Ecosystem Processes and Interannual Variability in Fluxes

At the University of Michigan Biological Station

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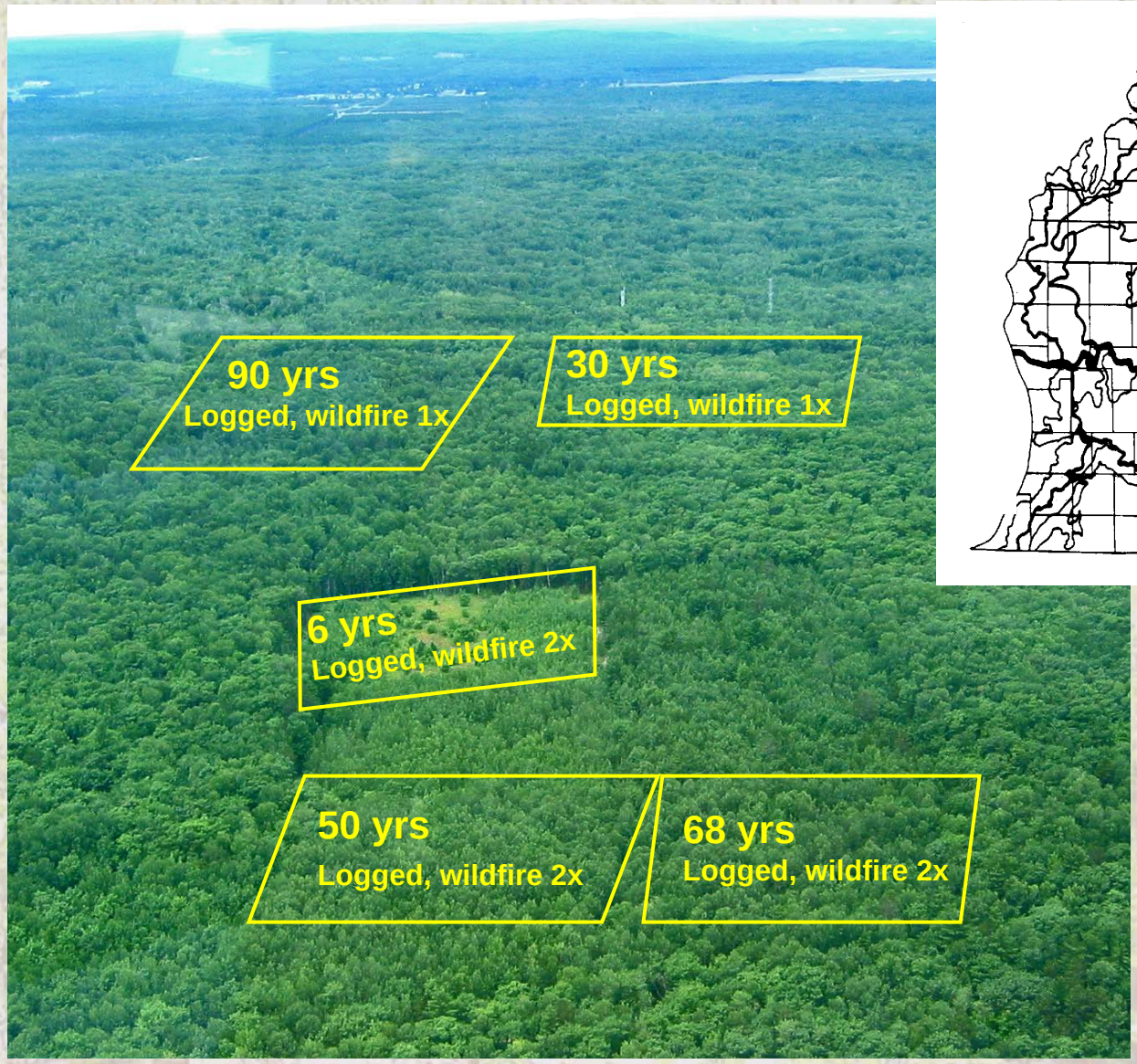
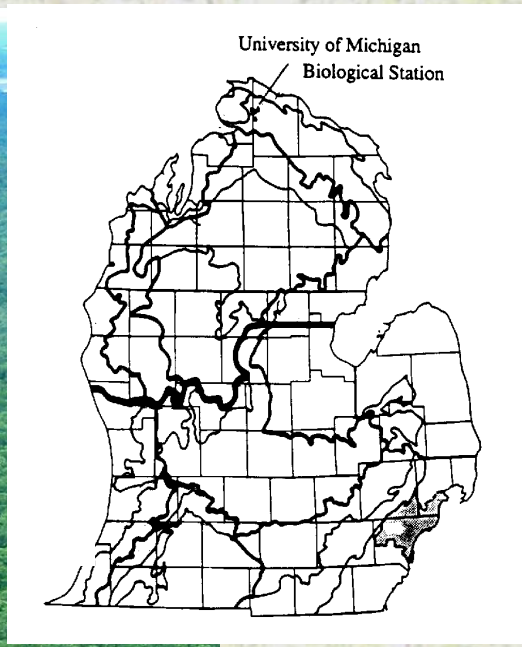
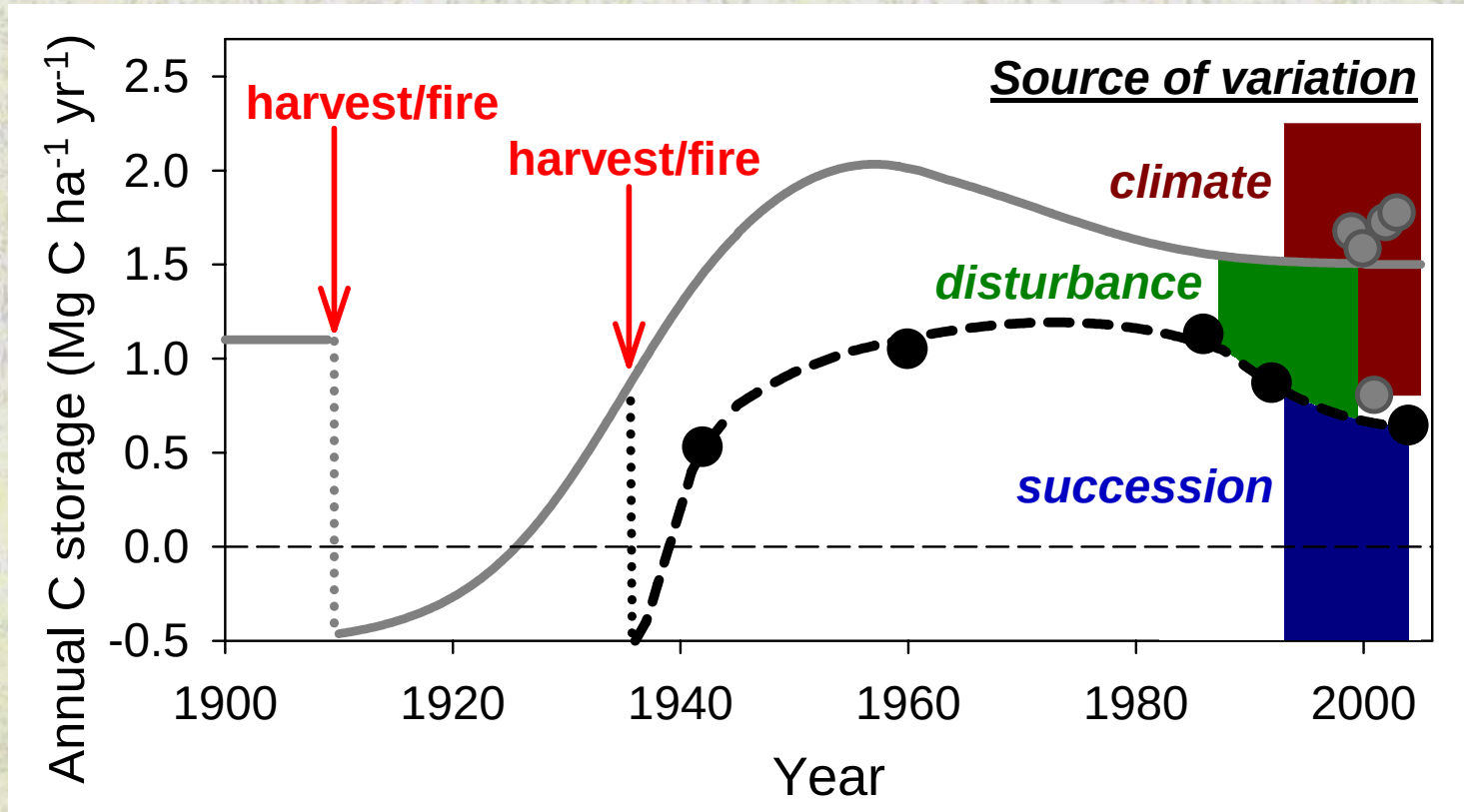
UMBS-Flux

