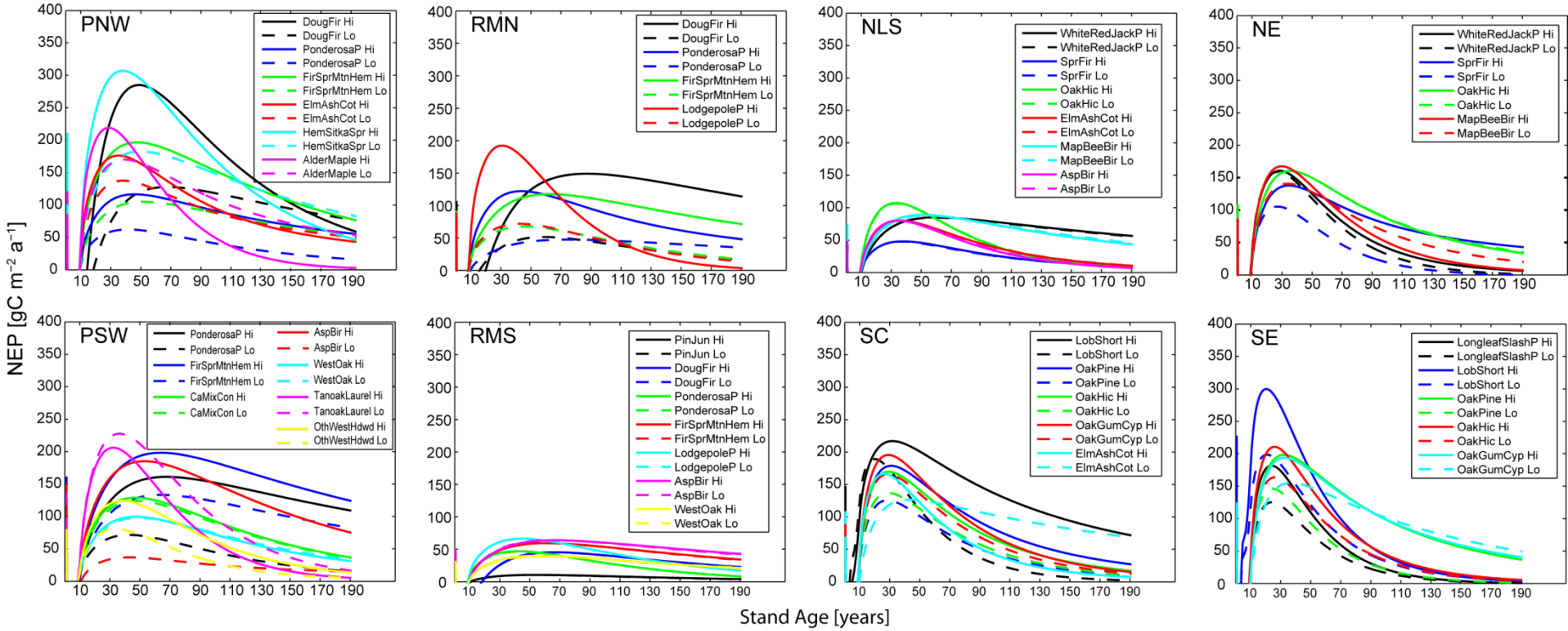
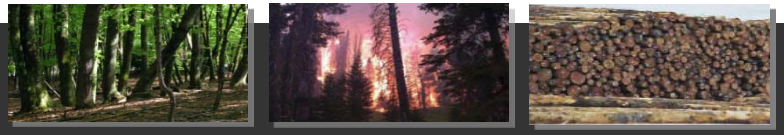


