Disturbance Effects on Ecosystem Carbon Balance in Tropical and Boreal Forests

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Why study the effect of disturbance?

- Disturbance can be a primary controller of ecosystem carbon balance, and humans have a major impact on the rate of disturbance.

- The active management of disturbance may provide a mechanism for increasing carbon sequestration.

- Good long term precision of eddy covariance makes it particularly well suited to comparative studies of the effect of disturbance.

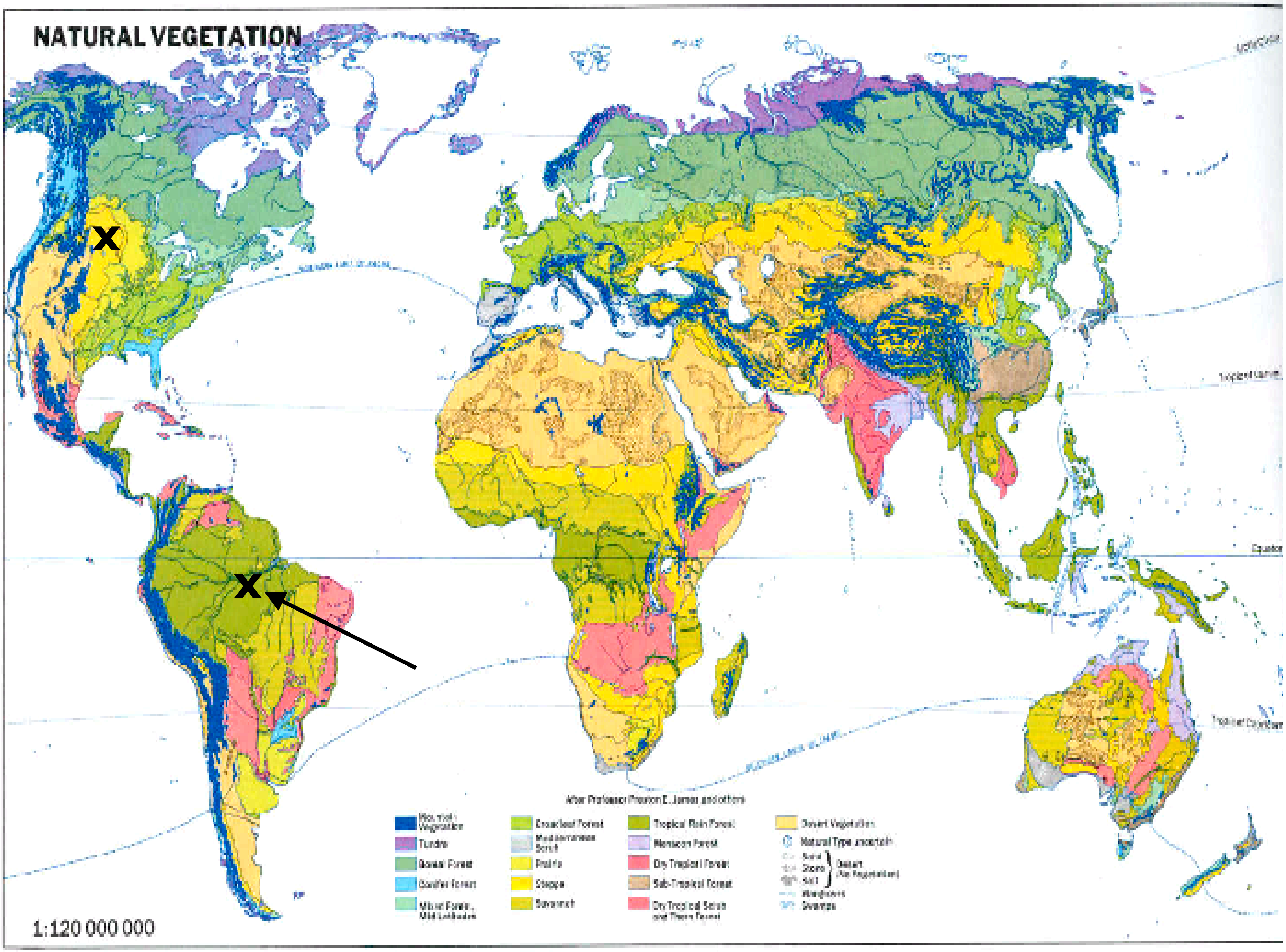
Where to study disturbance?