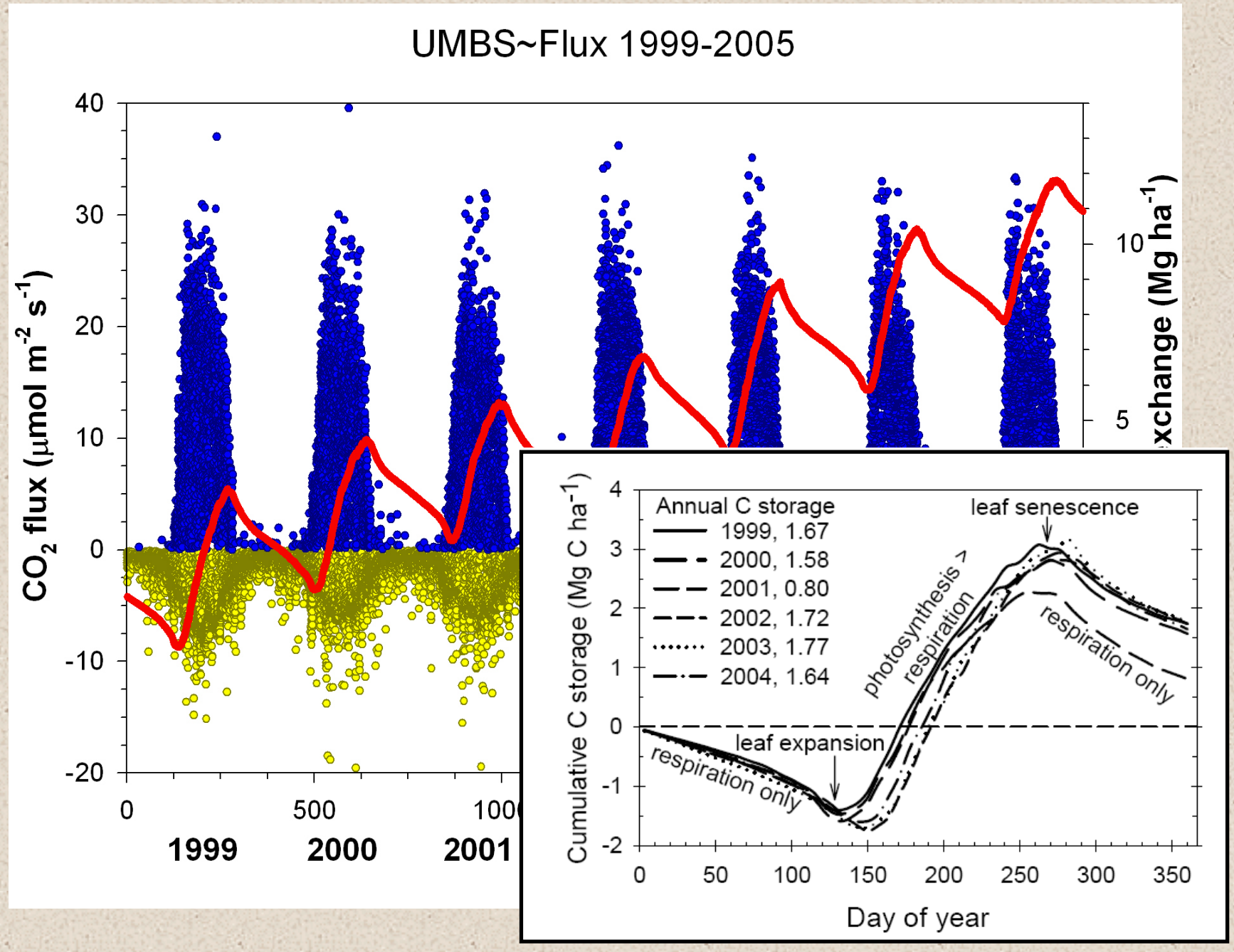
The UMBS landscape is a mosaic of forest stands varying in age and disturbance history



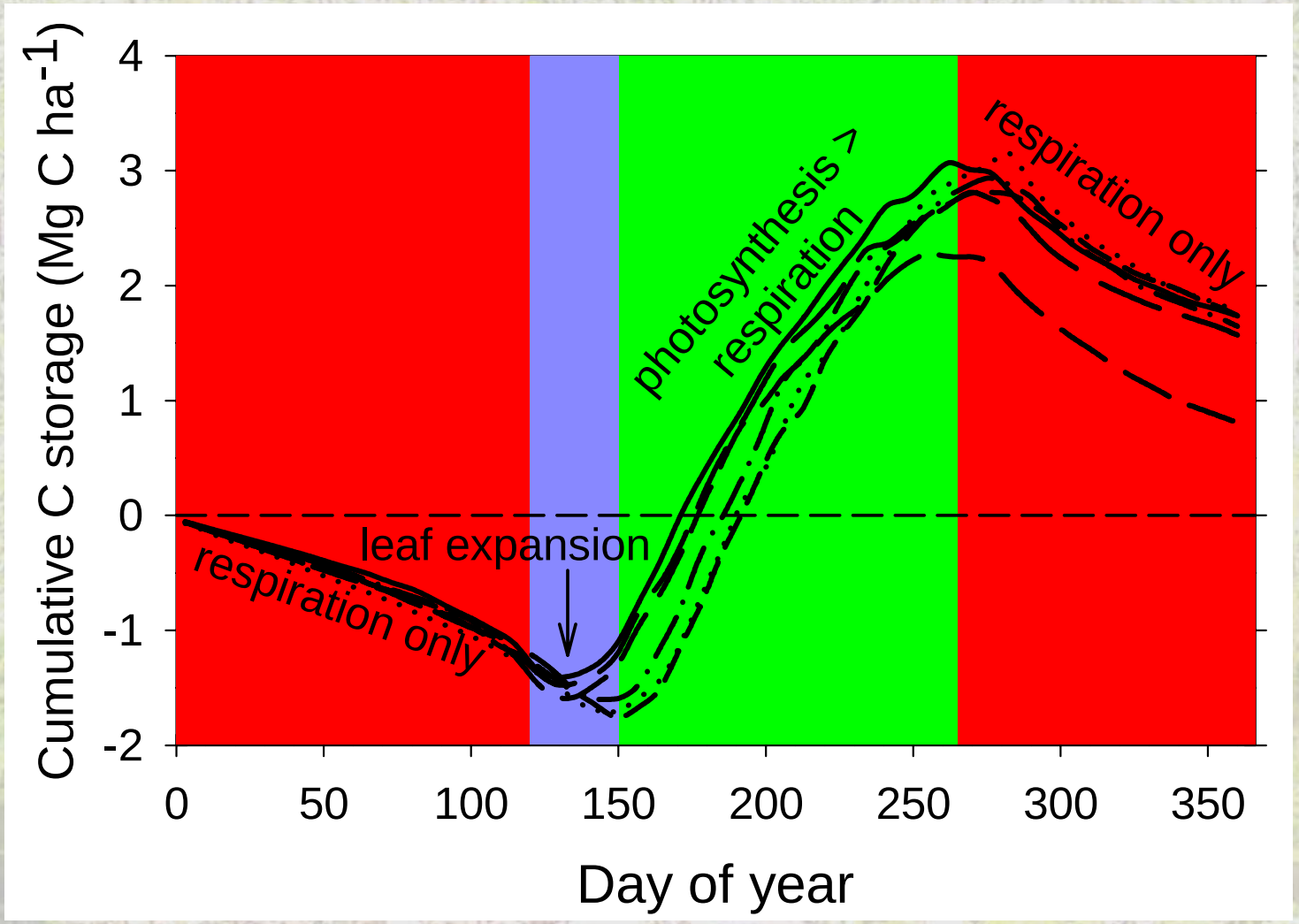


Climate, disturbance, and succession simultaneously control annual C storage




UMBS~Flux 1999-2005
CO2 flux (μmol m-2 s-1)
xchange (Mg ha-1)
40
30
20
10
0
-10
-20
10
5
0
500
1999
2000
2001
Cumulative C storage (Mg C ha-1)
Day of year
Annual C storage
1999, 1.67
2000, 1.58
2001, 0.80
2002, 1.72
2003, 1.77
2004, 1.64
leaf senescence
leaf expansion
photosynthesis
respiration
respiration only
respiration only
4
3
2
1
0
-1
-2
0
50
100
150
200
250
300
350