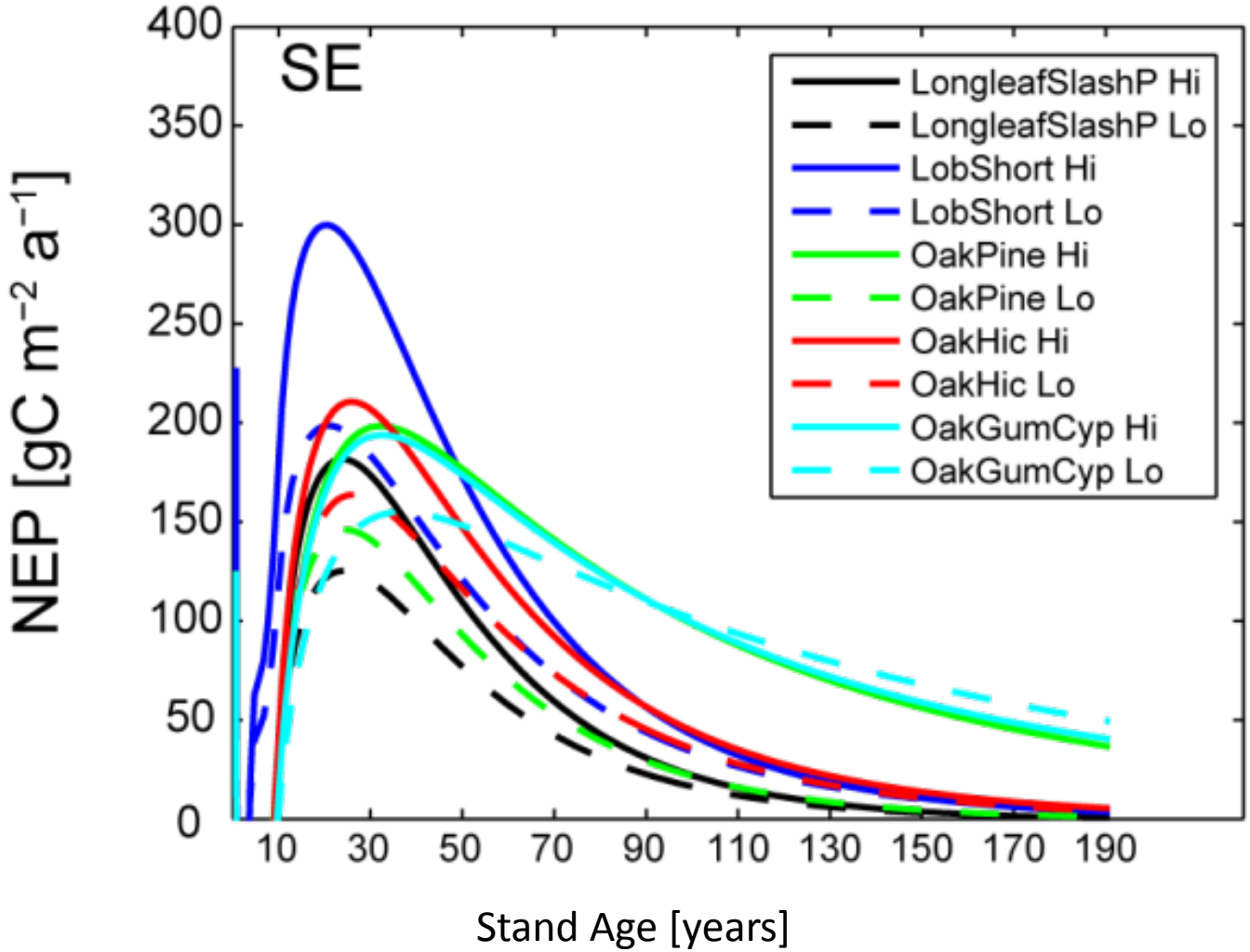
# Flux Trajectories Across Regions



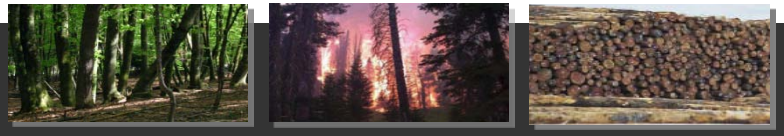

Williams et al. (in review)



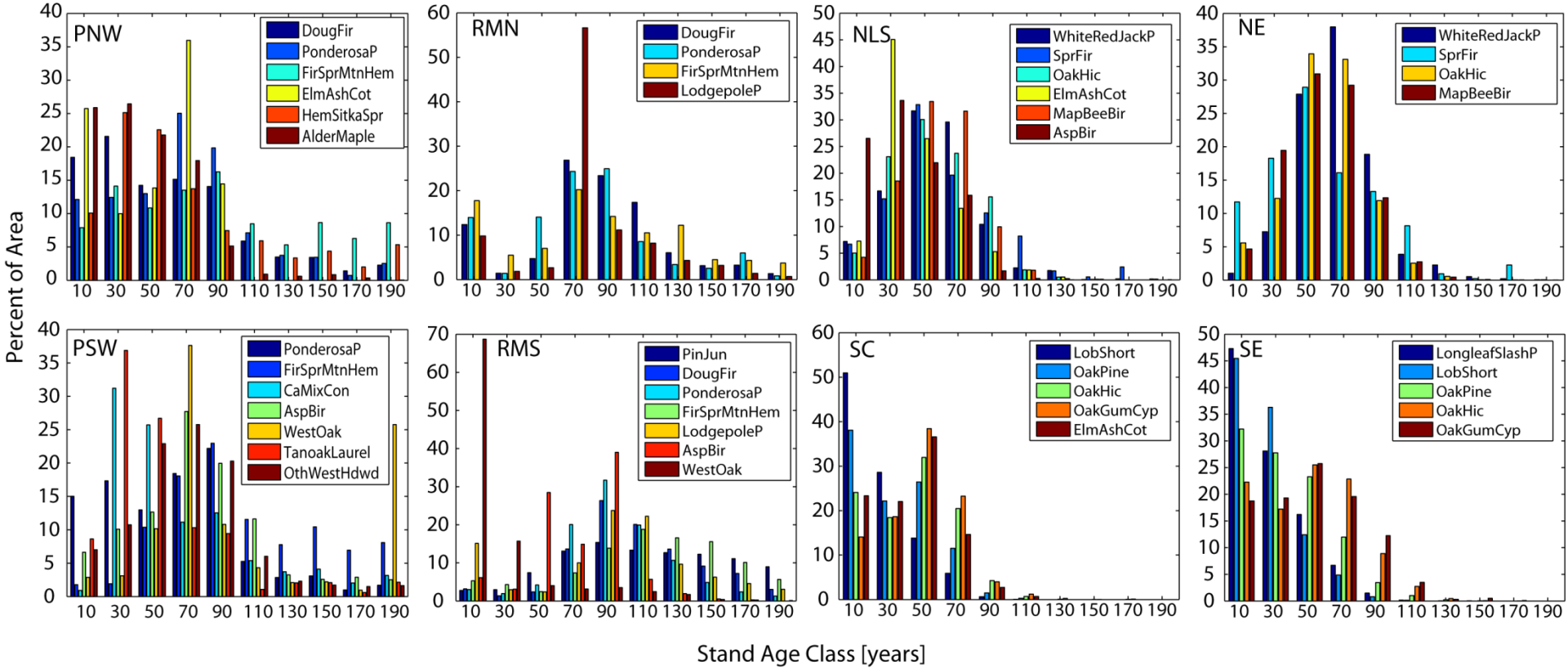
# Flux Trajectories Within Regions



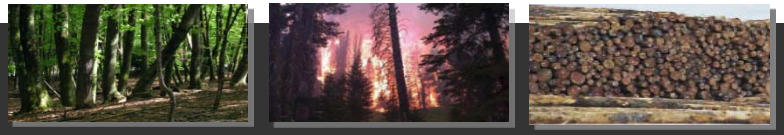

Williams et al. (in review)



