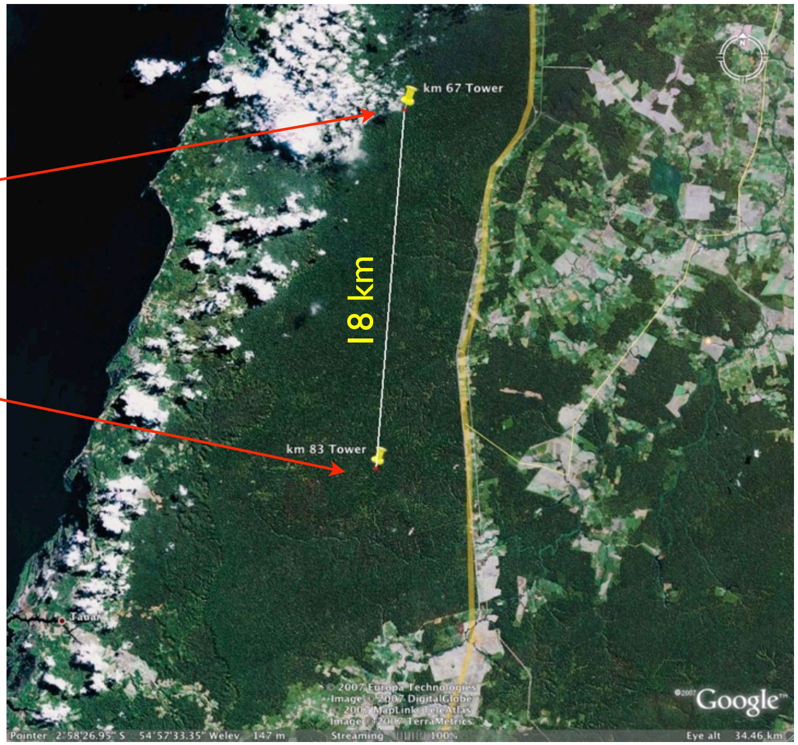
Carbon Dioxide Exchange of a Tropical Rainforest Before and After Selective Logging

Paired flux tower sites

control
(km67)

logged
(km 83)



Combined towers and biometry at each site

km 83 logged site: (SUNY Albany, UC Irvine, USP)
Scott Miller, Mike Goulden, Humberto da Rocha, Michela Figueira, Mary Menton, Chris Doughty, Albert da Sousa, Agosto Meia, Helber Freitas

km 67 control site: (Harvard and UA)
Steve Wofsy, Scott Saleska, Lucy Hutyra, Kathryn McKain

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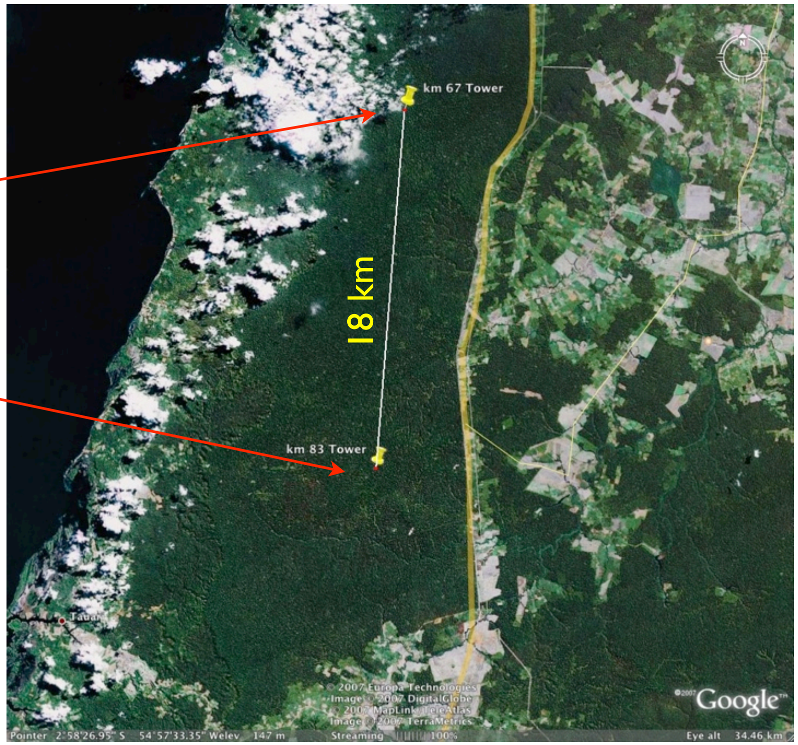

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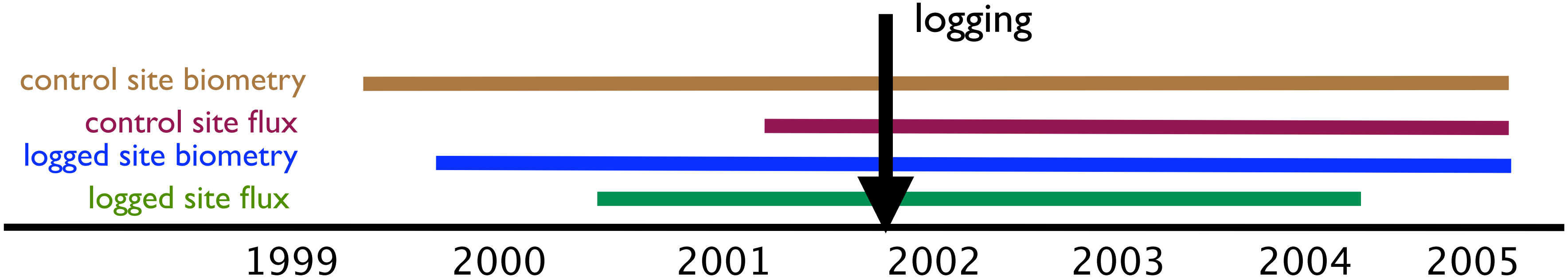

Selective logging and carbon balance

- removes canopy (~3 years)
- deposits tree crowns on forest floor (1-10 years)
- export reduces live biomass pool (decades)
- causes collatoral damage to remaining vegetation (increased mortality)

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net carbon balance of a recovering forest not well known

- 0.25*deforestation source basin-wide (Asner et al., 2005)
- source for several decades (Huang et al., in press JGR)

Questions/objectives:

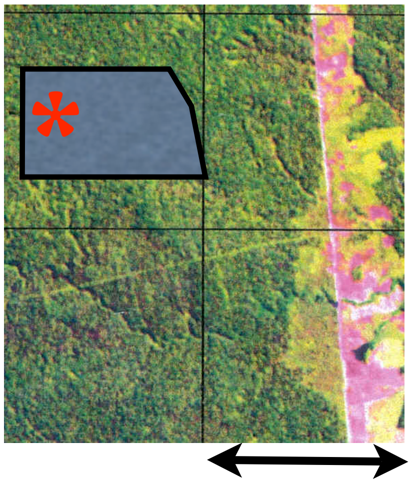
1. measure net carbon exchange exchange before/after selective logging. Is logged forest a net source or sink of carbon to the atmosphere? for how long? [towers]

2. how does logging affect patterns of carbon allocation (eg, wood growth) [dendrometers]

3. recovery mechanisms from selective logging [combined]

Physical Disturbance due to Logging

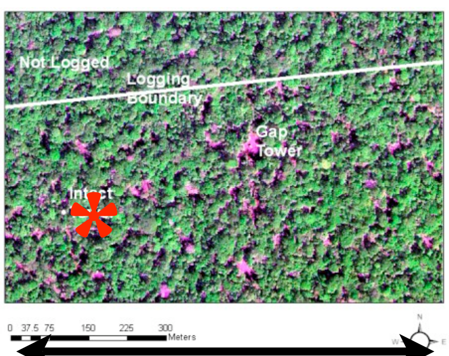
700 ha selectively logged Sept 2001



4 km

- reduced impact techniques
- 3.5 trees/ha (15% of large trees)
- gap fraction increased from 4% to 12%
- 30 Mg/ha in logged trees (10% of AG biomass)

- 9 Mg/ha logged tree boles removed (60%)
- 6 Mg/ha logged tree boles remained (40%)
- 10 Mg/ha canopy crowns on forest floor



600 m

Biometric Measurements

Dendrometer Bands		logged (km 83)		control (km 67)	
		area 18 ha		area ~20 ha	
class	DBH	6 weeks		1 month	
small trees	10 cm<DBH<35 cm	79	2/01 - 11/04	615	7/'99 -4/05
medium trees	35 cm<DBH<55 cm	204	11/00 - 11/04	142	“
large trees	DBH>55 cm	108	11/00 - 11/04	203	“
gap trees	10 cm<DBH<35 cm	270	2/02 -11/04	n/a	n/a
total		661		1000	

biomass increment

allometric equations

Brown 1997 (quadratic form)
Brown 1997 (exponential form)
Araujo 1999 (power law)
Chambers 2001