Distribution of Carbon Pools

	Area (10^{12} m^2)	Plant C (kg C m^{-2})	Soil C (kg C m^{-2})	Total C (10^{15} gC)
Tropical forest	**18.1**	**11.5**	**10.4**	**400**
Temperate forest	9.2	8	11.8	170
Boreal forest	**15**	**9.5**	**14.9**	**370**
Desert	18.2	0.3	5.6	110
Tundra	11	0.8	21.6	250
Wetland	2.9	2.7	68.6	210
Global				**~2000**

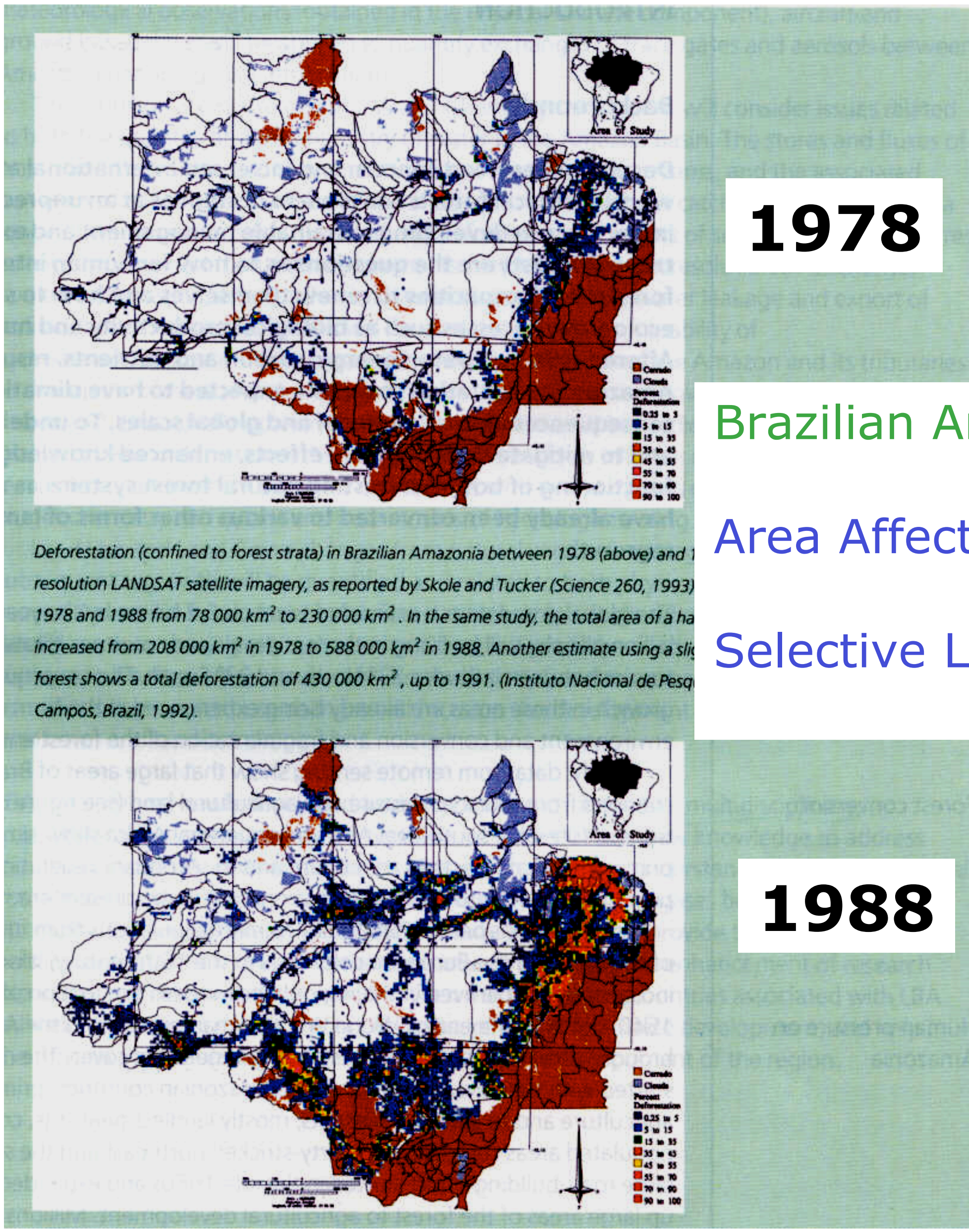
Tropical and boreal forests account for about 50% of terrestrial carbon, yet have been studied less.

Schlesinger 1997



NATURAL VEGETATION
X
X
Equator
After Professor Preston E. James and others
Mountain Vegetation
Tundra
Boreal Forest
Conifer Forest
Mixed Forest, Mid Latitudes
Broadleaf Forest
Mediterranean Scrub
Prairie
Steppe
Savannah
Tropical Rain Forest
Monsoon Forest
Dry Tropical Forest
Sub-Tropical Forest
Dry Tropical Scrub and Thorn Forest
Desert Vegetation
Natural Type uncertain
Sand
Stone
Salt
Desert (No Vegetation)
Mangroves
Swamps
1:120 000 000

Tropical forest



Brazilian Amazon: 6 million km^2

Area Affected by Deforestation: 10% (1988)