Climate variation caused 6-yr interannual variation in carbon storage of >100 %

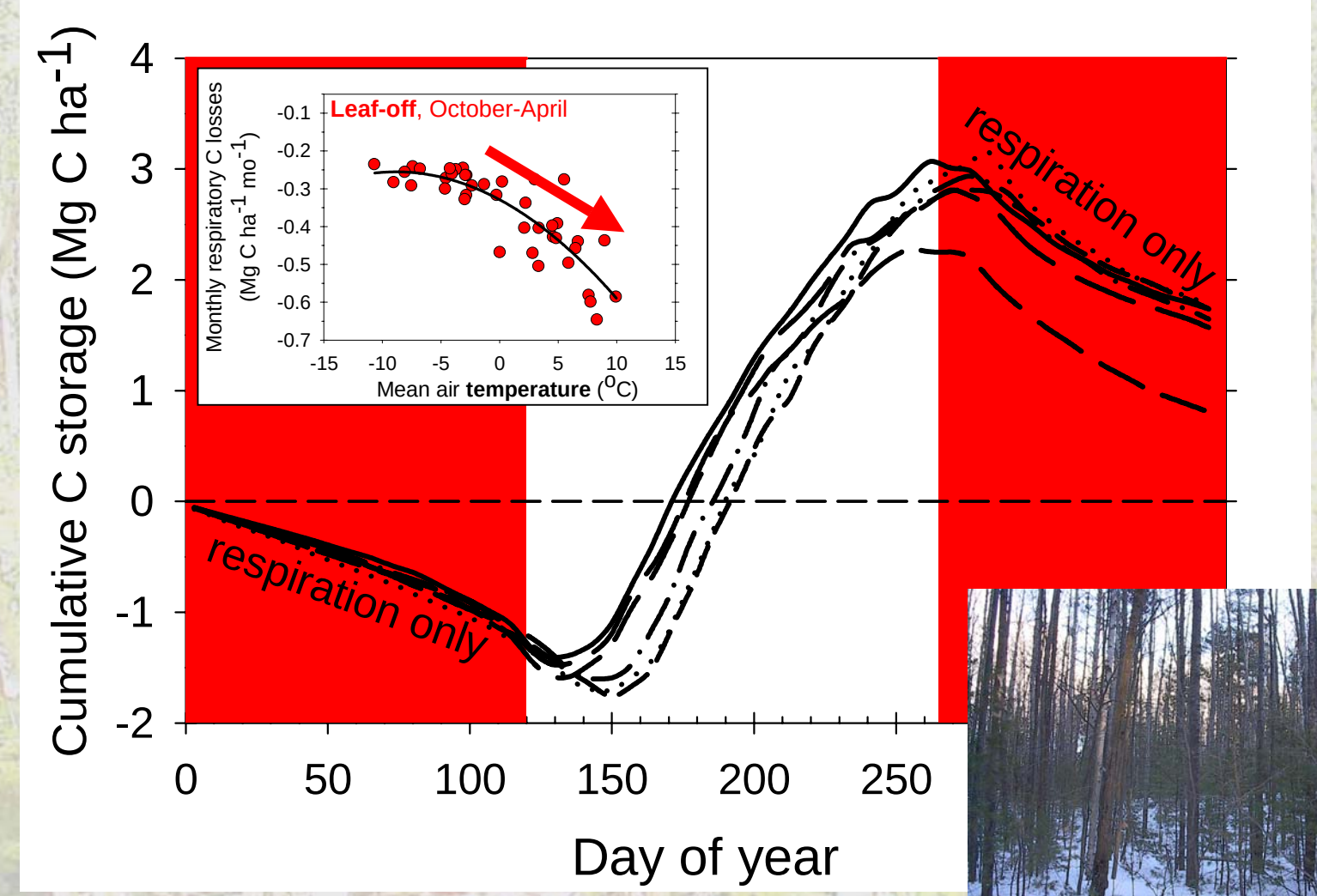


Annual C Storage
(Mg C ha^{-1} yr^{-1})