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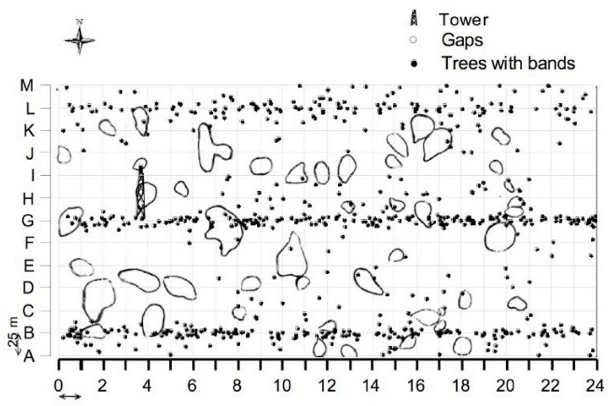
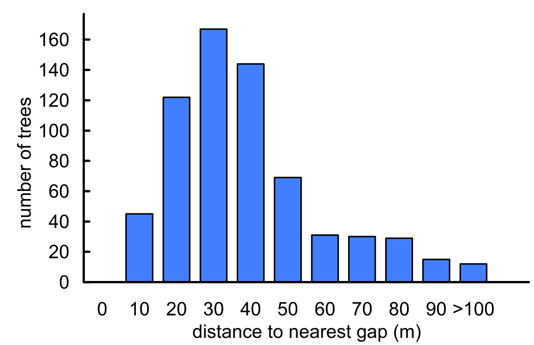
distance to nearest gap

$$d_{i,j} = \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2} \qquad i{=}tree,\ j{=}gap$$

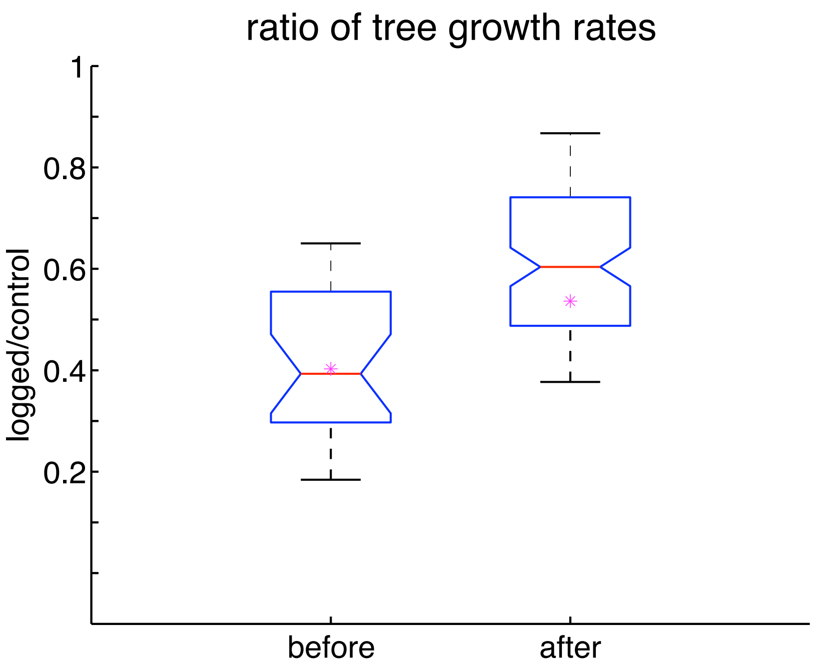




Figueira et al. submitted to JGR-Biogeosciences

Tree growth Logged vs Control Site

$$\frac{\Delta\, DBH_{\mathrm{logged}}}{\Delta\, DBH_{control}}$$



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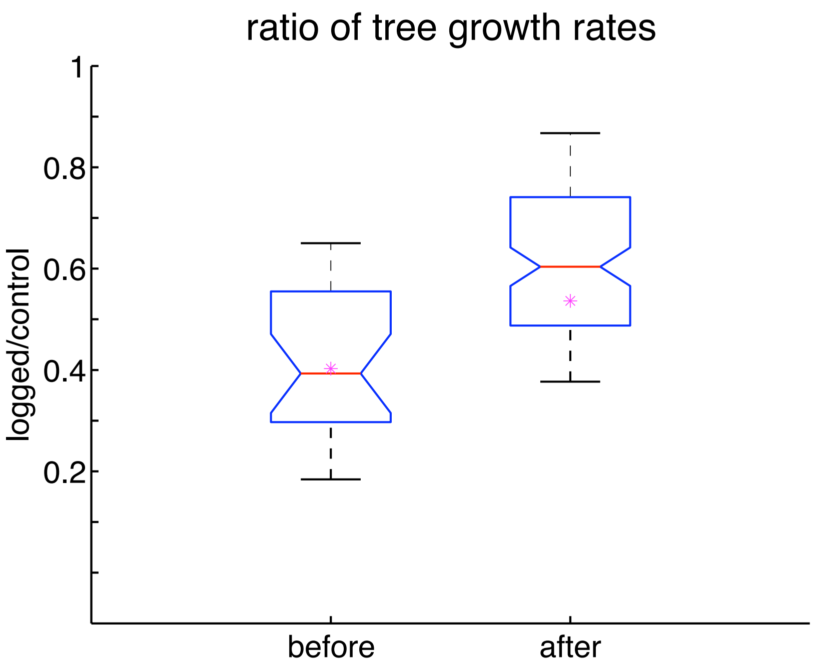
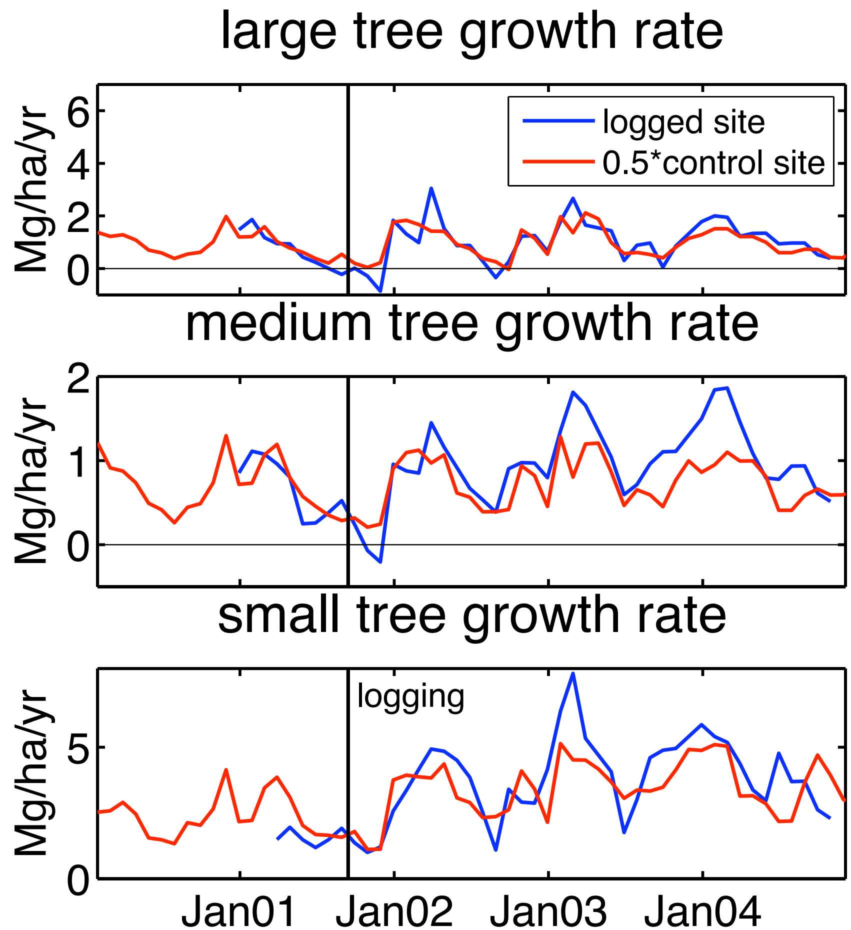
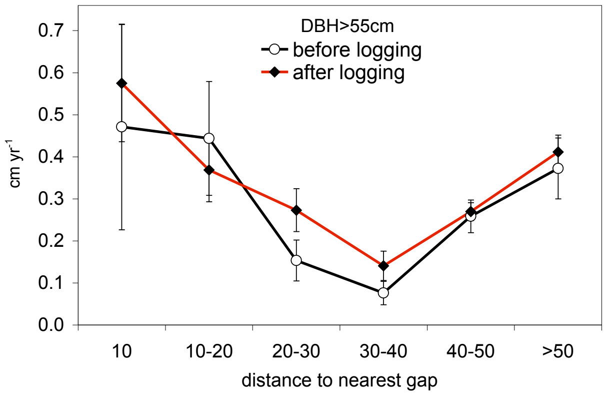