Selective Logging: 10,000-15,000 km^{2}yr^{-1}

Nepstad et al. 1999
Skole and Tucker 1997

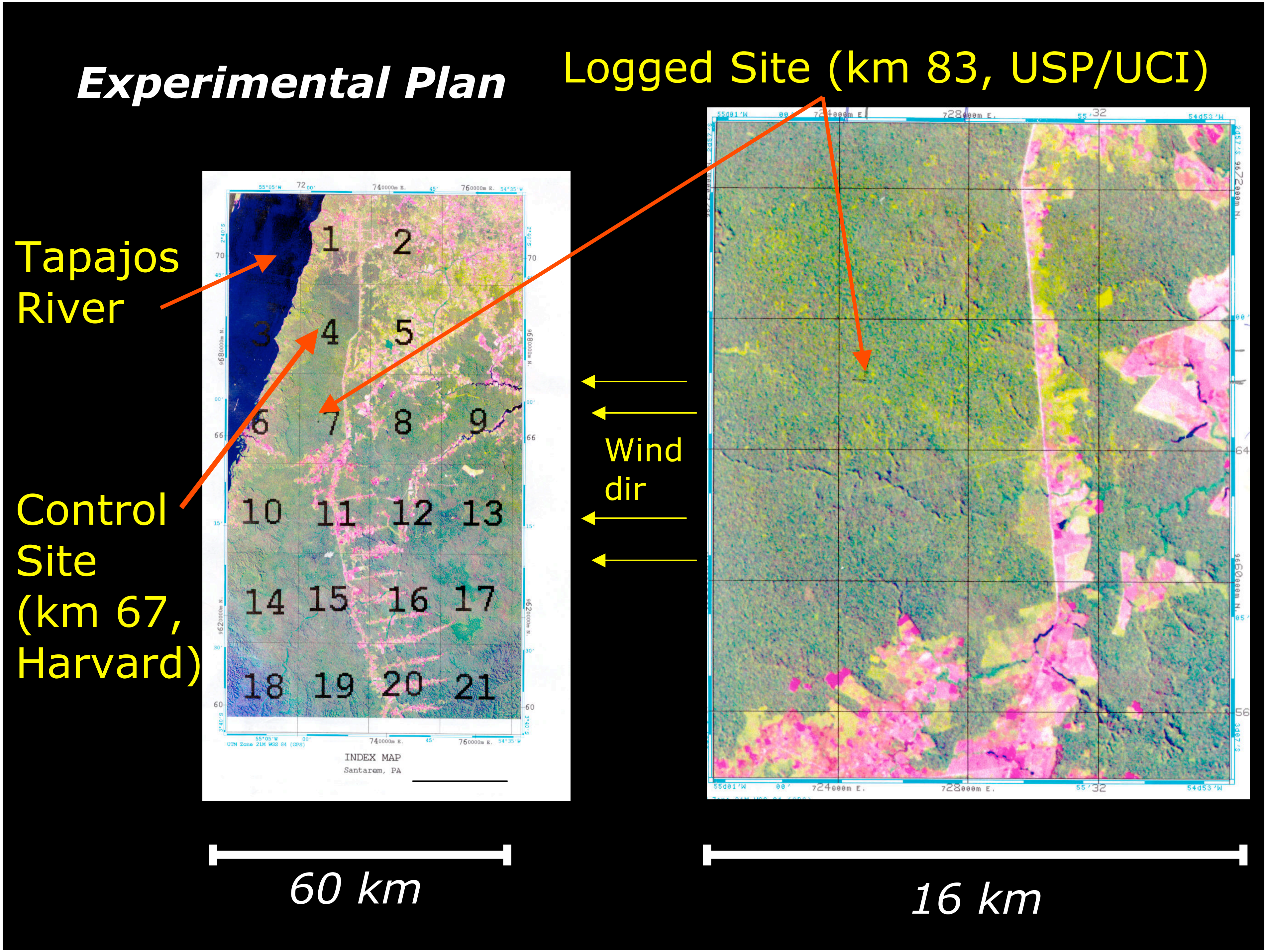
LBA

EXPERIMENTO DE GRANDE ESCALA DA BIOSFERA-ATMOSFERA NA AMAZÔNIA - LBA

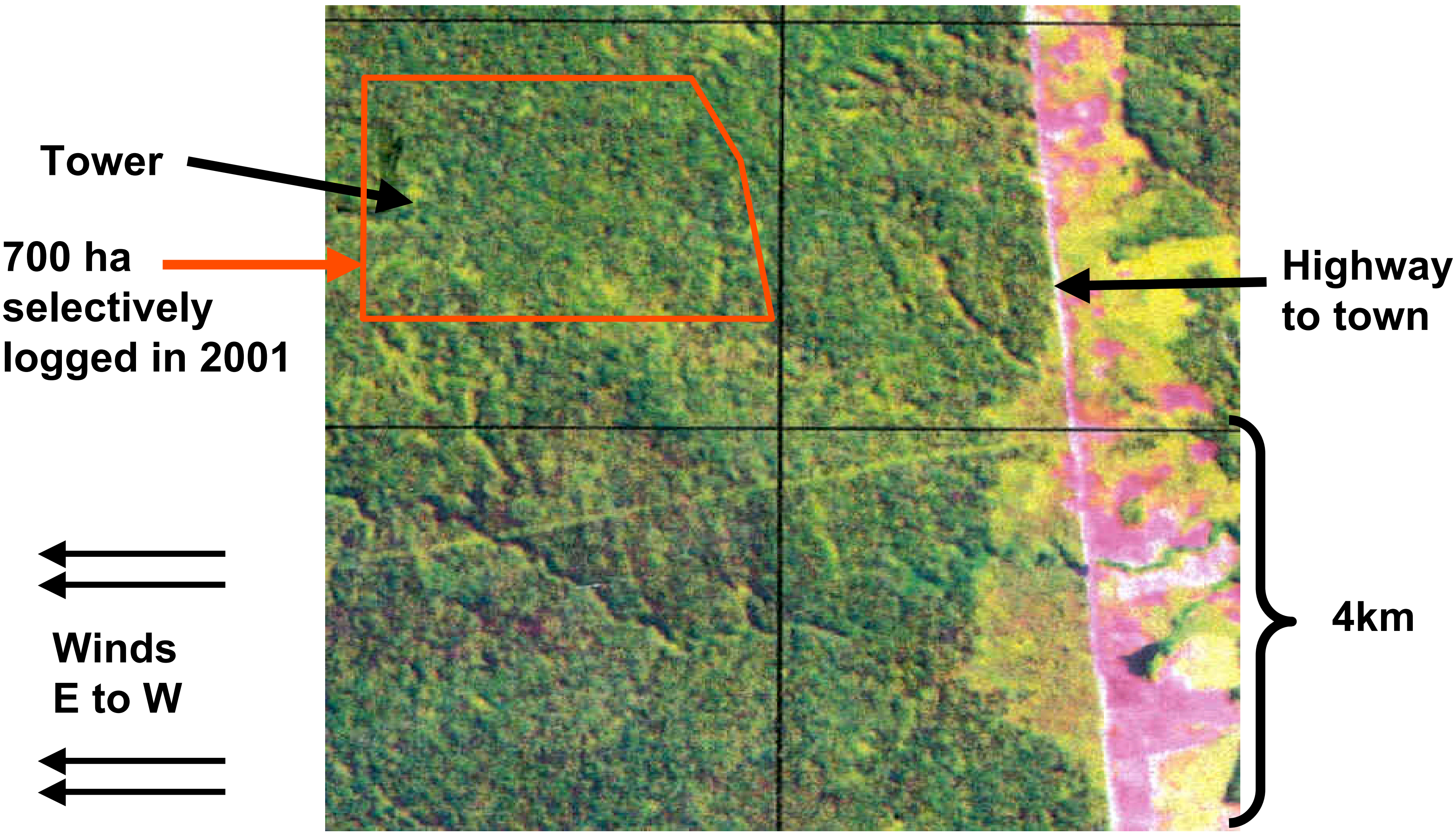
LBA-Ecology Sites

Santarem, Para

LBA = Large Scale Biosphere-Atmosphere Experiment in Amazonia


Experimental Plan
Logged Site (km 83, USP/UCI)
Tapajos River
Control Site (km 67, Harvard)
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21
INDEX MAP
Santarem, PA
Wind dir
60 km
16 km

Logging Detail



Tower Measurements

METEOROLOGY

PAR (up/down)
Radiation (short and long wave, up and down)
Rain

PROFILES

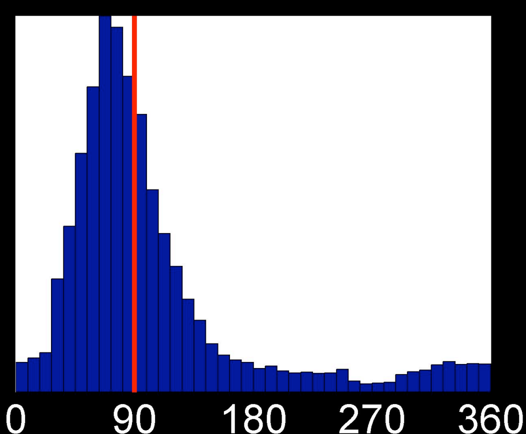
Wind (6 levels cups and 2D Sonics)
Temperature (6 levels)
CO_2/H_2O (12 levels)

FLUXES (64 meters)