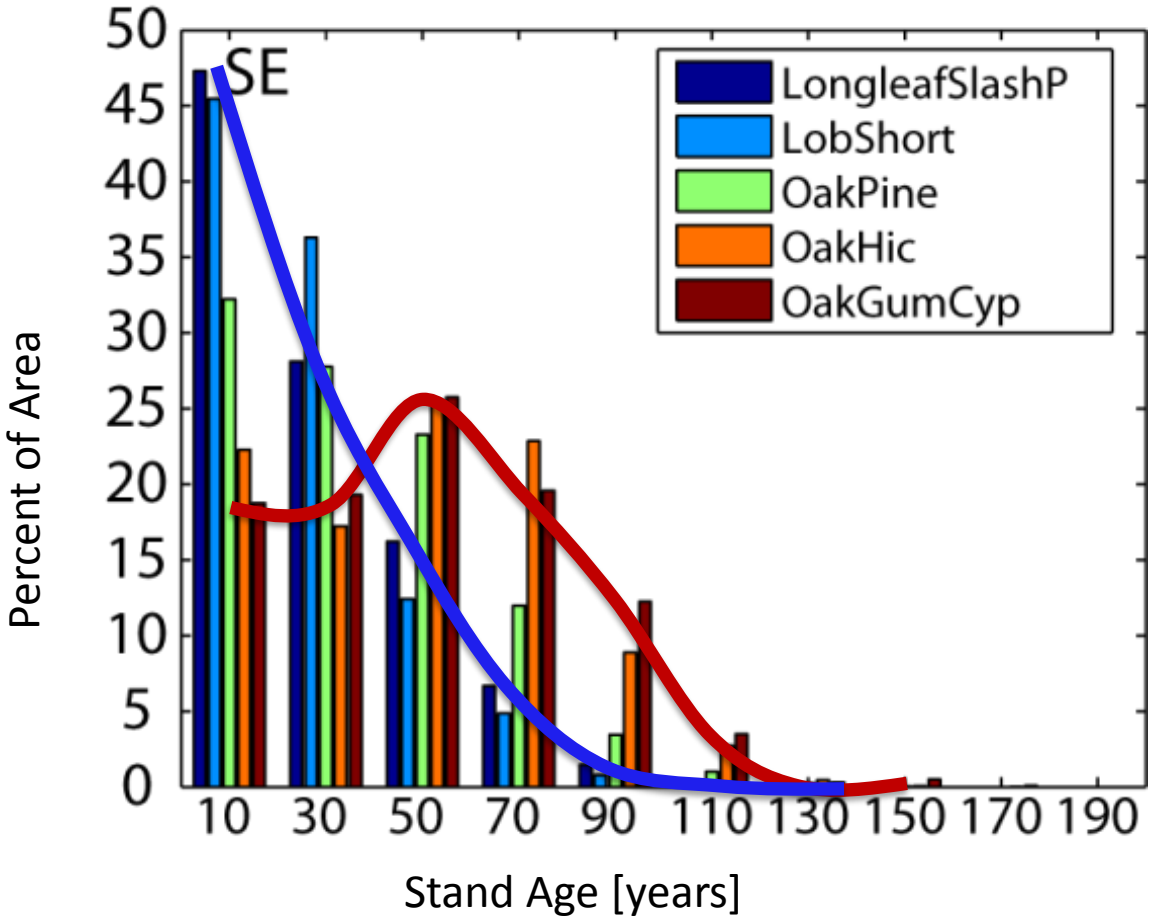
# Age Structures Across Regions



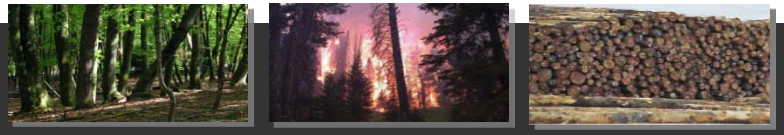

Williams et al. (in review)



# Age Structures Within Regions

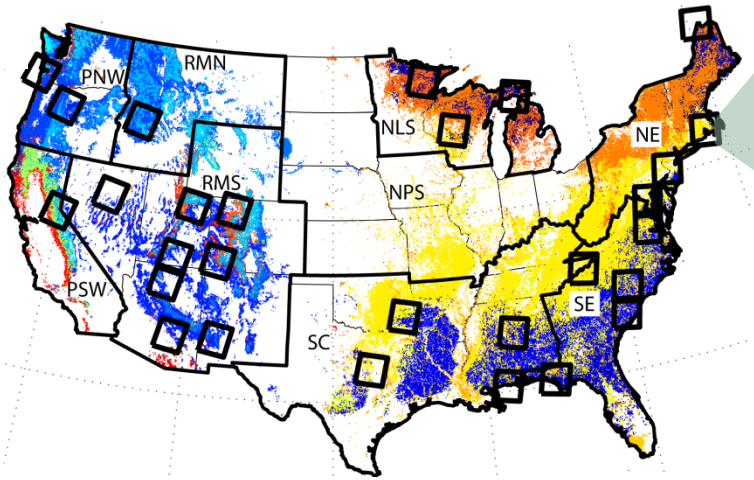



Williams et al. (in review)