- tree growth rates increased after logging
- increase mainly in small and medium trees

Logged Site tree growth relative to gaps

large



no benefit

Figueira et al. submitted to JGR-Biogeosciences

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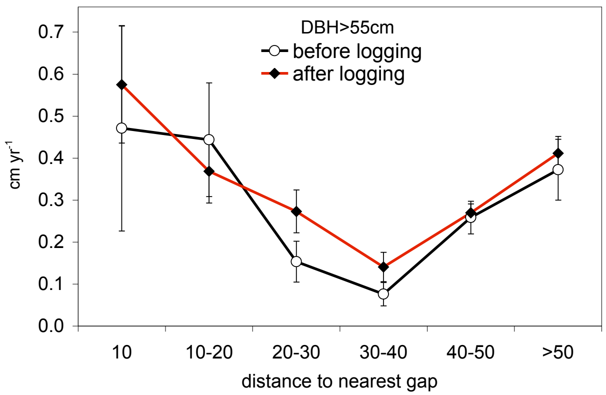
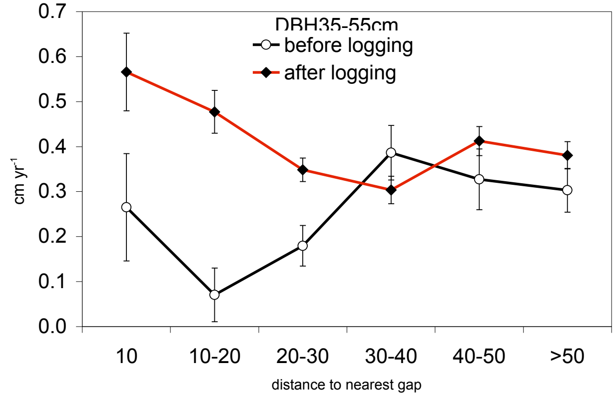
large



no benefit

medium



benefit

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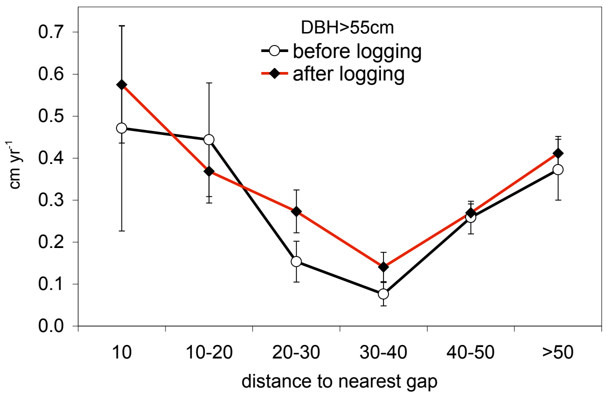

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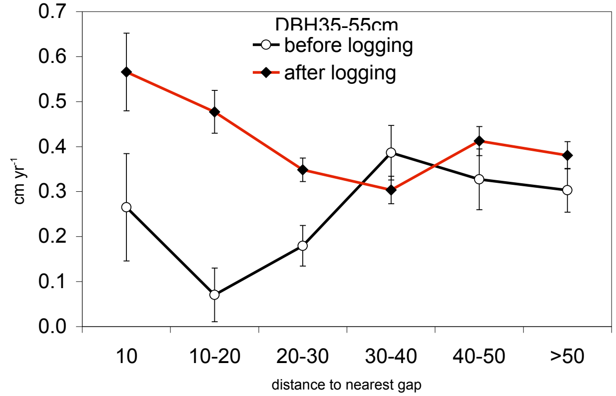

benefit

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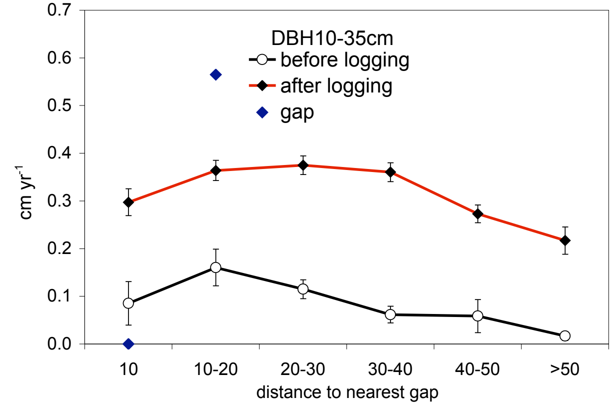

no benefit, all increase

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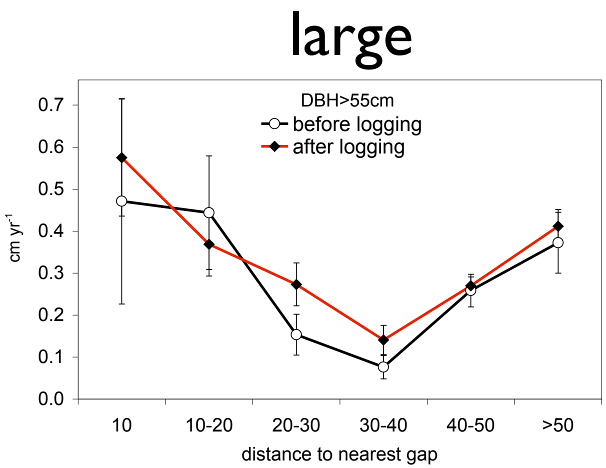

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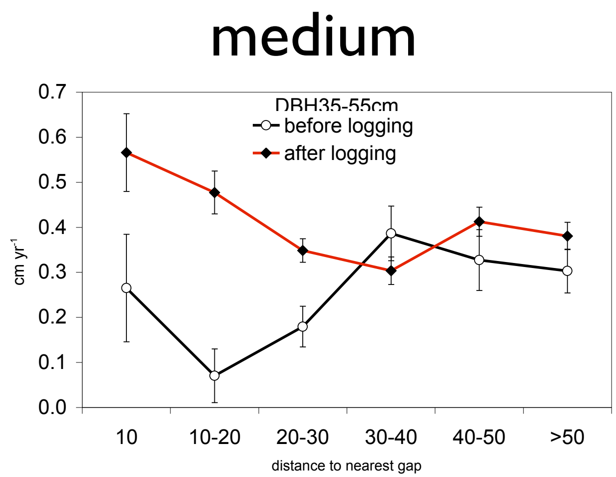

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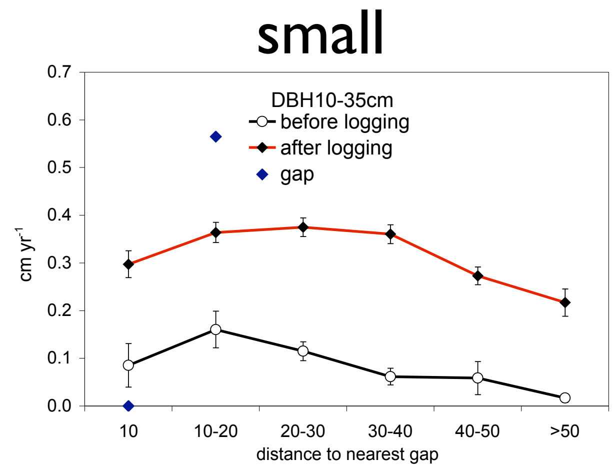

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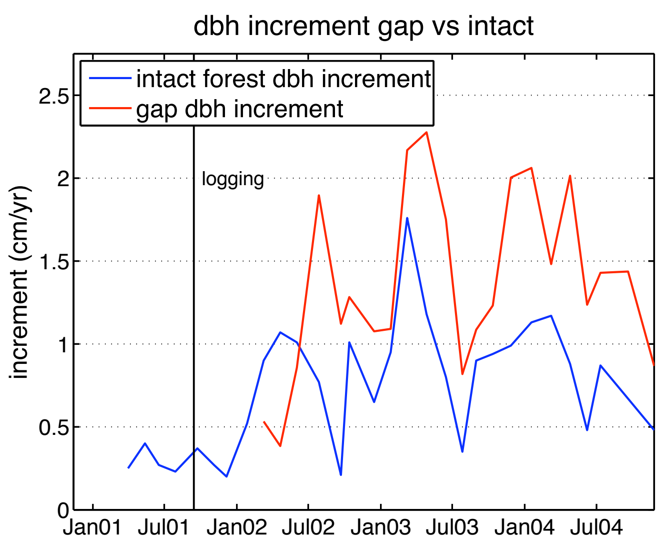