Momentum/Heat	sonic anemometer
CO_2/H_2O	Infrared Gas Anayzer

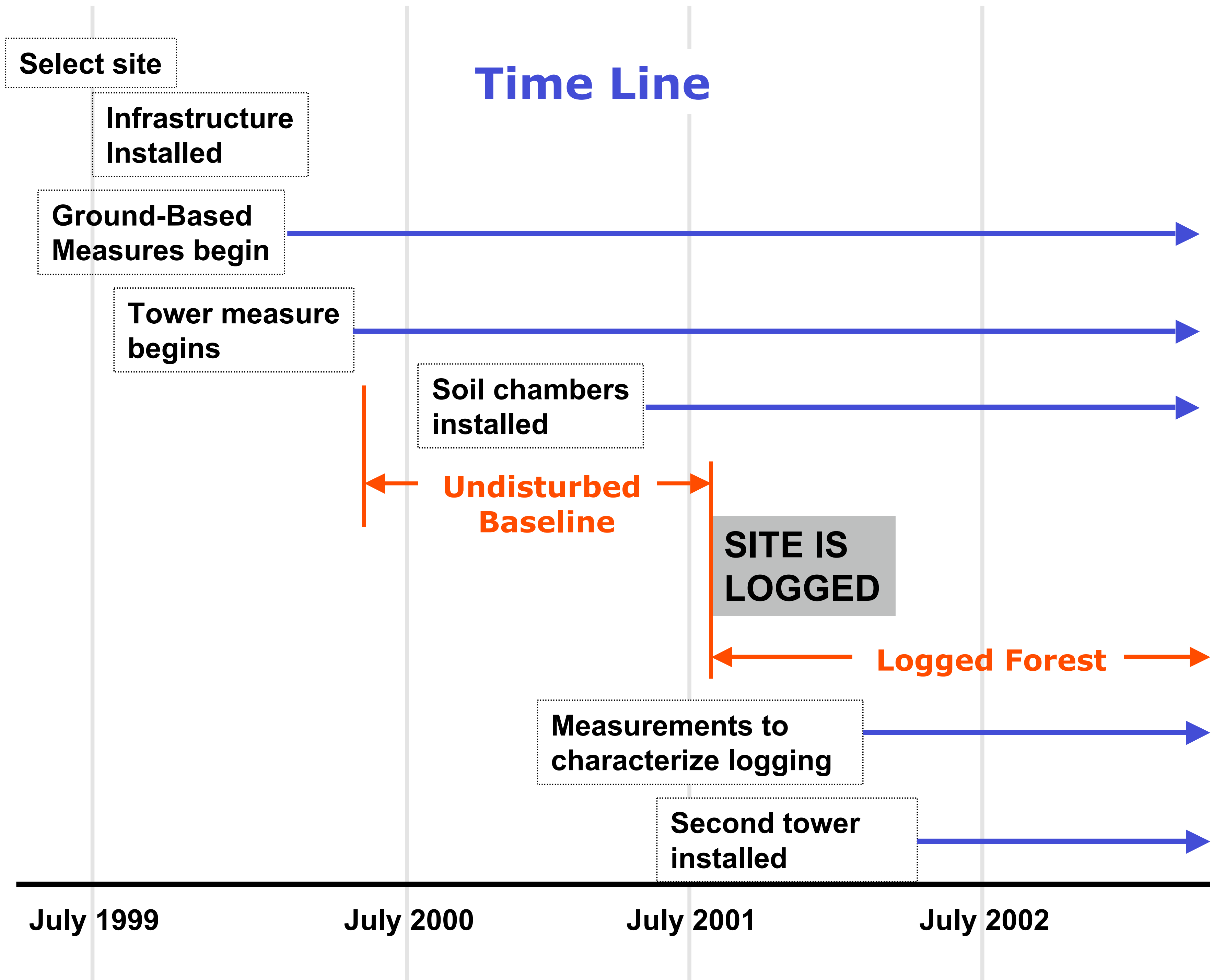
Air Inlet for **Closed Path IRGA**

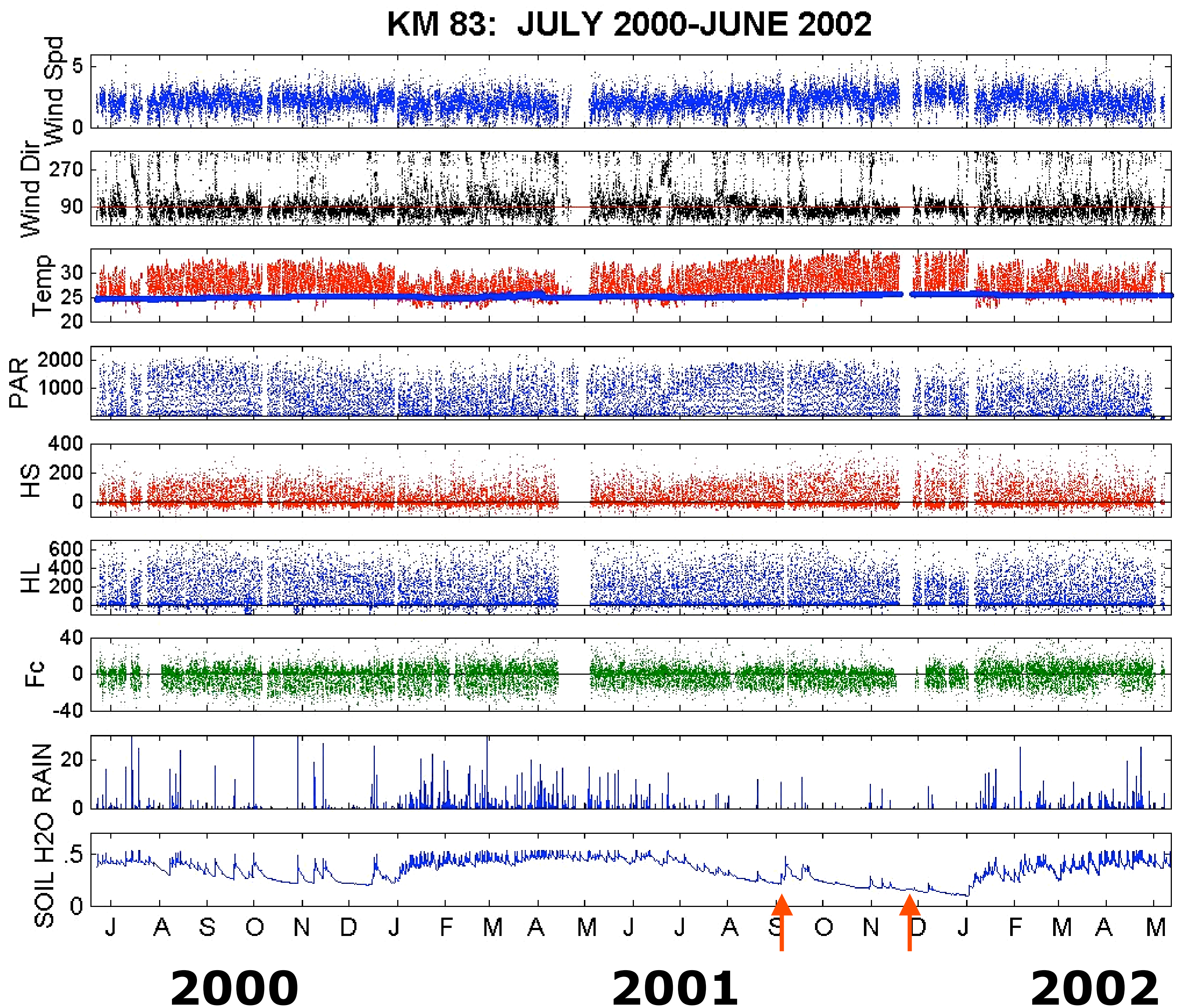
Open Path IRGA



Sonic anemometer looks **East**,
the most common wind direction

Elevator to raise and lower eddy flux sensors.


Time Line
Select site
Infrastructure Installed
Ground-Based Measures begin
Tower measure begins