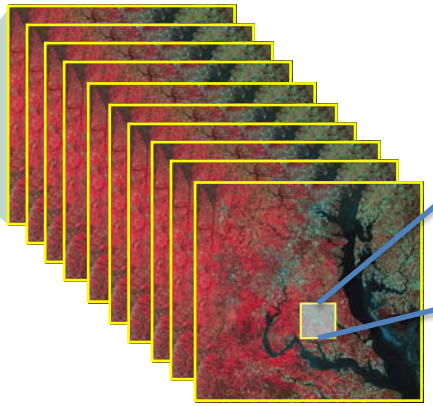


# Remote Sensing of Disturbance

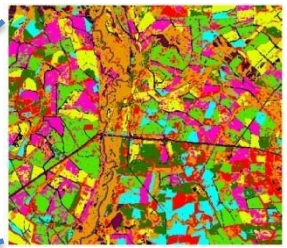
28 Landsat Time Series Stacks




Annual/Biennial Stacks



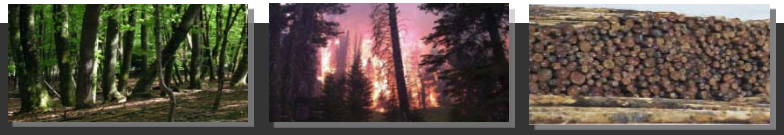
Disturbance history



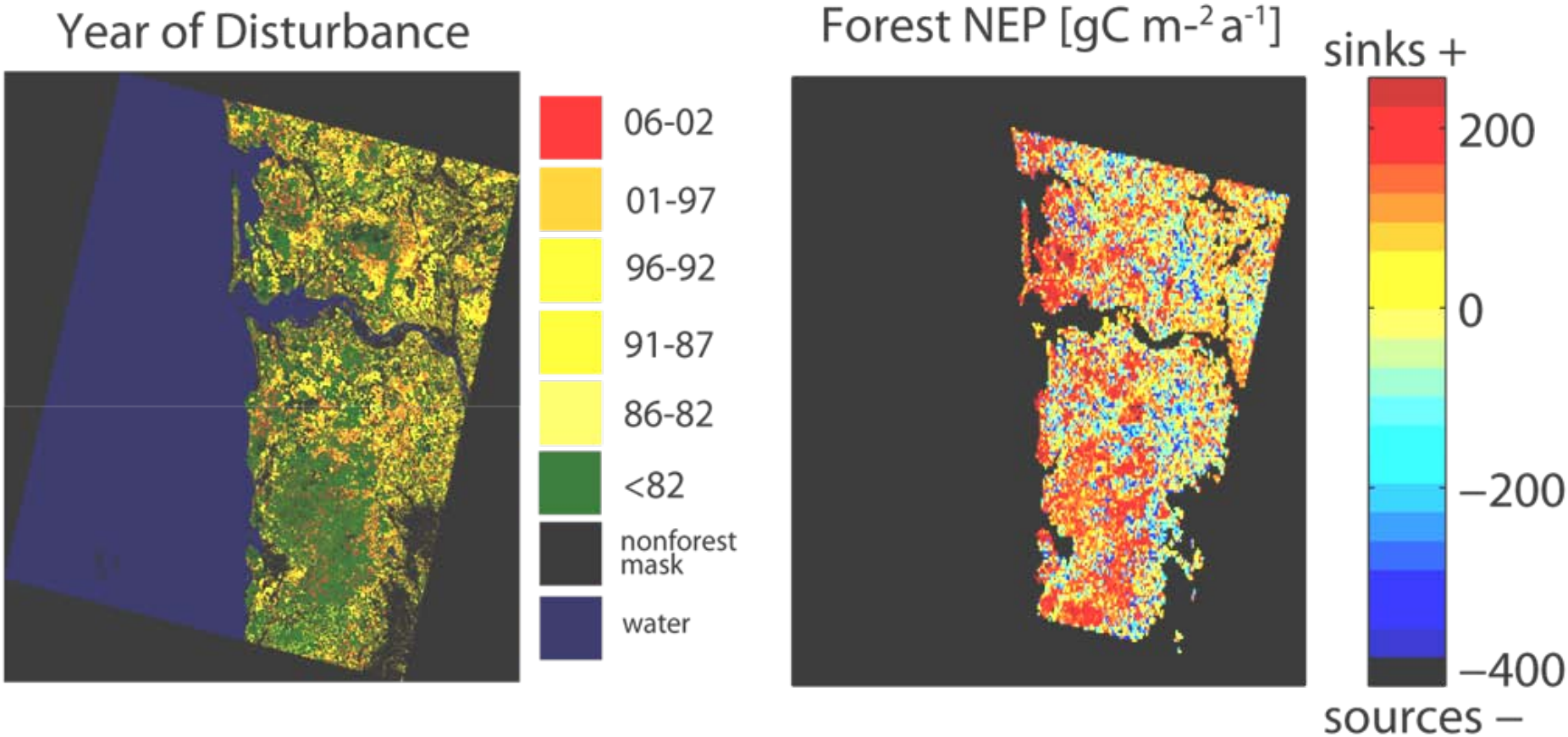
Used here to :

- adjust forest age distributions
- generate detailed maps of forest NEP, Biomass, etc.

**North American Forest Dynamics** Goward, Masek, Cohen, Moisen, Collatz, Healey, Huang, et al. (2008)



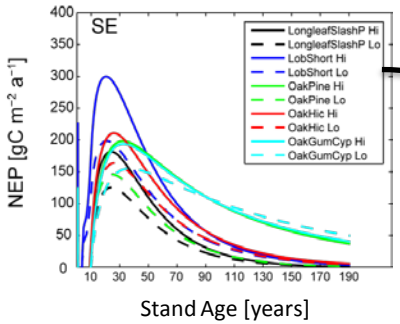
# Remote Sensing of Disturbance

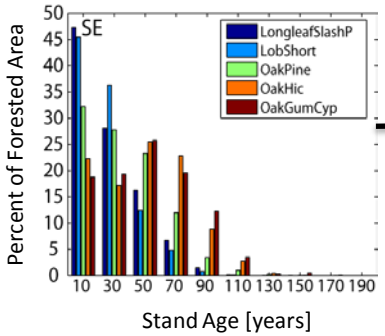



- generate detailed maps of forest NEP, Biomass, etc.

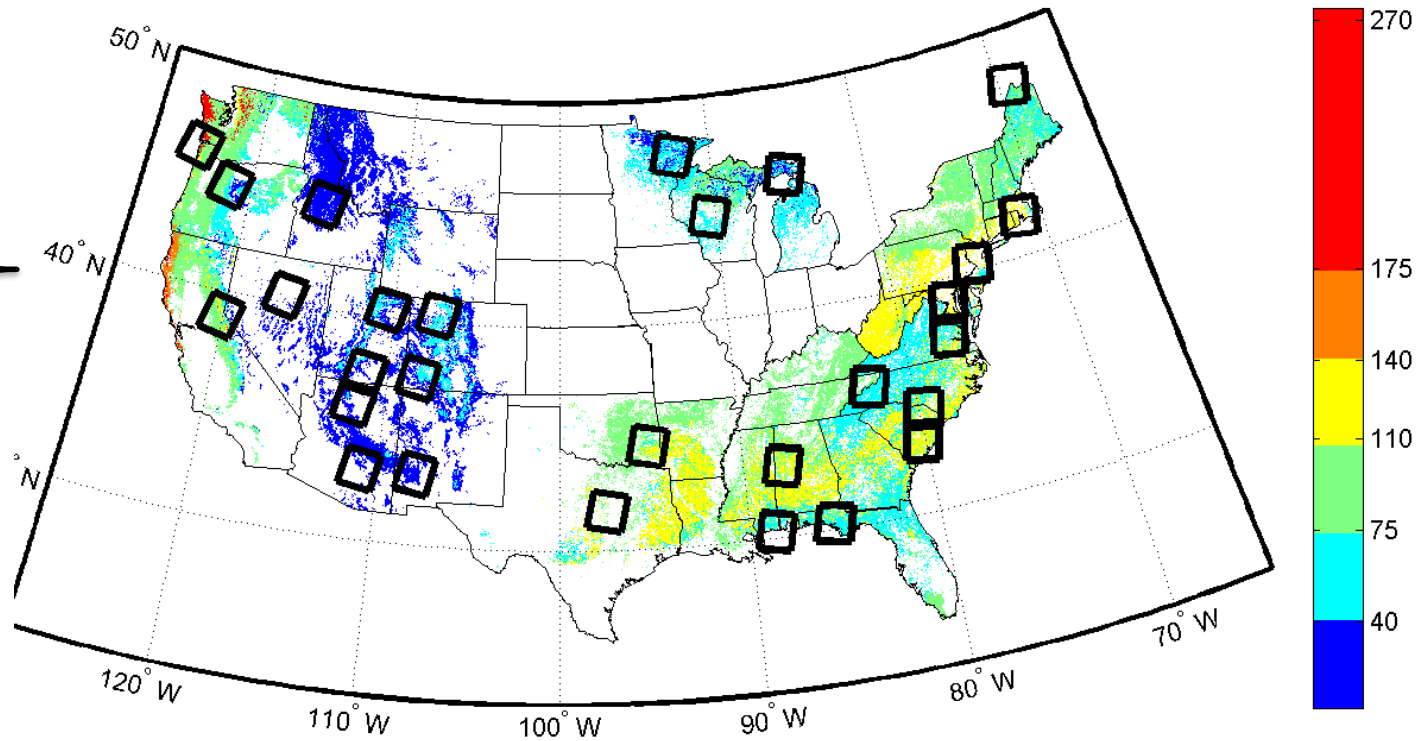
Williams et al. (in review)