(small) trees within gaps grew fastest

Figueira et al. submitted to JGR-Biogeosciences

Logged Site tree growth relative to gaps

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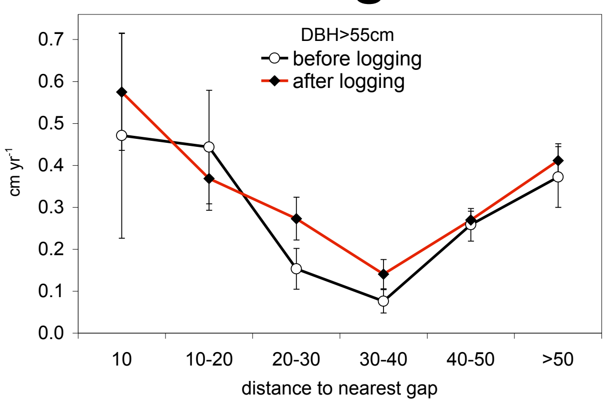

no benefit

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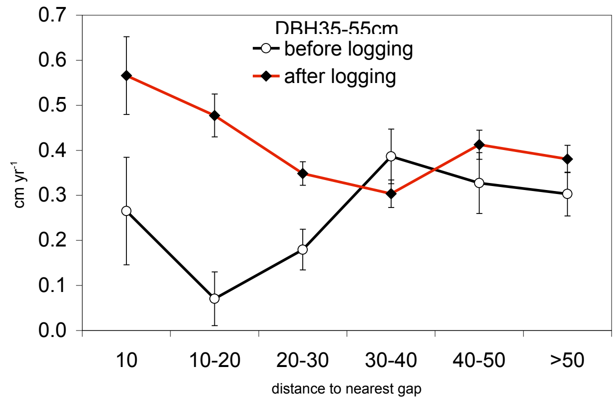

benefit

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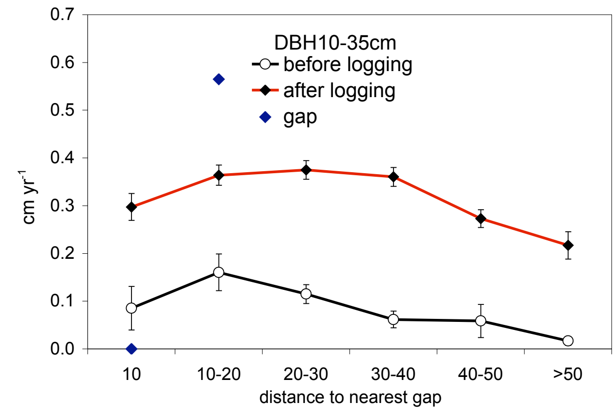

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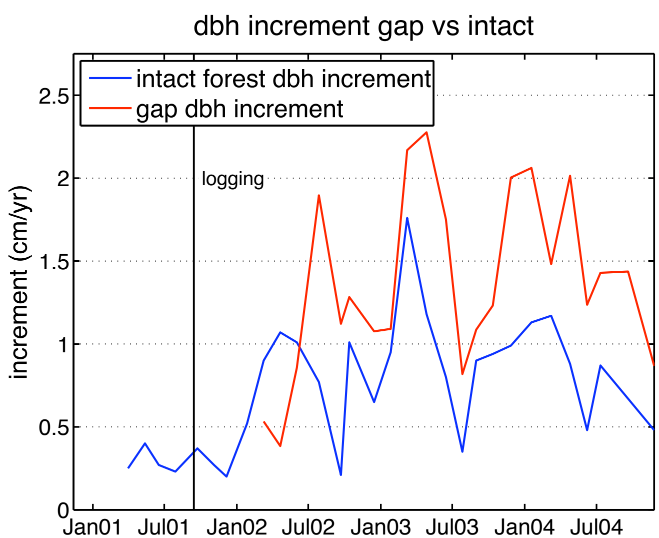

(small) trees within gaps grew fastest

spatial growth patterns can be explained by changes in available light

Figueira et al. submitted to JGR-Biogeosciences

Tower flux measurements

$$NEE = F_C + F_{STOR}$$

$$R = NEE\ (u_* > 0.22\ nights)$$

$$GPP = R - NEE$$

	logged site (km 83)	control site (km 67)
	7/00 - 3/04	4/01 - 1/06
hours	32500	41600
Fc	87%	82%
Fstor	86%	87%
NEE	78%	81%
nighttime lost	76%	55%

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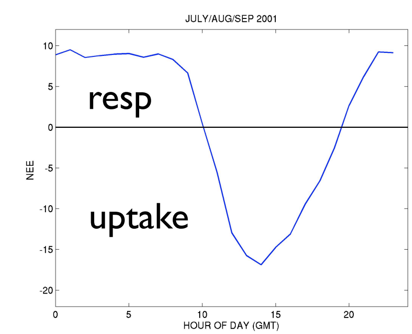
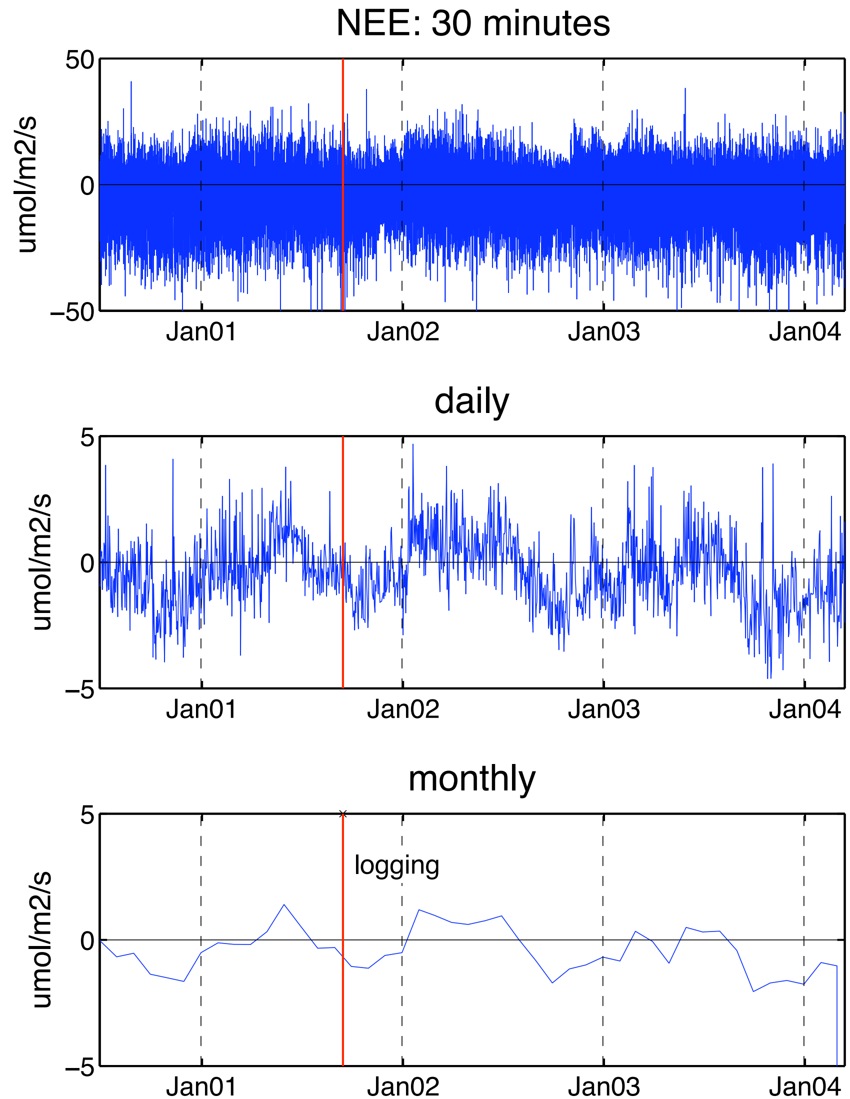
NEE uncertainty

- small difference between big numbers (uptake and respiration).
- want NEE diff between two sites.