Soil chambers installed
Undisturbed Baseline
SITE IS LOGGED
Logged Forest
Measurements to characterize logging
Second tower installed
July 1999
July 2000
July 2001
July 2002


KM 83: JULY 2000-JUNE 2002
Wind Spd
Wind Dir
Temp
PAR
HS
HL
Fc
RAIN
SOIL H2O
J A S O N D J F M A M J J A S O N D J F M A M
2000
2001
2002

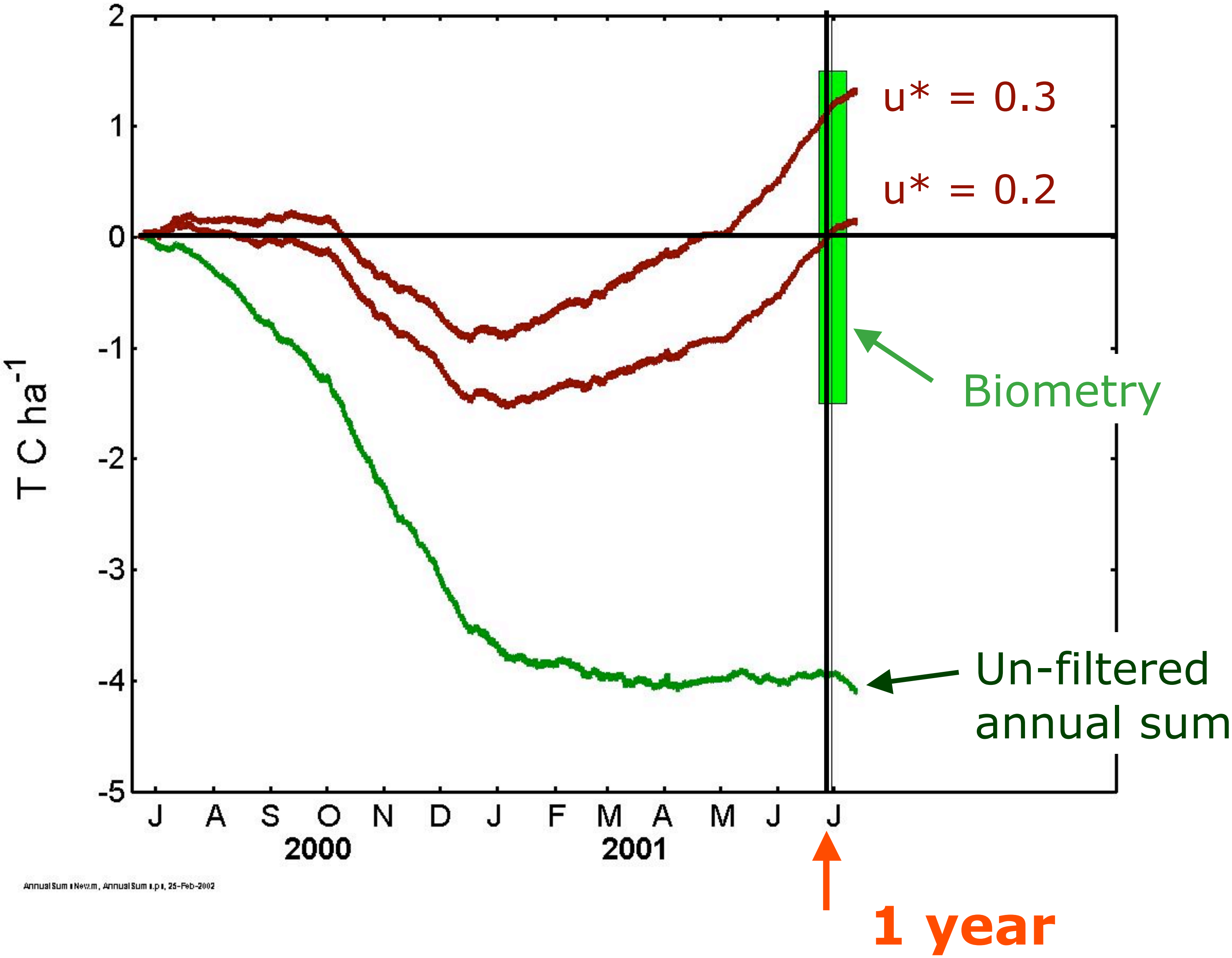
Carbon Balance - Results from undisturbed baseline period