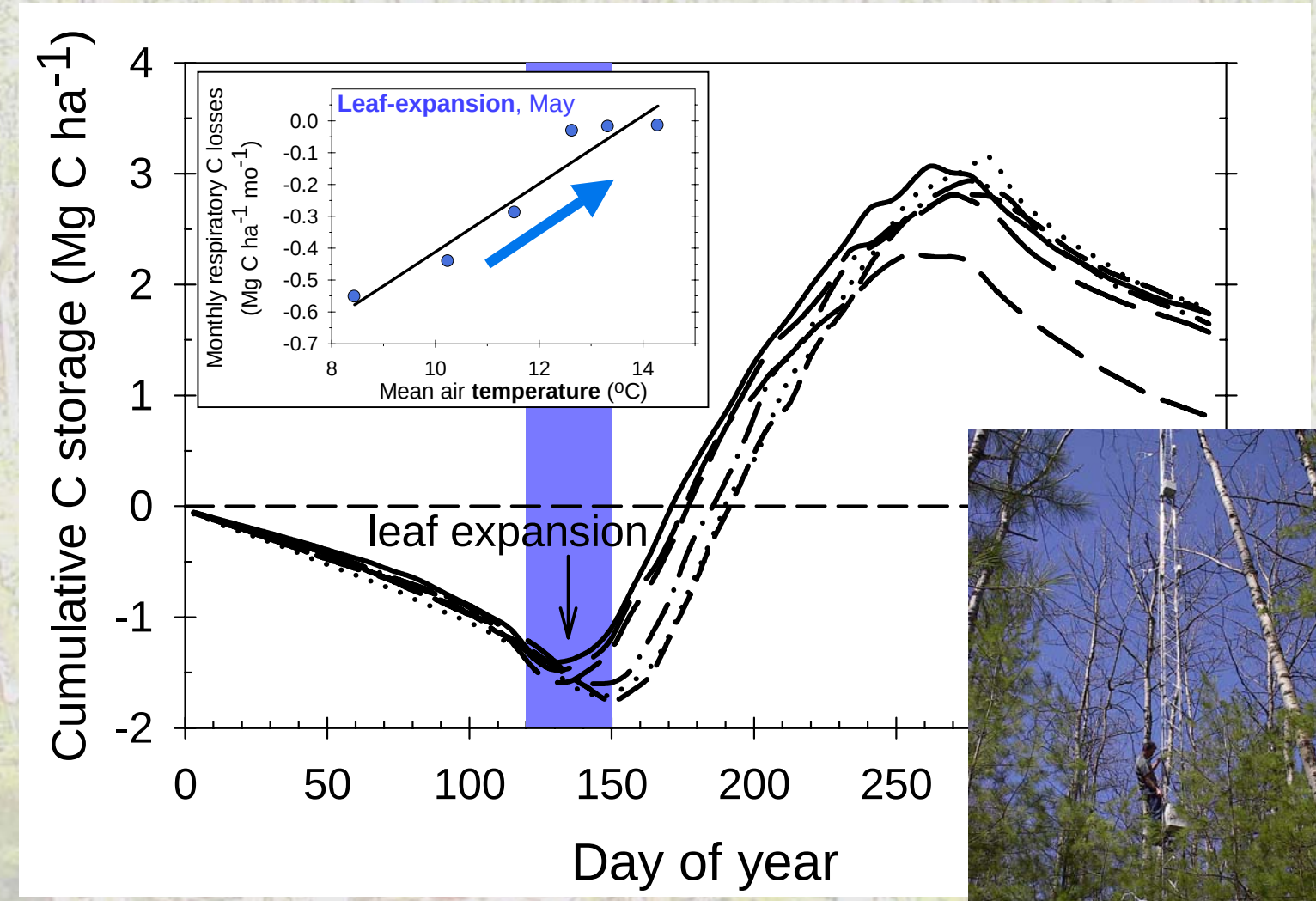
← 1.77

← 0.80

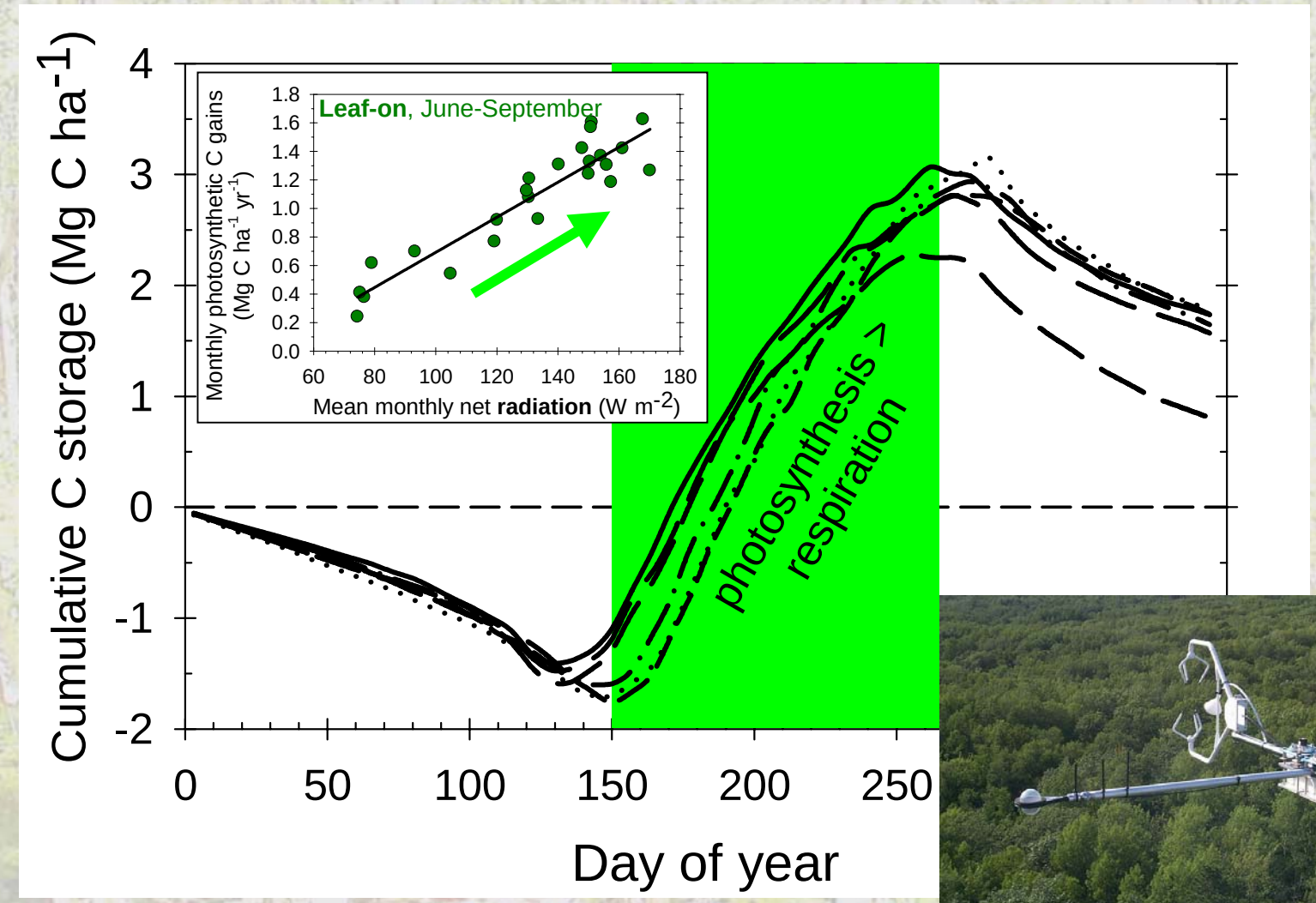
Climate effects: Warmer temperatures during leaf-off increase respiratory C losses



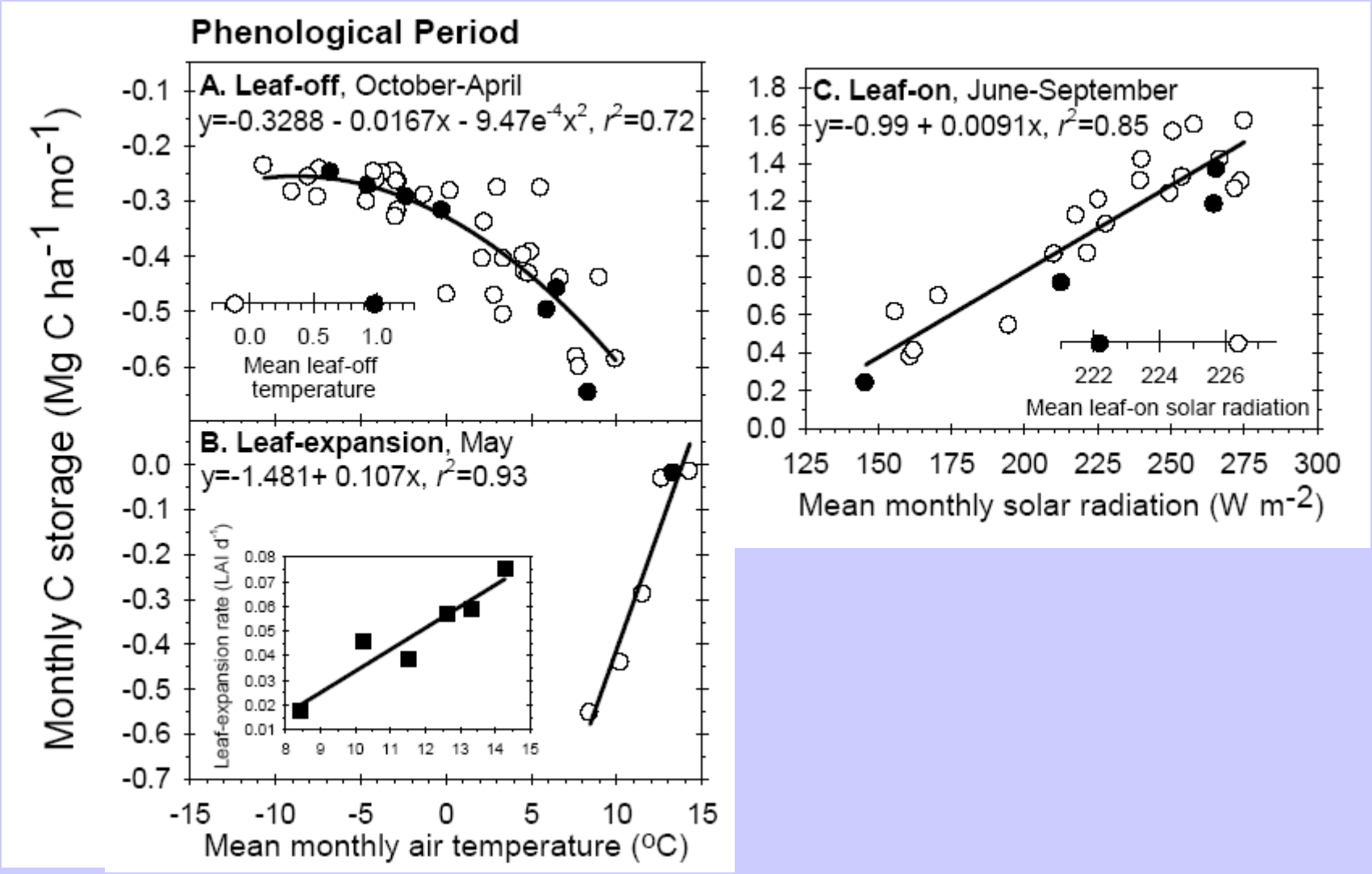
Climate effects: Warmer temperatures during leaf-expansion decrease the transition time of the forest from C source to sink