# Regrowth Uptake

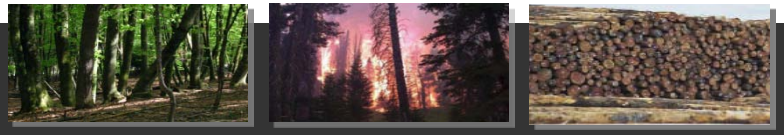



## $NEP_{regrowth\ modeling}$ [gC m$^{-2}$ a$^{-1}$]

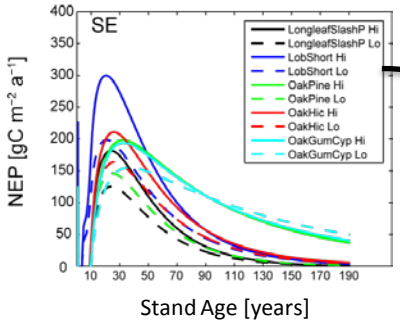


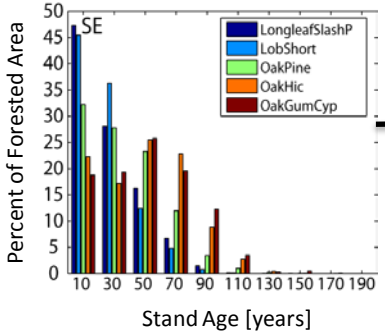

Williams et al. (in review)

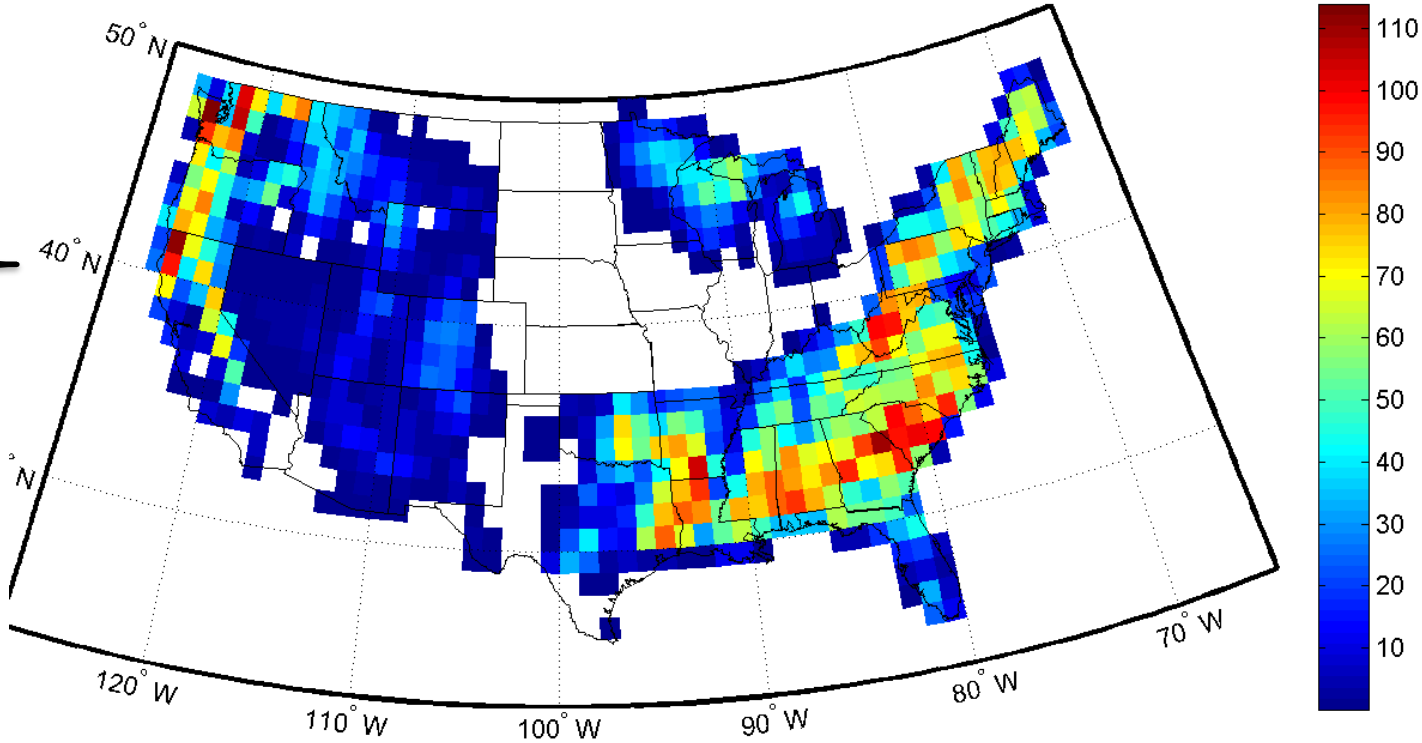


# Regrowth Uptake

$NEP_{regrowth\ modeling}$ [gC m$^{-2}$ a$^{-1}$]