- From allometry, forest was **not gaining or losing** large amounts of carbon prior to logging
(0 +/- 1.5 T C ha^{-1} yr^{-1})

- Tower-based annual sum using a **u* filter of 0.2 ms^{-1}** was 0.1 T C ha^{-1} yr^{-1}, in agreement with the allometry.

- Annual CO2 exchange in tropical forest is **extremely sensitive to the treatment of nocturnal fluxes** (-5.2 to +1.0 T C ha^{-1} yr^{-1}).

Carbon Balance - Results from undisturbed baseline period



Seasonality - Results from undisturbed baseline period

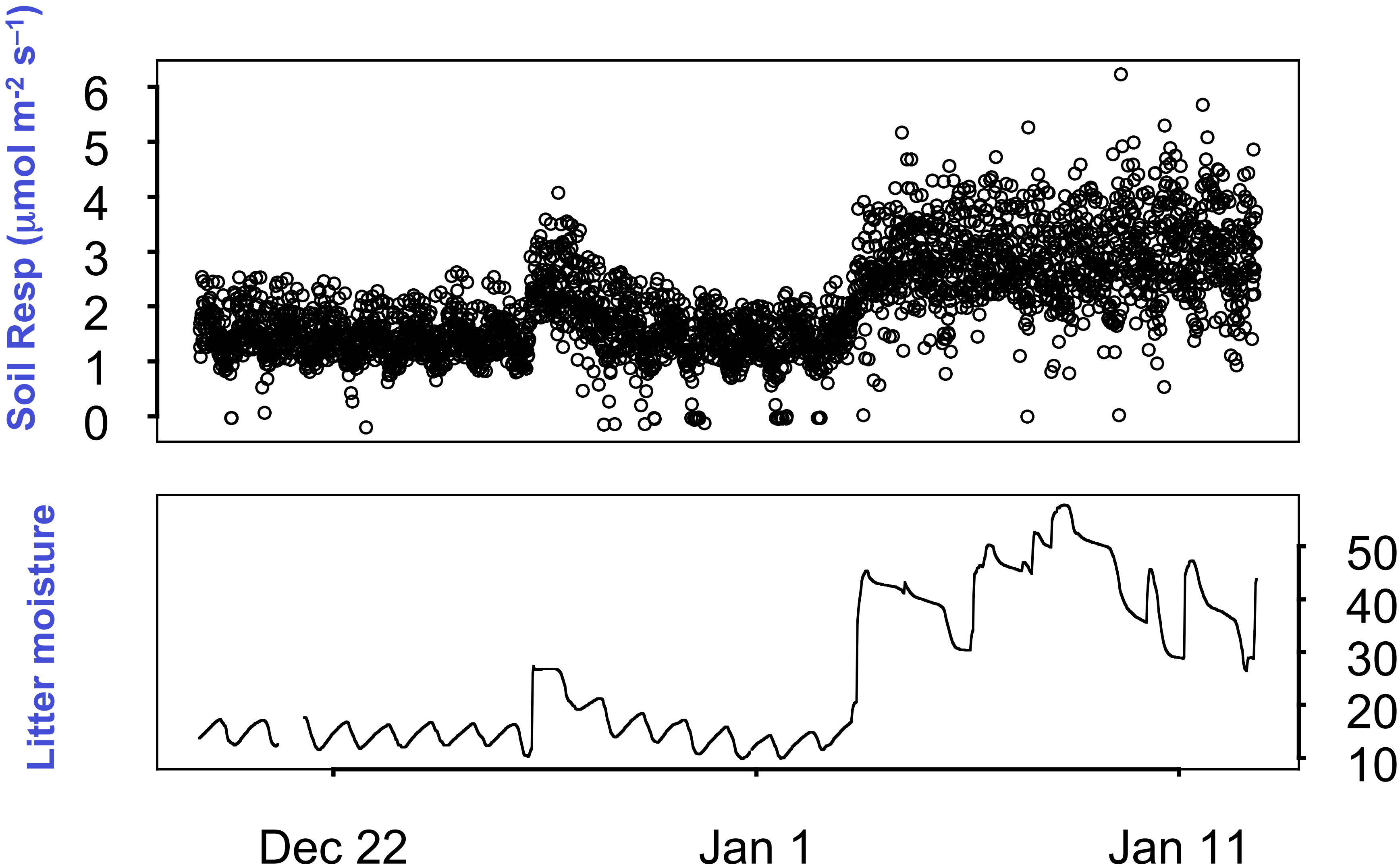
- Canopy photosynthesis and evapotranspiration **do not decline** in the dry season. Hydraulic lift redistributes water in the soil column, and may help trees avoid drought stress