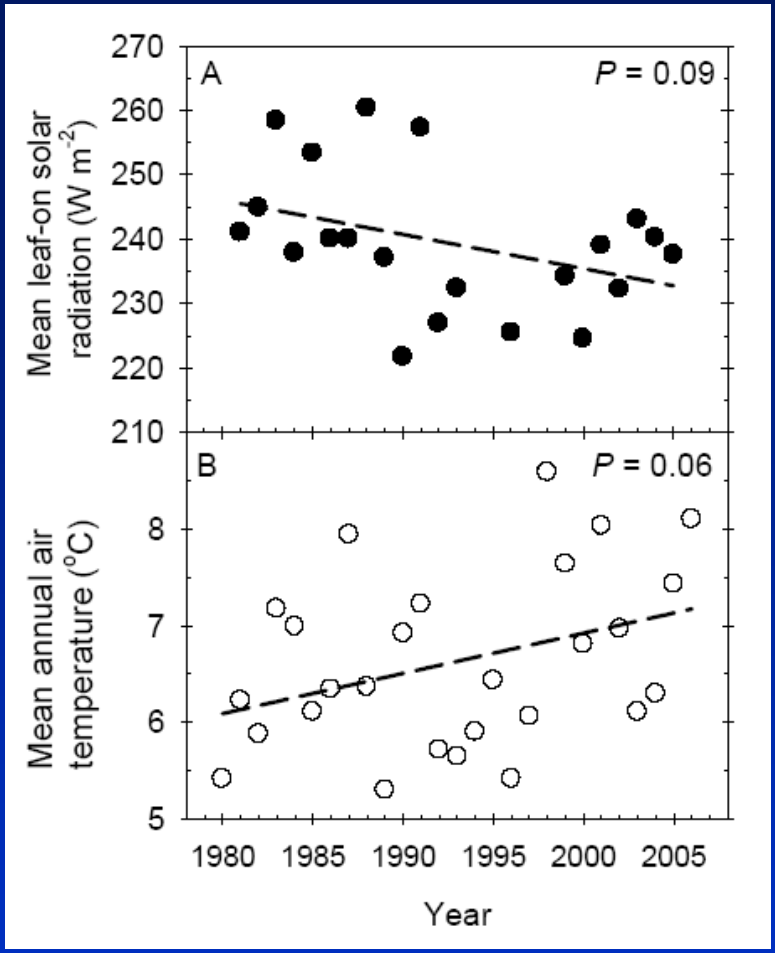


Climate effects: Photosynthetic C gains during leaf-on are positively correlated with net radiation



Climatic Drivers of Interannual Variation in NEP





25 year record of growing season solar radiation and annual air temperature at UMBS

Analysis of net ecosystem production across a disturbance chronosequence

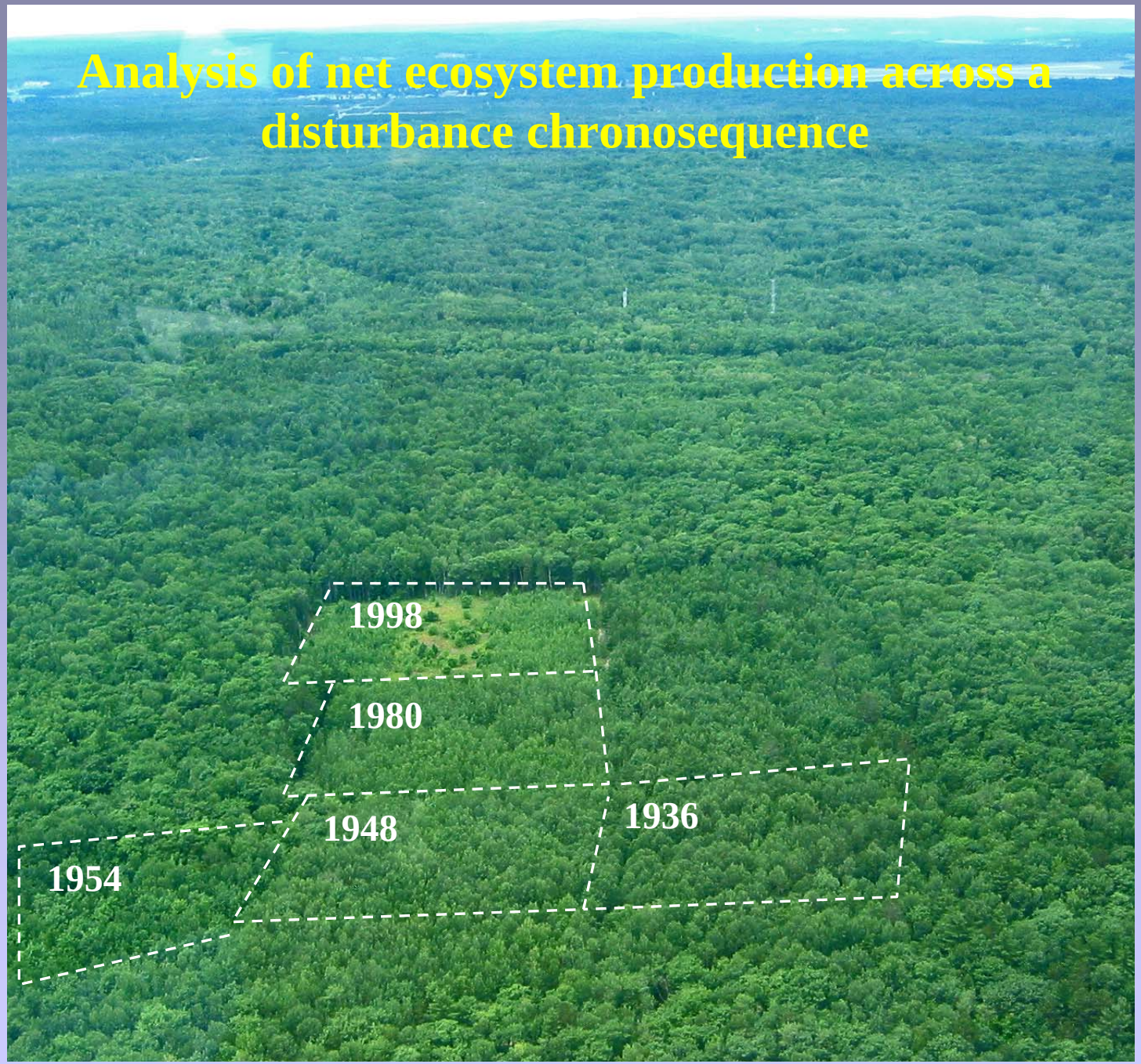
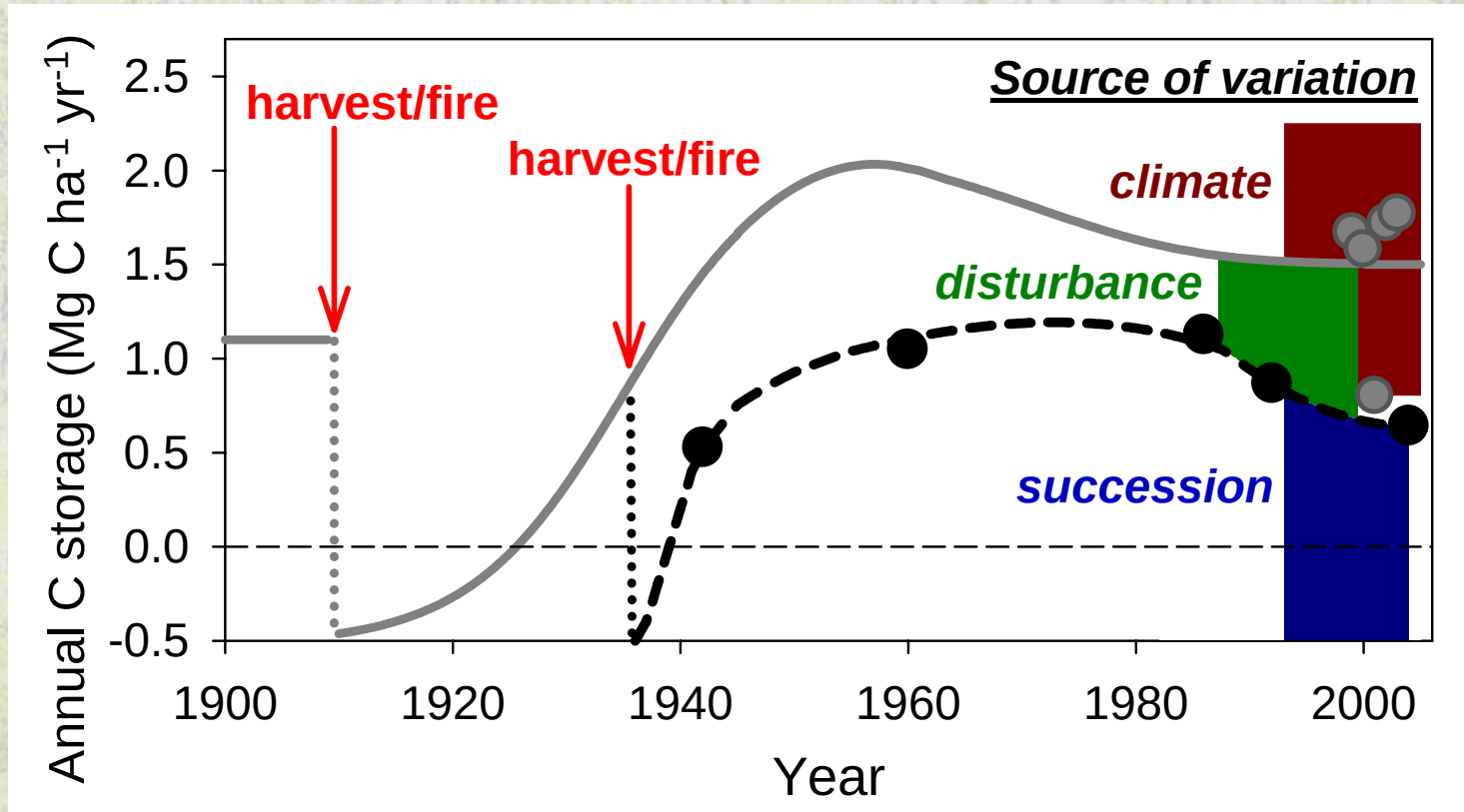