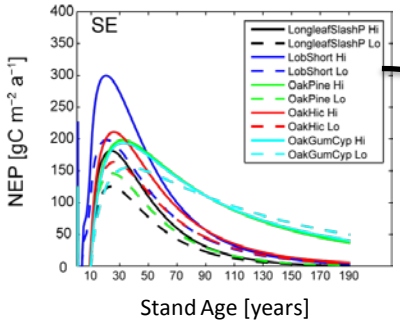



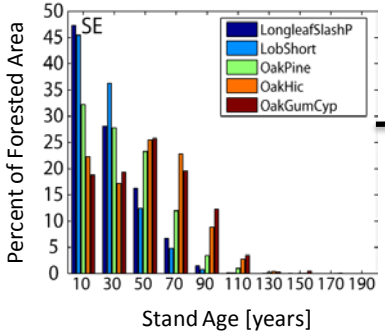



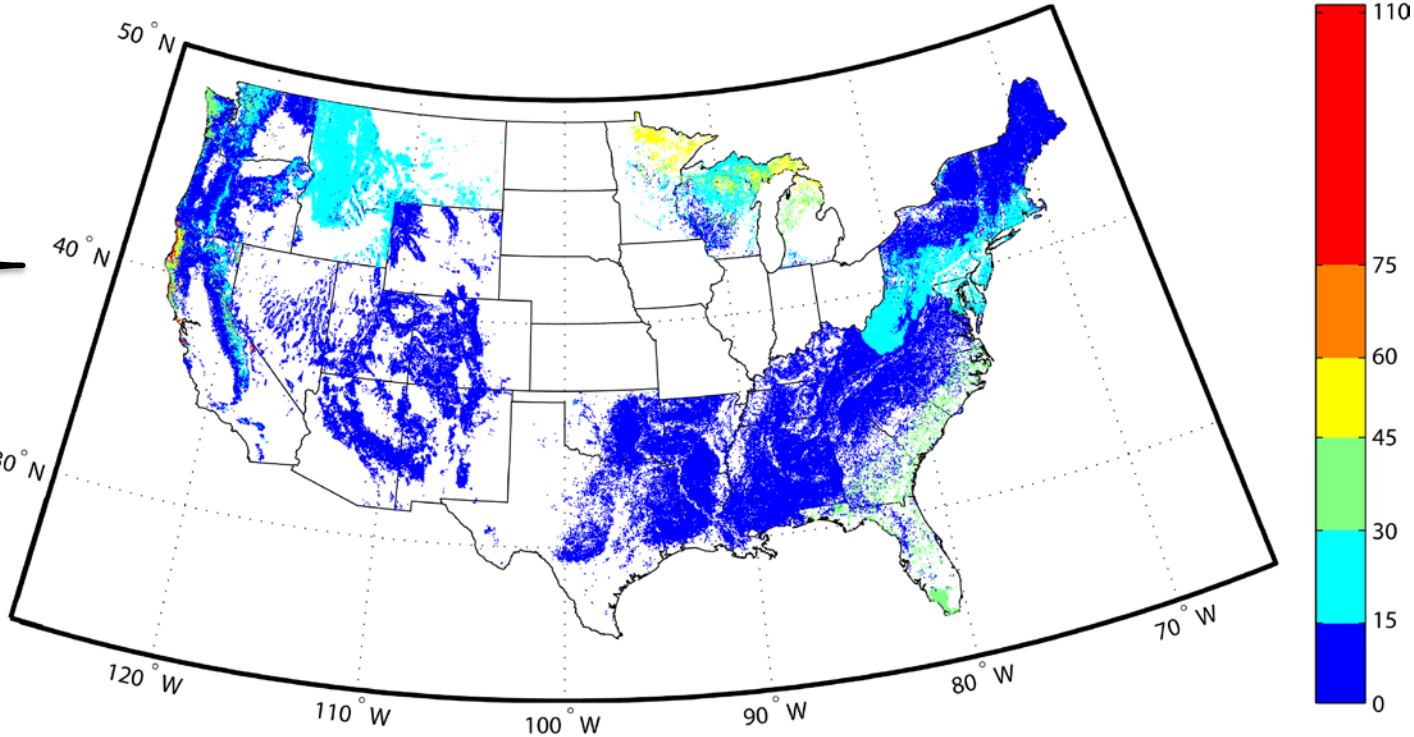

160 Tg C a$^{-1}$

# Regrowth Uptake

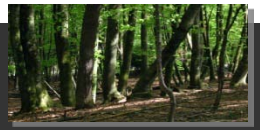
## Std Dev ($NEP_{regrowth\ modeling}$) [$gC\ m^{-2}\ a^{-1}$]




30 Tg C $a^{-1}$

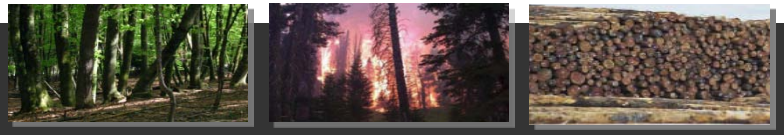


# Regrowth Uptake

- Landsat derived disturbance analysis indicates younger forests than seen in FIA age histograms
- Results in a 25% reduction in NEP estimated for D/R

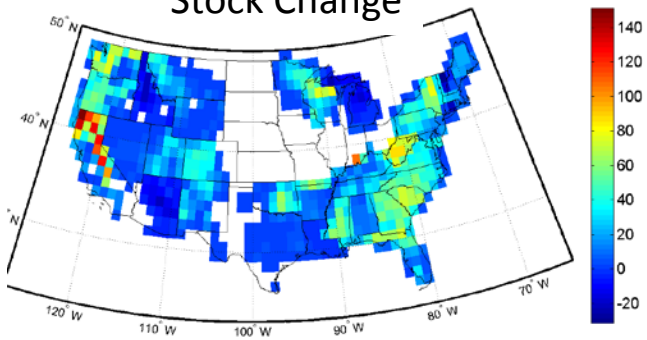
| **Method** | **$NEP_{regrowth\ modeling}$** |
|---|---|
| FIA-only Age Histograms | 178 Tg C $a^{-1}$ |
| RS & FIA Age Histograms | 135 Tg C $a^{-1}$ |