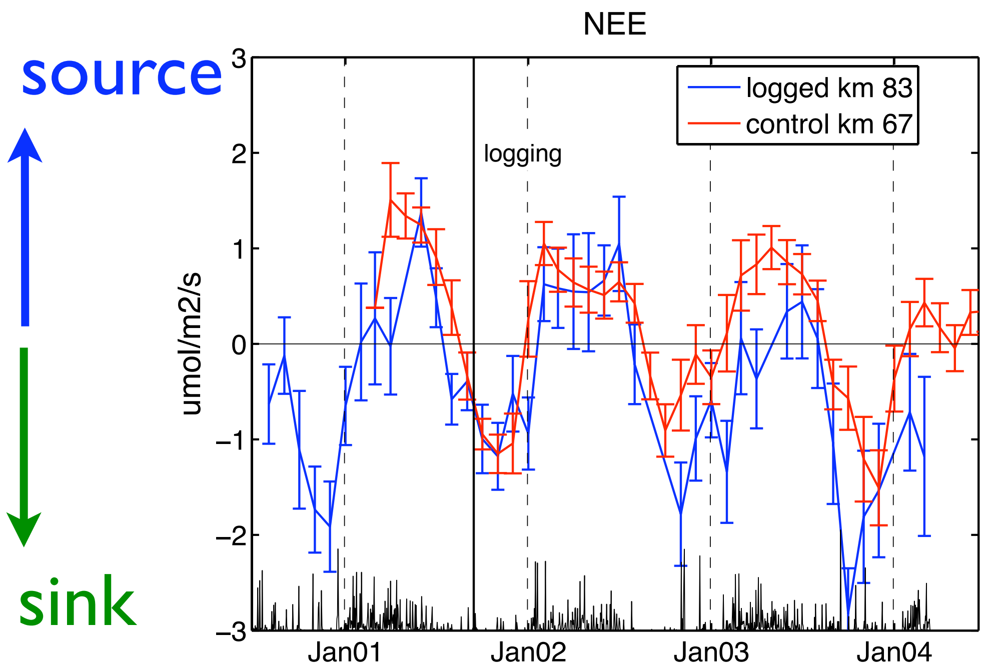


Logged Site NEE

- no obvious logging impact on NEE at 30 min or daily
- extracting logging signal requires long averaging times
- control site needed to account for seasonal and interannual variability



Logged vs. Control NEE and R

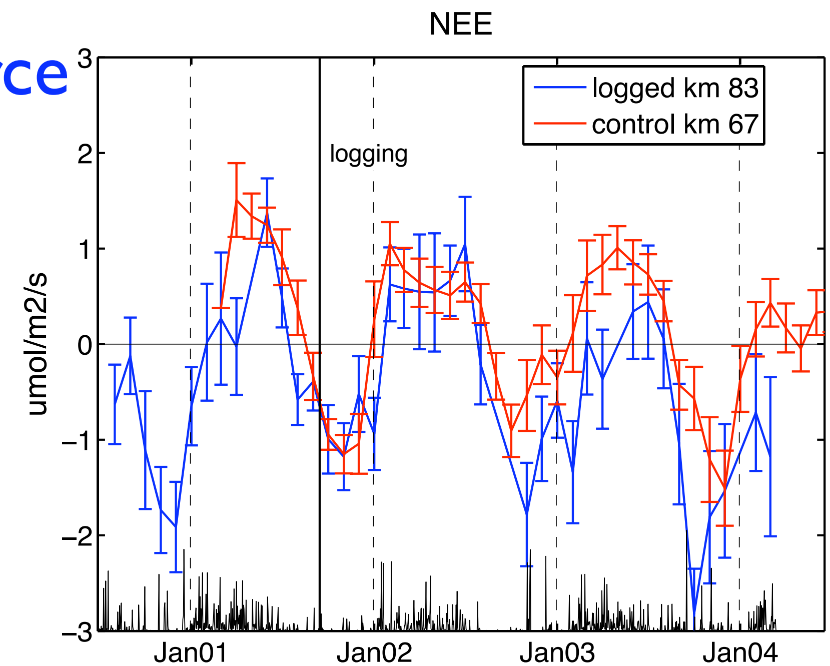


- relative NEE decrease at logged site over time

Logged vs. Control NEE and R

source

sink



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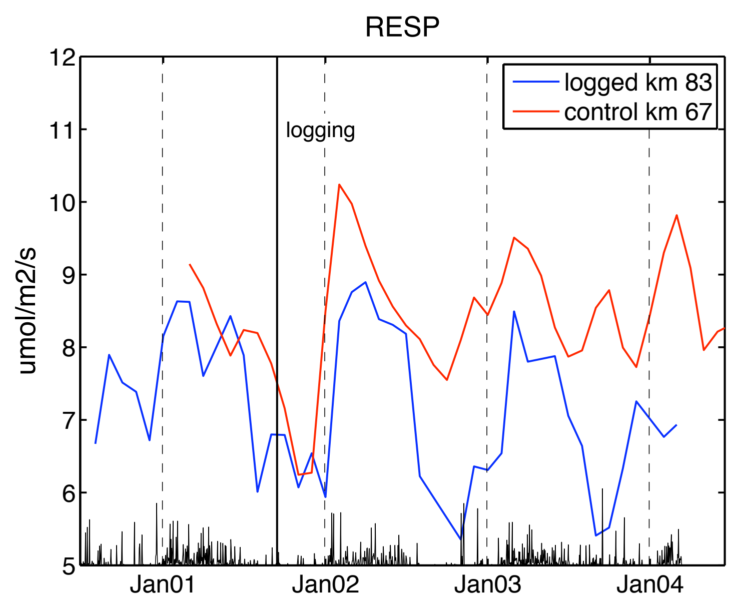
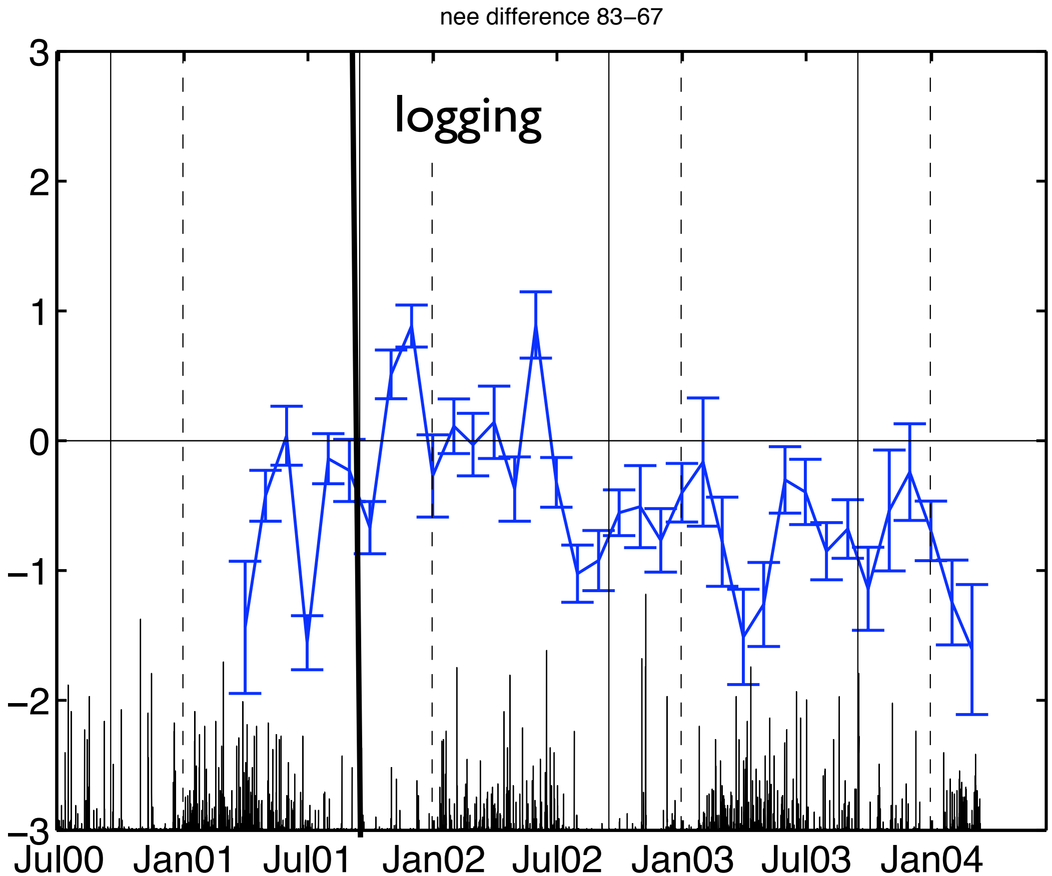