Table 3. Annual gain or loss of carbon from ecosystem components and total annual carbon storage across a disturbance chronosequence and for the reference stand. Abbreviations: ANPP-aboveground net primary production, BNPP-belowground net primary production, NPP-net primary production, F'_{h1}, F'_{h2}-heterotrophic soil respiration, NEP-net ecosystem production, ΔC-ecosystem carbon increment. Estimate ± (s.e.).

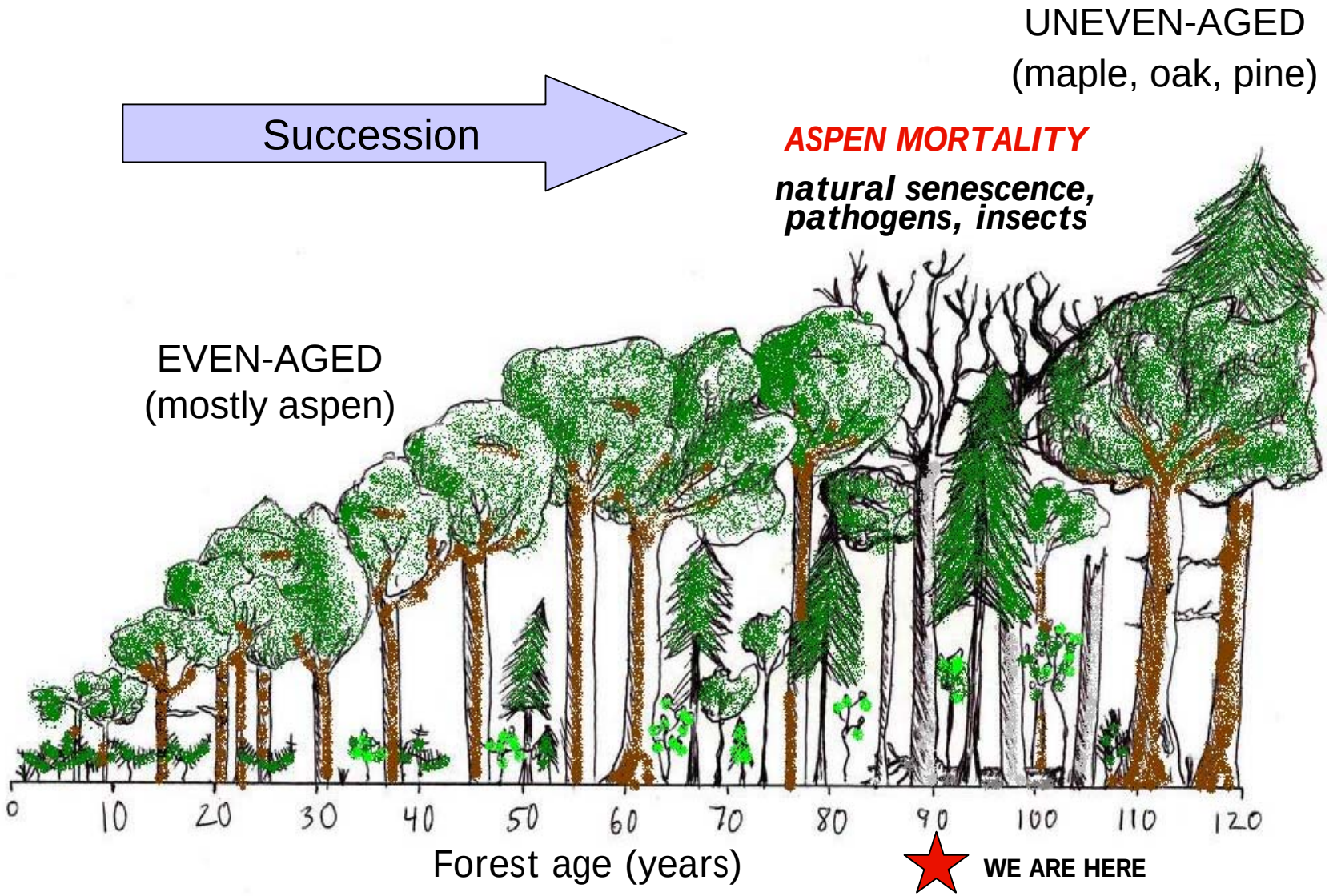
Production/loss (Mg C ha^{-1} yr^{-1})	Stand age (yrs)					
	6	24	50	56	68	Reference, 85
[1]Wood (bole, branch, stem)	1.00 (0.07)	0.78 (0.03)	0.68 (0.01)	0.66 (0.01)	0.64 (0.01)	1.73 (0.10)
[2]Herb layer	0.62 (0.03)	0.19 (0.01)	0.16 (0.04)	0.14 (0.02)	0.17 (0.02)	0.14 (0.01)
[3]Herbivory losses	0.03 (0.01)	0.06 (0.01)	0.08 (0.01)	0.08 (0.01)	0.07 (0.01)	0.07 (0.01)
[4]Leaf litter and fine debris	0.68 (0.06)	1.12 (0.10)	1.60 (0.14)	1.54 (0.14)	1.45 (0.13)	1.51 (0.12)
[5]Coarse woody debris	-0.67 (0.03)	-0.18 (0.01)	0.09 (0.01)	0.08 (0.01)	-0.03 (0.02)	0.00 (0.58)
[6]Fine roots (>2 mm)	2.44 (0.41)	2.78 (0.47)	2.67 (0.45)	2.61 (0.44)	2.56 (0.43)	2.69 (0.46)
[7]Coarse roots (> 2 mm)	0.30 (0.02)	0.20 (0.01)	0.16 (0.01)	0.16 (0.01)	0.15 (0.01)	0.40 (0.02)
[8]Mineral soil	-0.39 (0.02)	-0.19 (0.03)	0.09 (0.04)	0.15 (0.04)	0.28 (0.05)	-
[9]O-layer	0.26 (0.21)	0.13 (0.29)	-0.07 (0.42)	-0.12 (0.45)	-0.21 (0.50)	-
[10]ANPP$^{(1+2+3+4+5*)}$	**2.33 (0.10)**	**2.15 (0.11)**	**2.61 (0.15)**	**2.50 (0.14)**	**2.33 (0.13)**	**3.45 (0.60)**
[11]BNPP$^{(6+7)}$	**2.74 (0.41)**	**2.98 (0.47)**	**2.83 (0.45)**	**2.77 (0.44)**	**2.71 (0.43)**	**3.09 (0.46)**
[12]NPP total$^{(10+11)}$	**5.07 (0.42)**	**5.13 (0.48)**	**5.44 (0.47)**	**5.27 (0.46)**	**5.04 (0.45)**	**6.54 (0.76)**
[13]F'_{h1} (Table 2+5*)	**-4.52 (0.70)**	**-3.78 (0.55)**	**-4.14 (0.77)**	**-4.47 (0.56)**	**-4.59 (0.65)**	**5.02 (0.86)**
[14]F'_{h2} -(2+4+6)+5*+8+9	**-4.57 (0.47)**	**-4.39 (0.56)**	**-4.49 (0.63)**	**-4.34 (0.65)**	**-4.21 (0.67)**	-
NEP (12+13)	**0.55 (0.82)**	**1.35 (0.73)**	**1.30 (0.90)**	**0.80 (0.73)**	**0.45 (0.79)**	**1.53 (1.15)**
ΔC$^{(1+3+5+7+8+9)\text{ or }(12+14)}$	**0.50 (0.63)**	**0.74 (0.74)**	**0.95 (0.79)**	**0.93 (0.79)**	**0.83 (0.81)**	-

*Coarse woody debris included in ANPP calculation when positive and F_h calculation when negative.