~160 Tg C $a^{-1}$

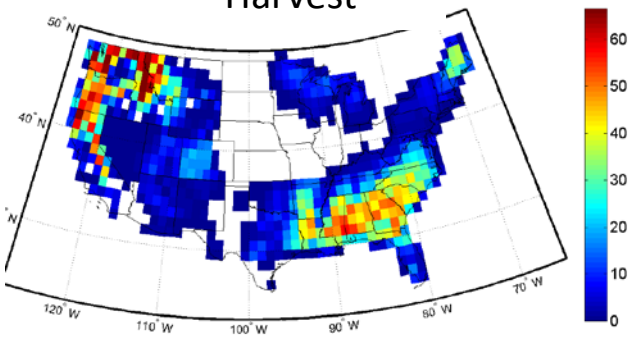


# NEP from Stock Changes

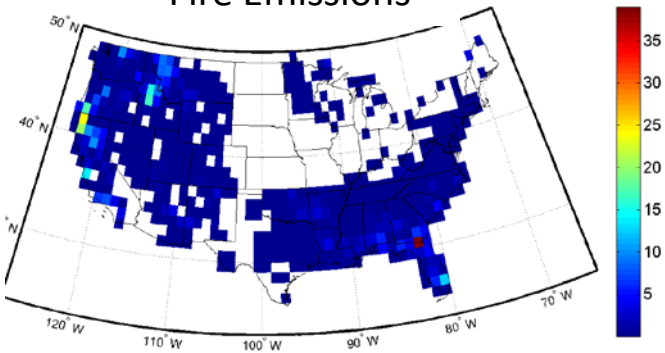
Stock Change




Harvest

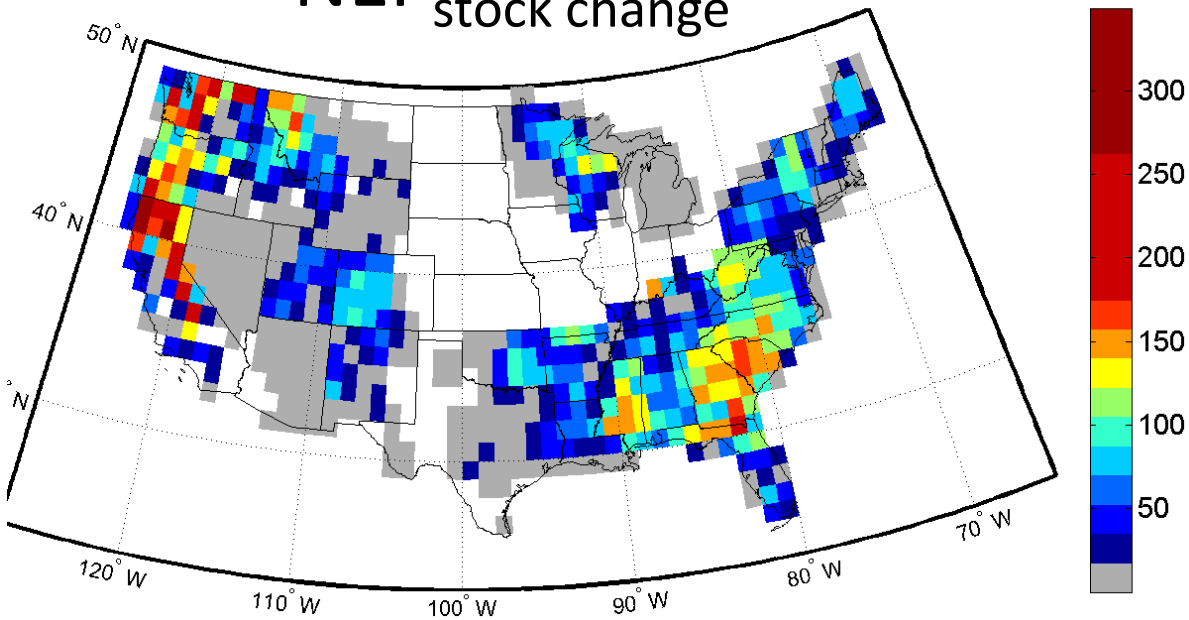



Fire Emissions



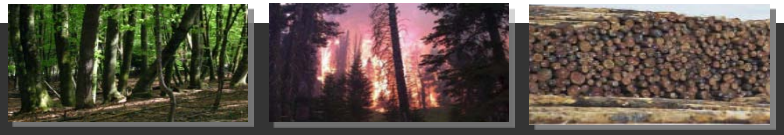

$NEP_{stock\ change}$

[gC m$^{-2}$ a$^{-1}$]




310 Tg C a$^{-1}$

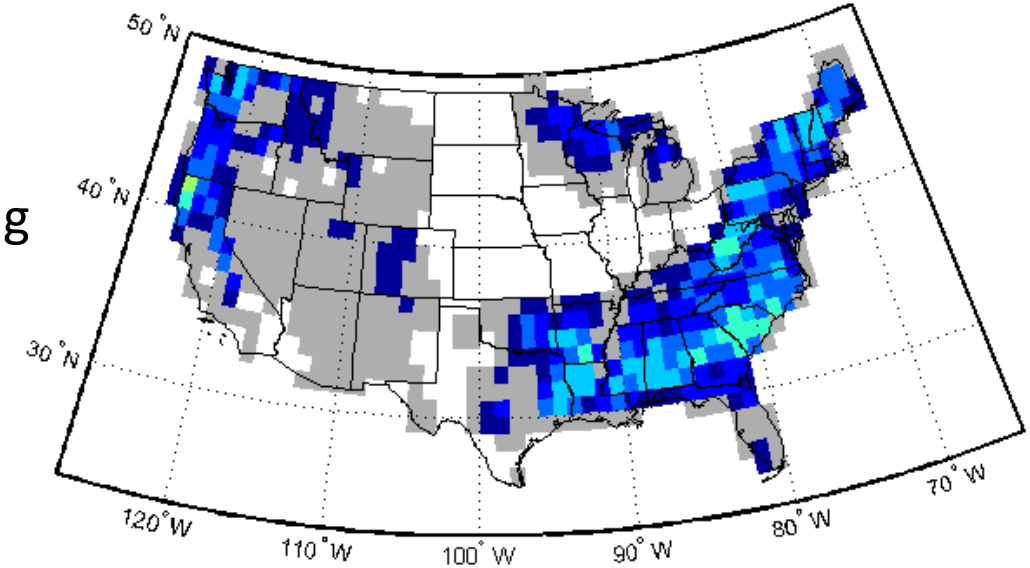
$NEP_{stock\ change}$ = ΔForest Stock + Harvest Flux + Fire Flux