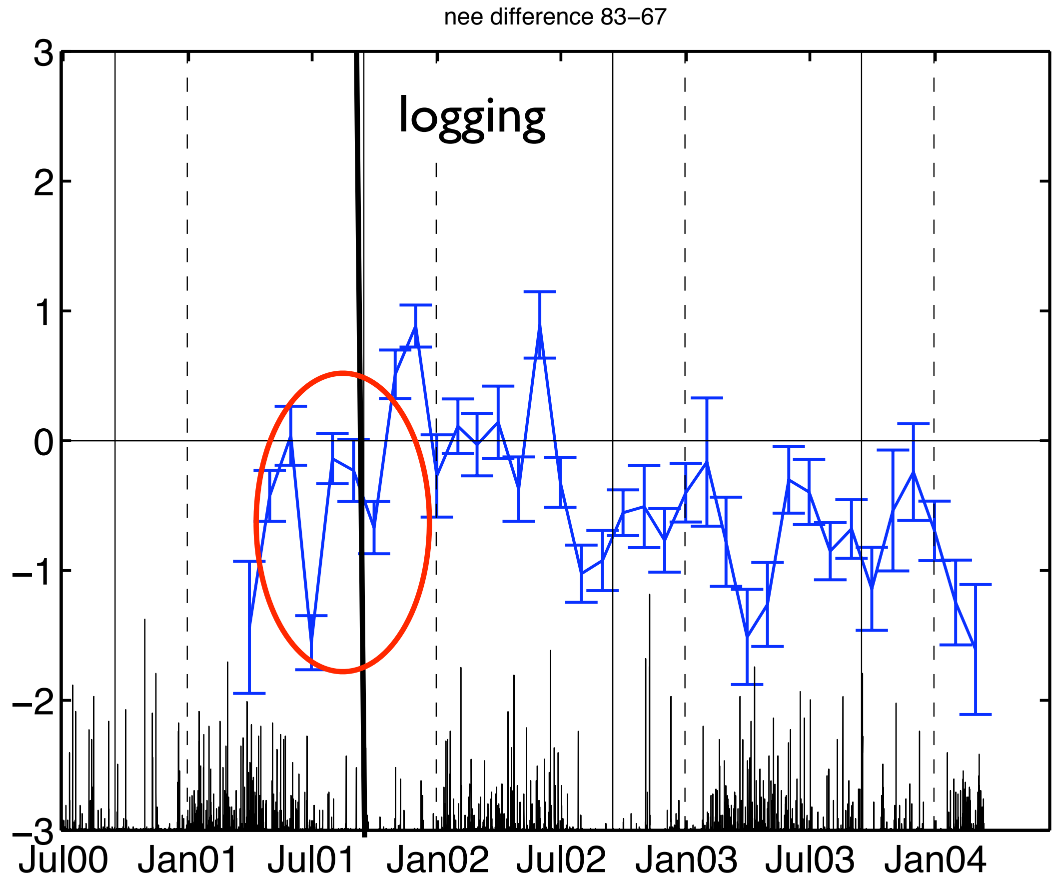
- long term trend in NEE controlled by respiration, analogous to seasonal control on R (Goulden et al. 2004)

Residual NEE (logged-control)



Residual NEE (logged-control)

- reprocessing pre-logging data at both sites



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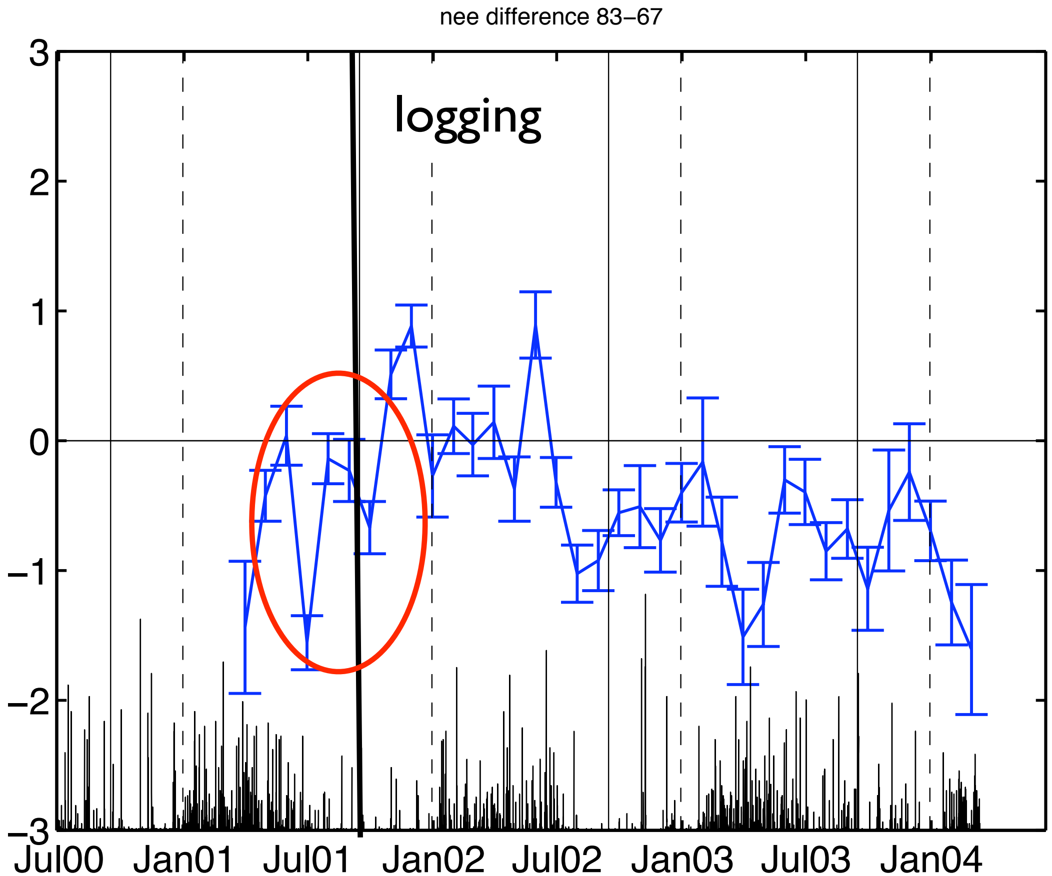
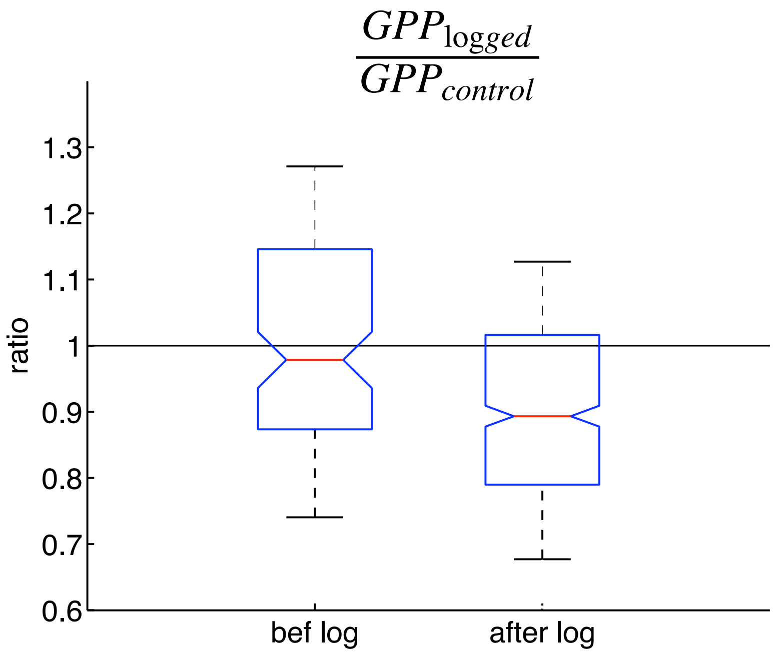


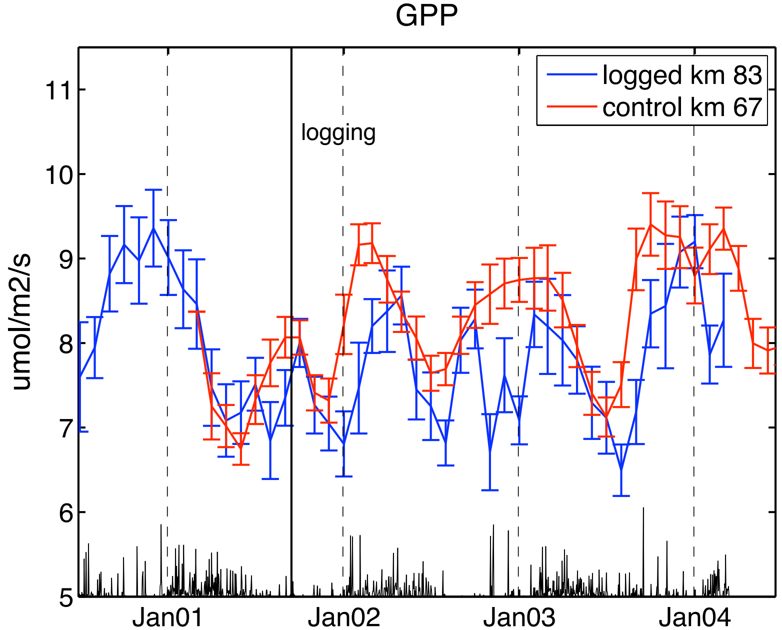
- reprocessing pre-logging data at both sites

depending on the pre-logging period, two possibilities:

1. logging gives a 1 year respiration pulse to atmosphere, then recovers to pre-logging balance
2. after logging, NEE quickly recovers and begins sinking carbon