Climate, disturbance, and succession simultaneously control annual C storage



Changes in forest age and species composition will alter future annual C storage



New Project

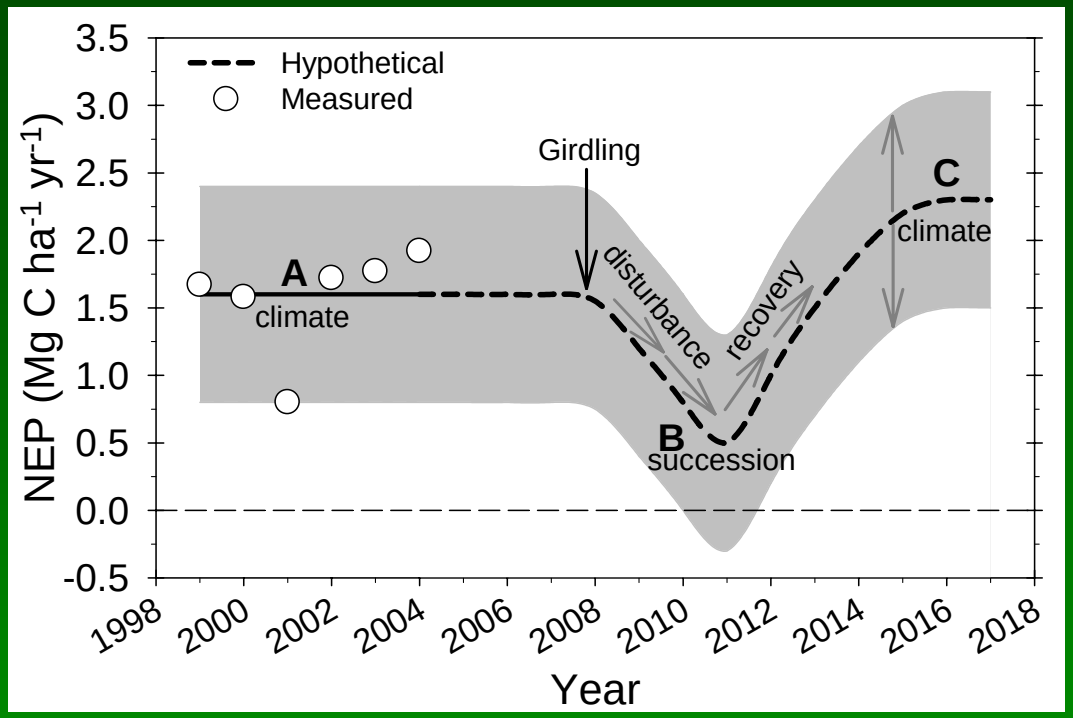
UMBS Forest Accelerated Succession ExperimenT (FASET)

Funding through DOE, National Institute for Climate Change Research

- By killing mature aspen in 39 ha (96 acres), we will expedite successional changes that typically occur over decades.
- **Objectives:**
  - Quantify C and N exchange processes during and after ecological succession from a mature aspen to a young mixed confer/deciduous forest.
  - Investigate the interactive role of disturbance and succession in governing landscape-level variability in C storage.

Expected results

Disturbance, succession, and climate effects on forest carbon cycling



A. Climate variability is the primary driver of current interannual variability in carbon storage.

B. Disturbance will prompt accelerated succession, reducing leaf area and temporarily decreasing carbon storage.

C. Following leaf area recovery, increased species and structural complexity of the canopy will result in carbon storage that is higher than pre-disturbance levels. The dominant driver of carbon storage variability will once again be climate.

Acknowledgements

PEOPLE

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- *Undergraduate researchers:* Clare Kazanski, Laura Nagel, Katie Harrold, Kristen George, Brad Ewing, Claire Baldeck
- *Graduate student researchers:* Suparna Biswas, Charlie Flower, Luke Nave
- *Others:* Bob Vande Kopple, Mike Grant

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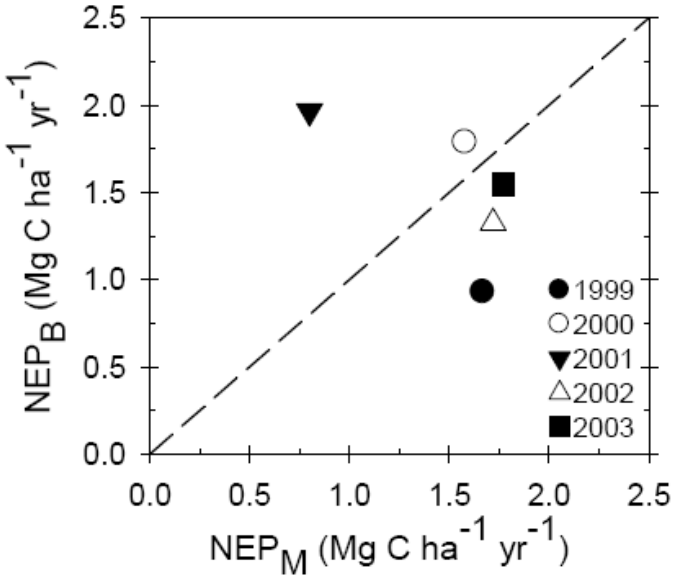
FUNDING