# Larger Sinks from Stock Change

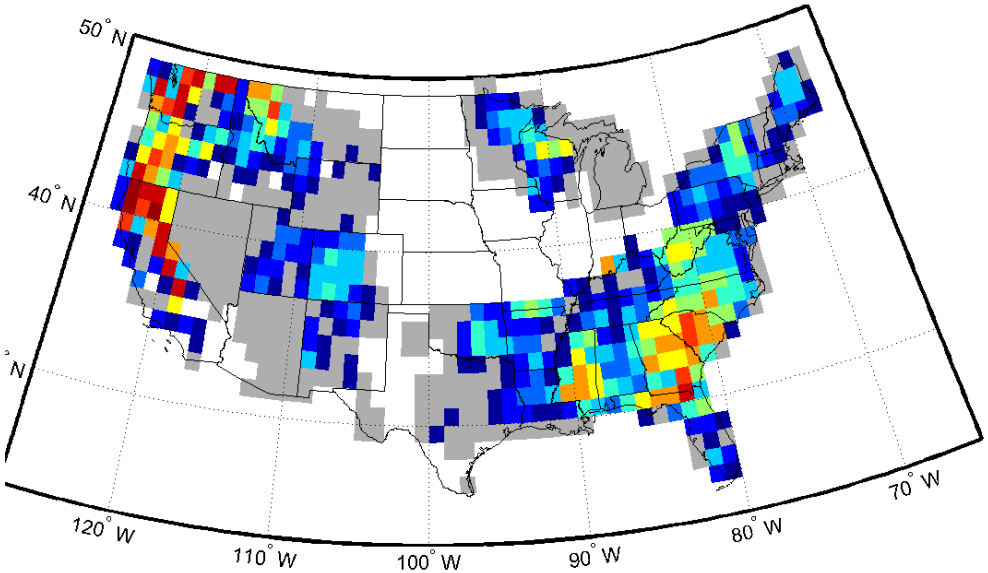
$NEP_{regrowth\ modeling}$

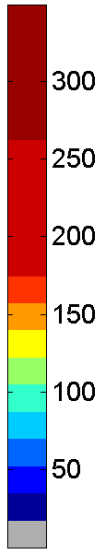
160 Tg C $a^{-1}$




$NEP_{stock\ change}$

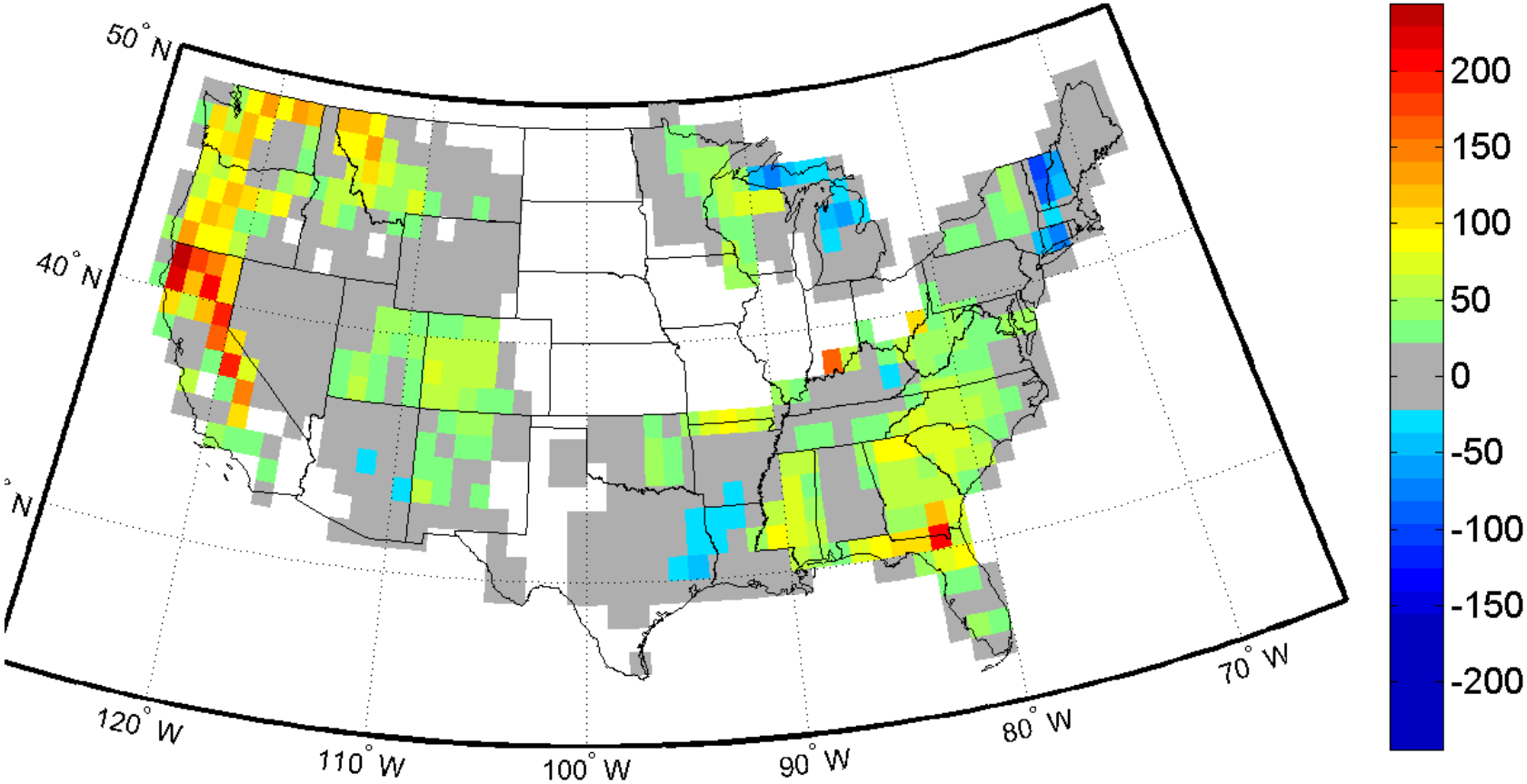
310 Tg C $a^{-1}$



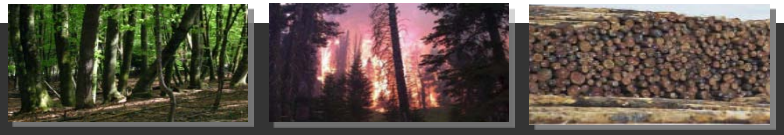
# Growth Enhancement Sink

$NEP_{stock\ change} - NEP_{regrowth\ modeling}$




[gC $m^{-2}$ $a^{-1}$]

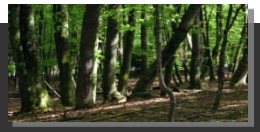
150 Tg C $a^{-1}$



# Compare Across Studies

Forest NEP [TgC $a^{-1}$]

| | Source | Mean | Low | High |
|---|---|---|---|---|
| D/R Modeling | $NEP_{regrowth}$ | 161 | 99 | 223 |
| | Dixon 1994 | 175 | 75 | 275 |
| | Houghton et al. 1999 | 188 | | |
| | Turner 1995 | 203 | | |
| Stock Change Method | $NEP_{stock\ change}$ | 310 | 160 | 460 |
| | EPA Reports | 330 | | |
| | Pacala 2001 | 371 | 141 | 601 |
| | Hurtt 2002 (D/R Modeling) | 381 | | |
| | SOCCR 2007 | 387 | 193 | 581 |
| | Birdsey 1993 | 402 | | |
| | Goodale 2002 | 431 | | |
| | Birdsey and Heath 1995 | 431 | | |



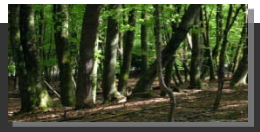
# Conclusions

Landsat-derived forest disturbance maps suggest higher rates of disturbance than inferred from age histograms in the FIA dataset.

Modeling disturbance and regrowth effects on forest NEP accounts for only half of that seen in stock changes

Additional sink is likely due to growth enhancements

Enhancement is concentrated in regions with active management and younger forests (SE, SC, PNW, PSW)



# Some Questions

What, specifically, is causing enhancement?

($CO_2$, N, climate change, management stimulations)

With enhancement:

Are big, mature forests getting bigger… OR

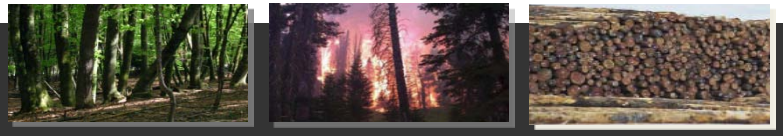
Are young, immature forests just reaching maturation faster?

What does this mean for managing forests?

enhancement is good news…

implying that forests mitigate $CO_2$ emissions

What does this mean for carbon credits from forest management?



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