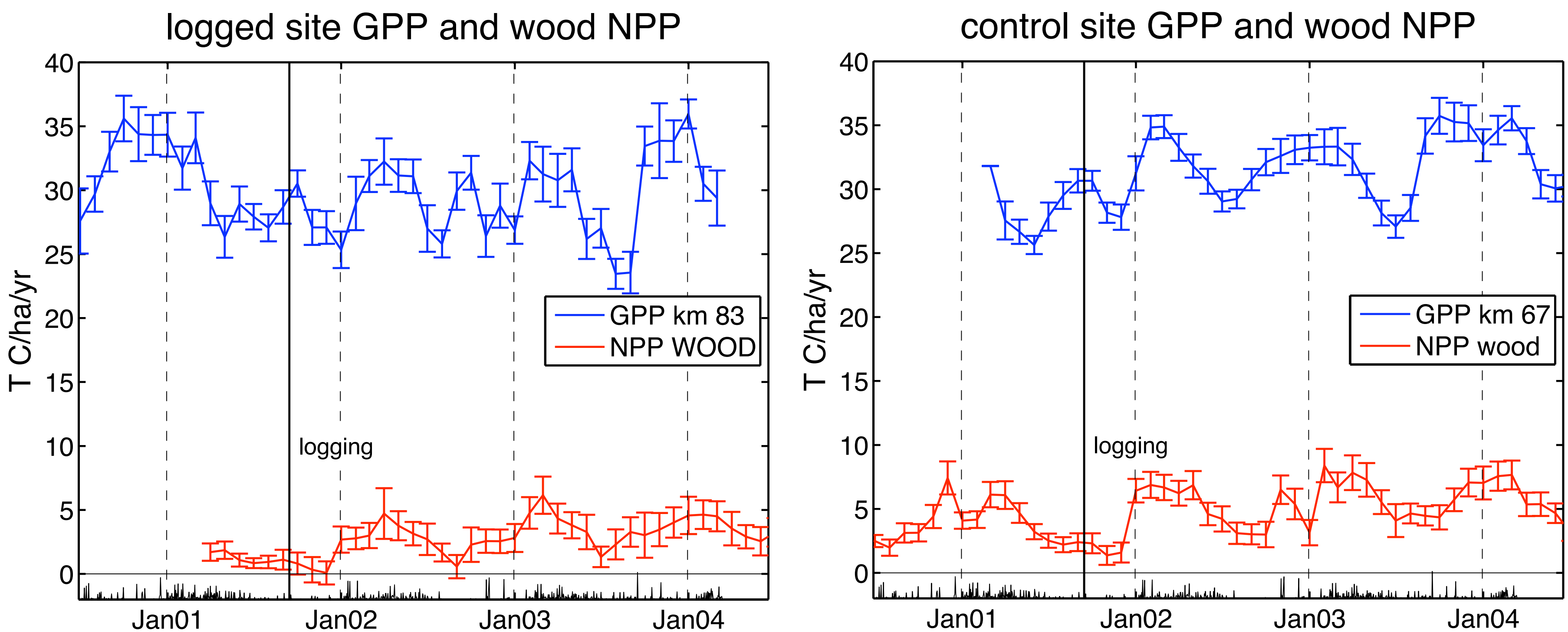
Logged vs. Control GPP





- after logging relatively lower GPP at logged site (~10%)
- GPP increased slightly at control site, and changed little at the logged site

Combining Biometry and Micromet



$$CUE_{WOOD} = \frac{NPP_{WOOD}}{GPP_{TOWER}}$$

wood carbon use efficiency

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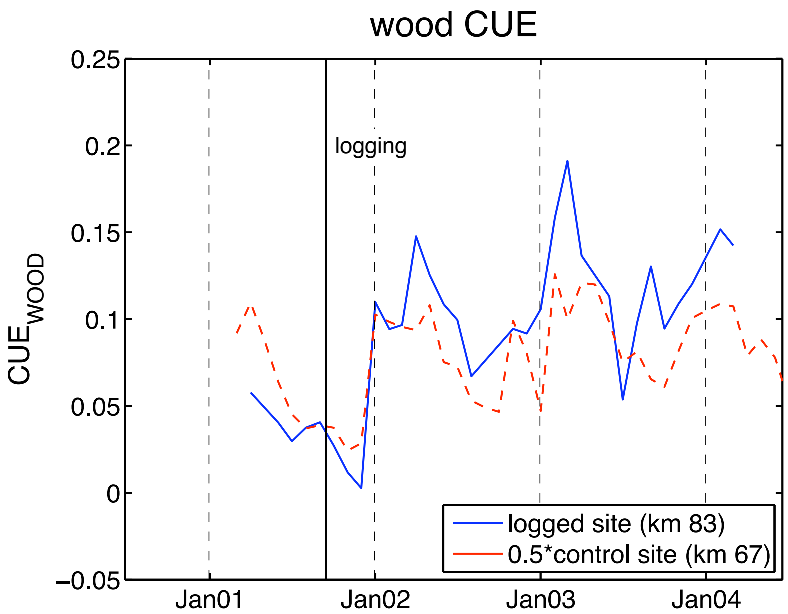

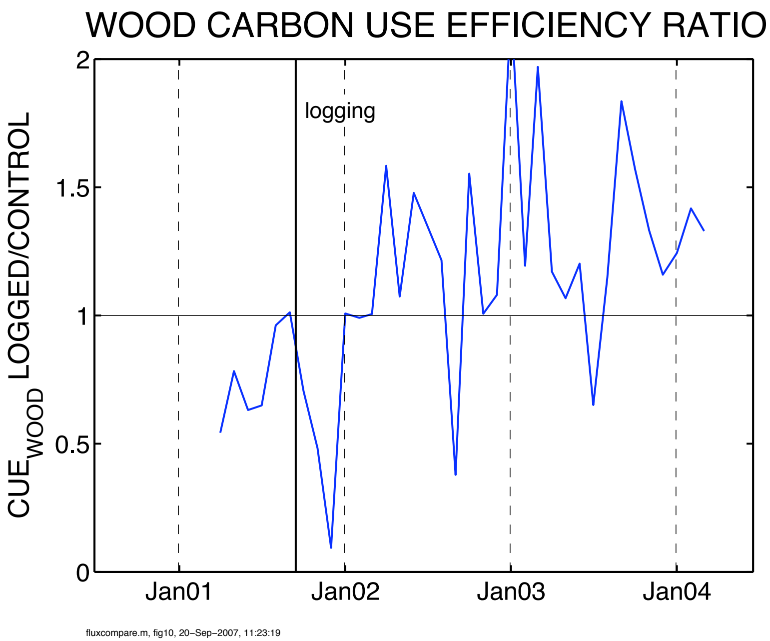

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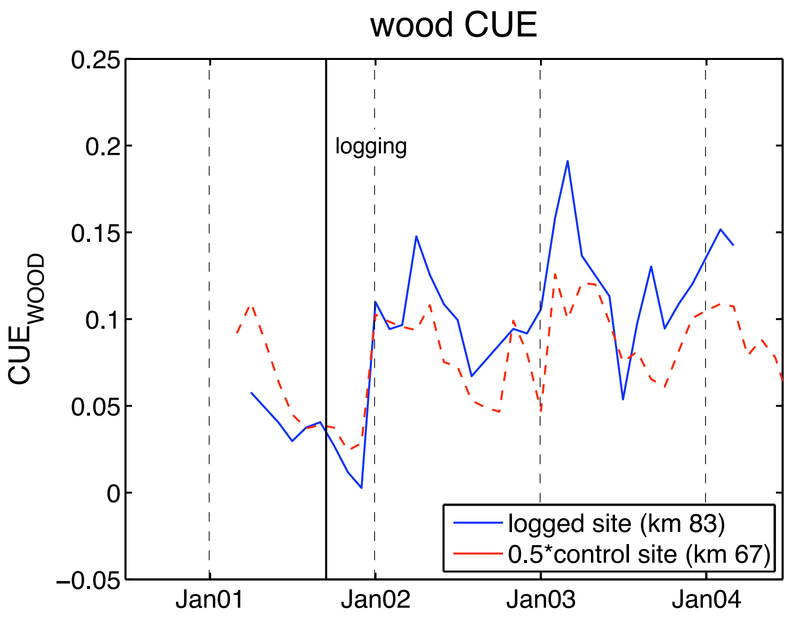

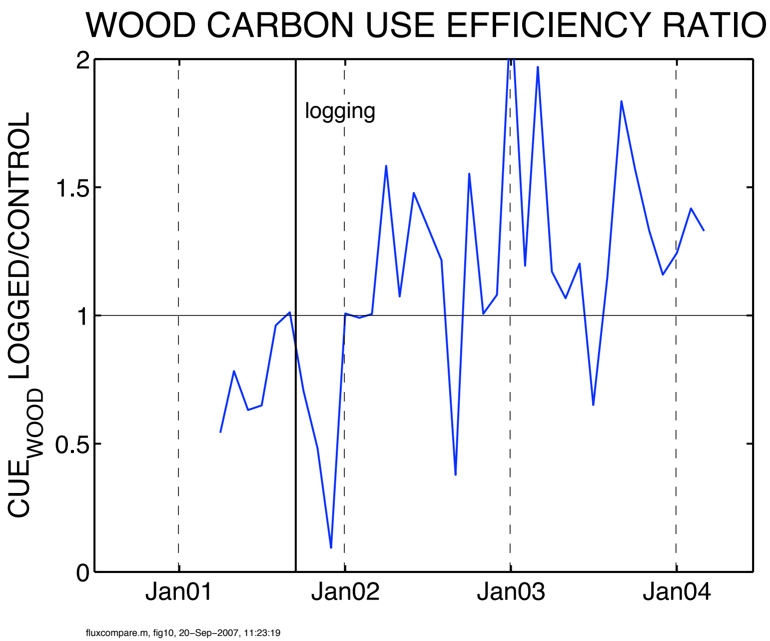

- CUE at logged site increased after logging.