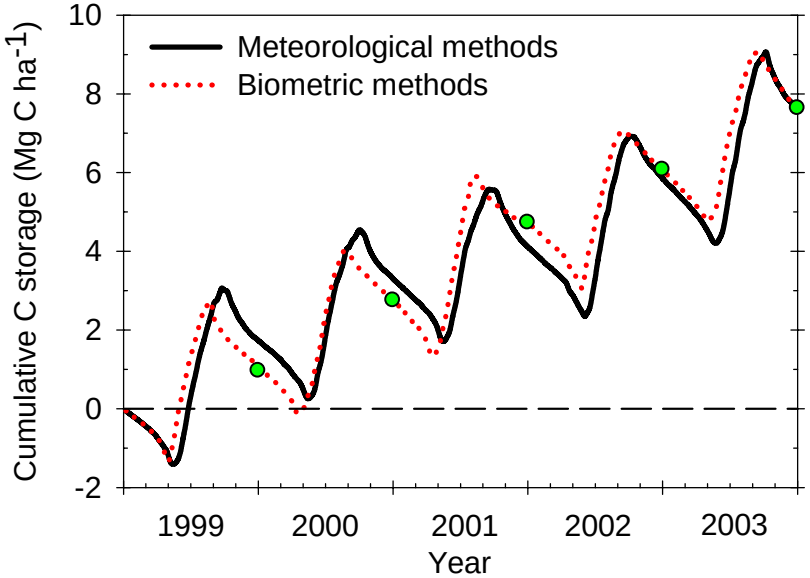
- Department of Energy
- NSF

PART II: Report on the NACP Working Group on Reconciling EC and Biometric NEP

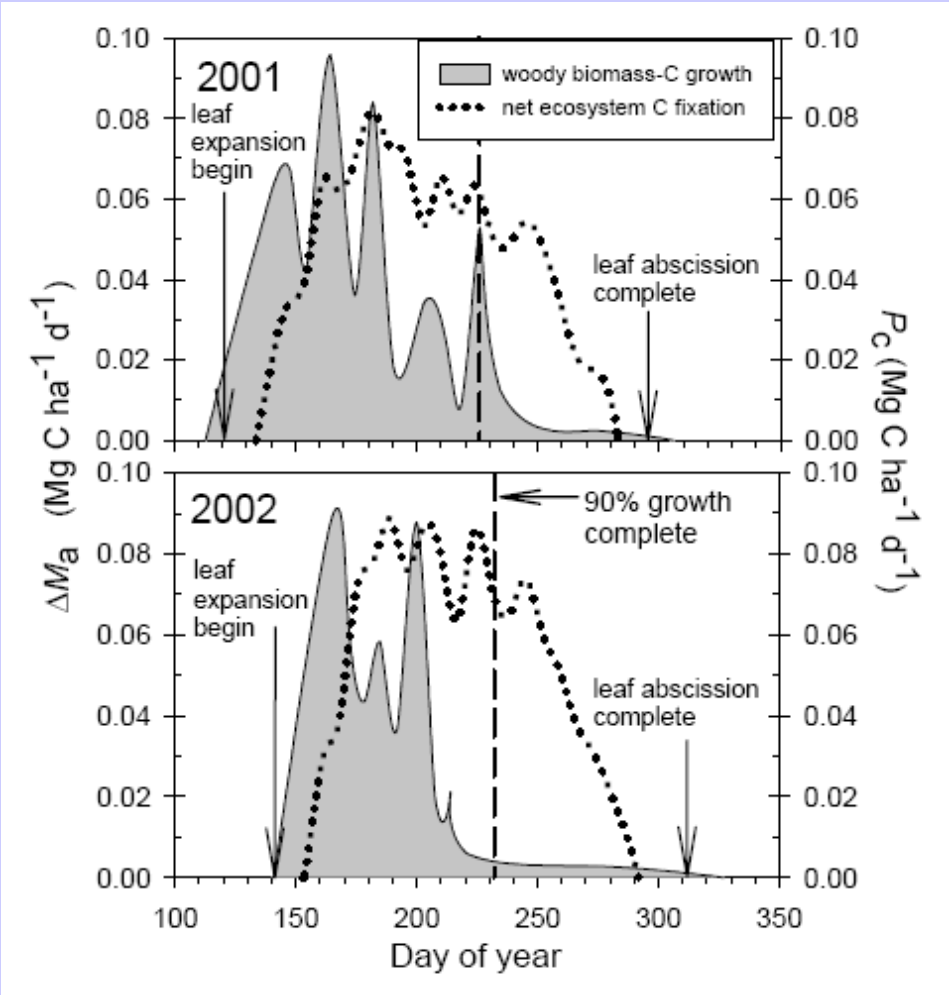
ANNUAL NET ECOSYSTEM PRODUCTION (NEP_B) CALCULATED FROM BIOMETRIC MEASUREMENTS OF C POOLS, 1999-2003. ALL UNITS ARE IN MG C HA^{-1} YR^{-1} EXCEPT 5-YEAR TOTALS

Year	ΔL		ΔD			ΔH	R_h	NEP_B
	ΔM_A	ΔM_B	ΔM_{LL}	ΔM_{FD+CD}	ΔM_{FR}			
1999	1.51 (0.18)	0.35 (0.04)	1.42 (0.12)	0.20 (0.29)	3.00 (0.58)	0.06 (0.01)	-5.58 (0.95)	0.96 (1.24)
2000	1.82 (0.08)	0.42 (0.02)	1.60 (0.13)	0.16 (0.29)	2.67 (0.41)	0.06 (0.01)	-4.94 (0.86)	1.79 (1.06)
2001	2.09 (0.07)	0.48 (0.02)	1.44 (0.12)	0.15 (0.29)	2.75 (0.44)	0.10 (0.01)	-5.03 (0.85)	1.98 (1.09)
2002	1.46 (0.05)	0.33 (0.01)	1.52 (0.15)	0.16 (0.29)	2.54 (0.40)	0.06 (0.01)	-4.73 (0.80)	1.34 (1.04)
2003	1.75 (0.11)	0.40 (0.03)	1.48 (0.14)	0.18 (0.29)	2.49 (0.45)	0.06 (0.01)	-4.80 (0.82)	1.56 (1.07)
Total	8.63 (0.49)	1.98 (0.12)	7.46 (0.66)	0.85 (1.45)	13.45 (2.28)	0.34 (0.05)	-25.08 (4.28)	7.63 (5.50)
Mean	1.73 (0.16)	0.40 (0.02)	1.49 (0.13)	0.17 (0.29)	2.69 (0.46)	0.07 (0.01)	-5.02 (0.86)	1.53 (1.10)

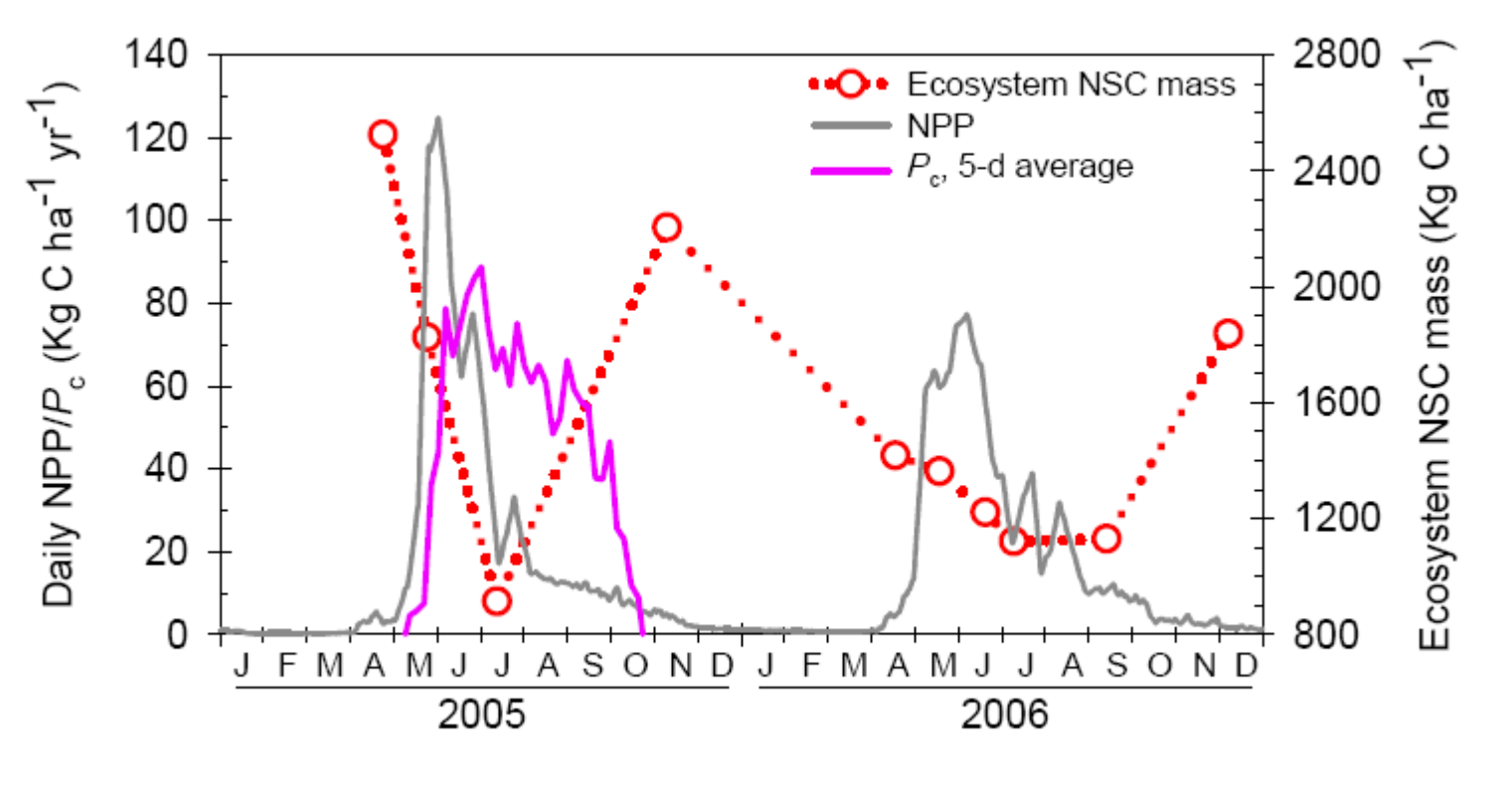




There is a temporal offset between carbon uptake measured ecologically and that measured meteorologically.



Wood growth begins earlier and ends earlier than does canopy photosynthesis


Ecosystem NSC mass
NPP
P_c, 5-d average
Daily NPP/P_c (Kg C ha^{-1} yr^{-1})
Ecosystem NSC mass (Kg C ha^{-1})
140
120
100
80
60
40
20
0
2800
2400
2000
1600
1200
800
J F M A M J J A S O N D
J F M A M J J A S O N D
2005
2006