Wood Carbon Use Efficiency

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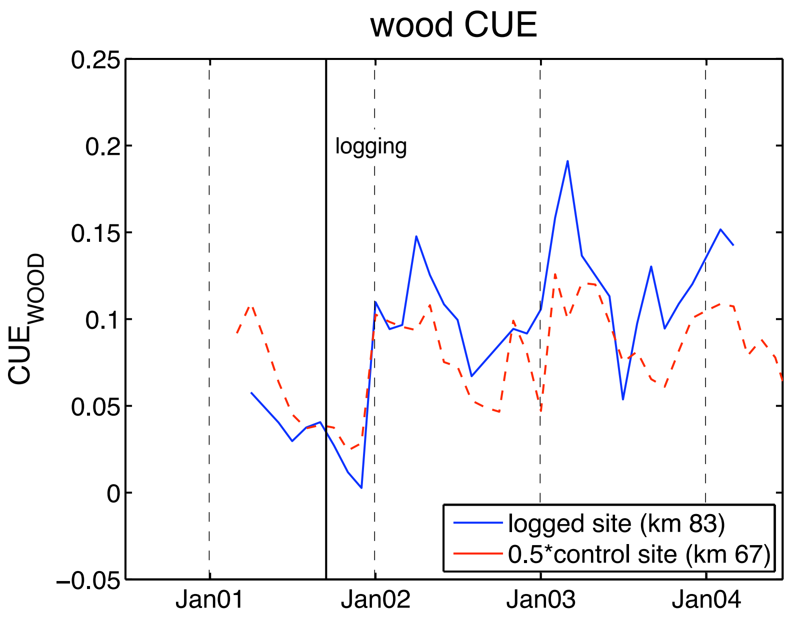

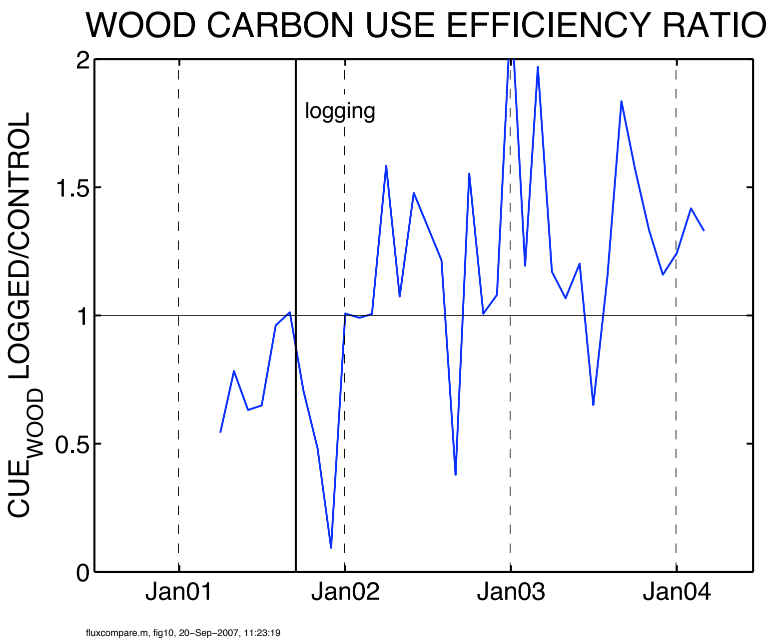

- CUE at logged site increased after logging.
- mechanism for regaining carbon

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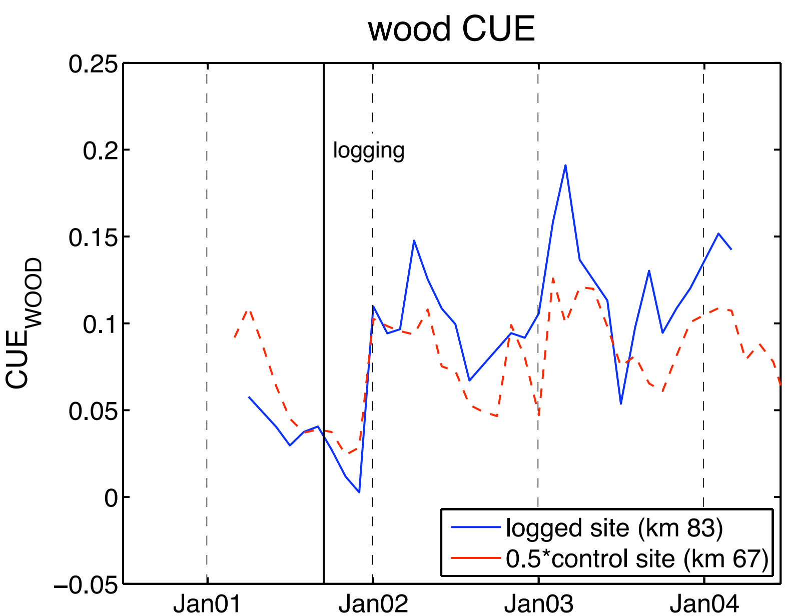

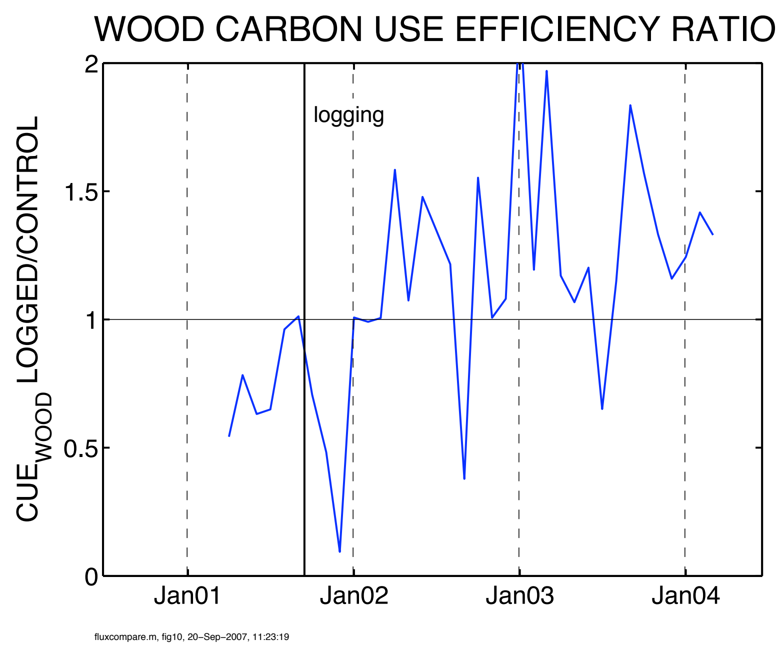

- CUE at logged site increased after logging.
- mechanism for regaining carbon
- parallels with results from yesterdays disturbance session

Conclusions

- *flux towers:* reduced impact selective logging did not have a major impact on GPP or R. Source or sink question not yet resolved.
- *dendrometers*: biggest winners were small trees and medium trees close to gaps
- *combined*: logged forest allocated carbon more efficiently

Collaborators:

km 83 logged site

SUNY Albany, UC Irvine, and USP
Scott Miller, Mike Goulden, Humberto da Rocha, Michela Figueira, Mary Menton, Chris Doughty, Albert da Sousa, Agosto Meia, Helber Freitas

km 67 control site

Harvard and UA
Steve Wofsy, Scott Saleska, Lucy Hutyra, Kathryn McKain

Thanks:
Dan Hodkinson Bethany Reed, Daniel Amarral, Marcy Litvak, Fernando Leão, Roberto Cardoso, Antonio Oviedo, Lisa Zweede and IBAMA, NASA and INPE.