- Soil respiration is **controlled by moisture**, with a rapid increase following litter rehydration.

- **Seasonal cycle** of net CO2 exchange was the **opposite** of what we expected. Daily carbon gain is **greatest in the dry season**; forest lost carbon throughout the wet season.


4 2 '01

Respiration is correlated with litter and soil moisture



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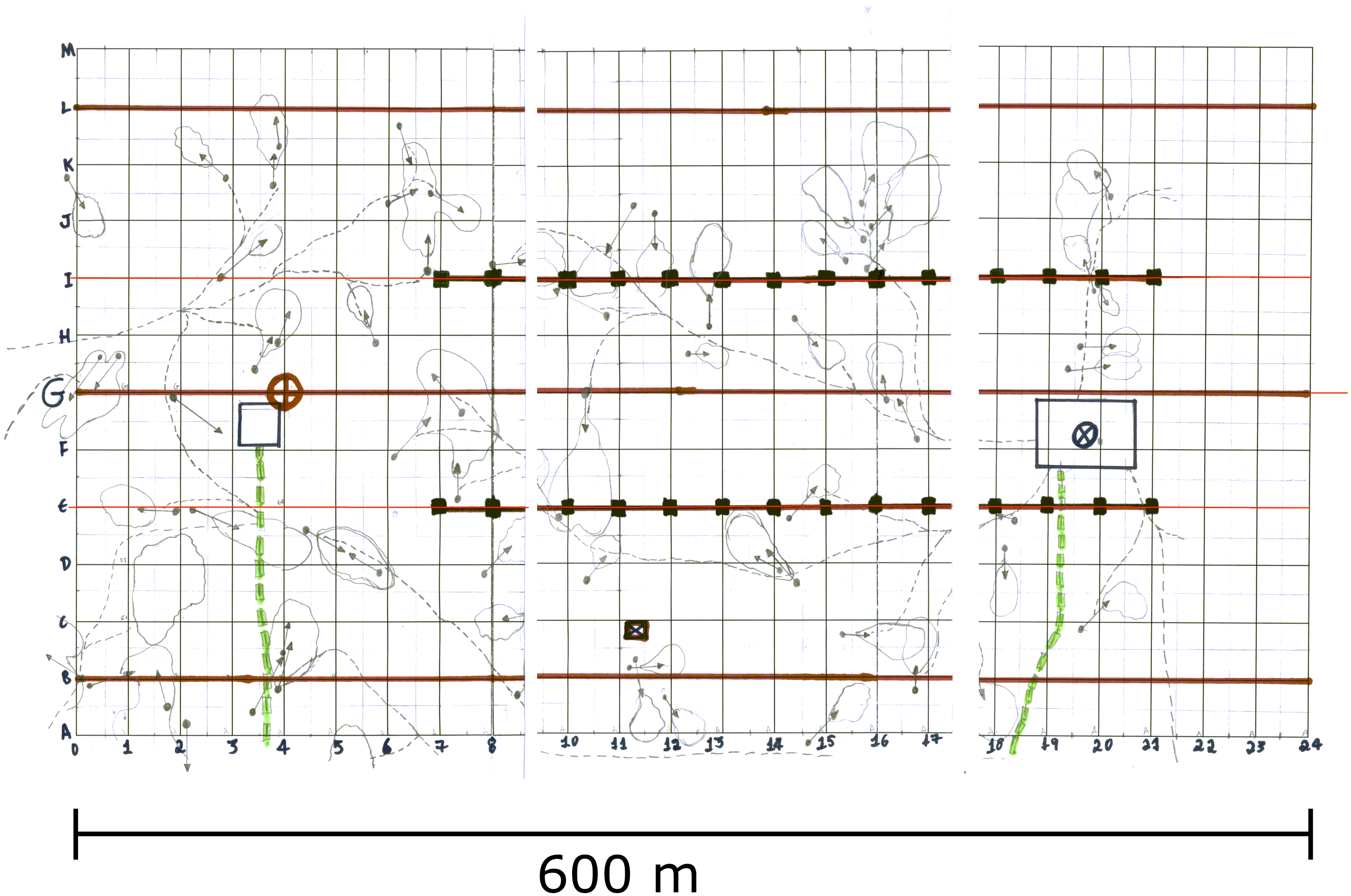
•2-3 trees ha^{-1} removed
• 5 T C ha^{-1} wood removed


•15 T C ha^{-1} slash introduced

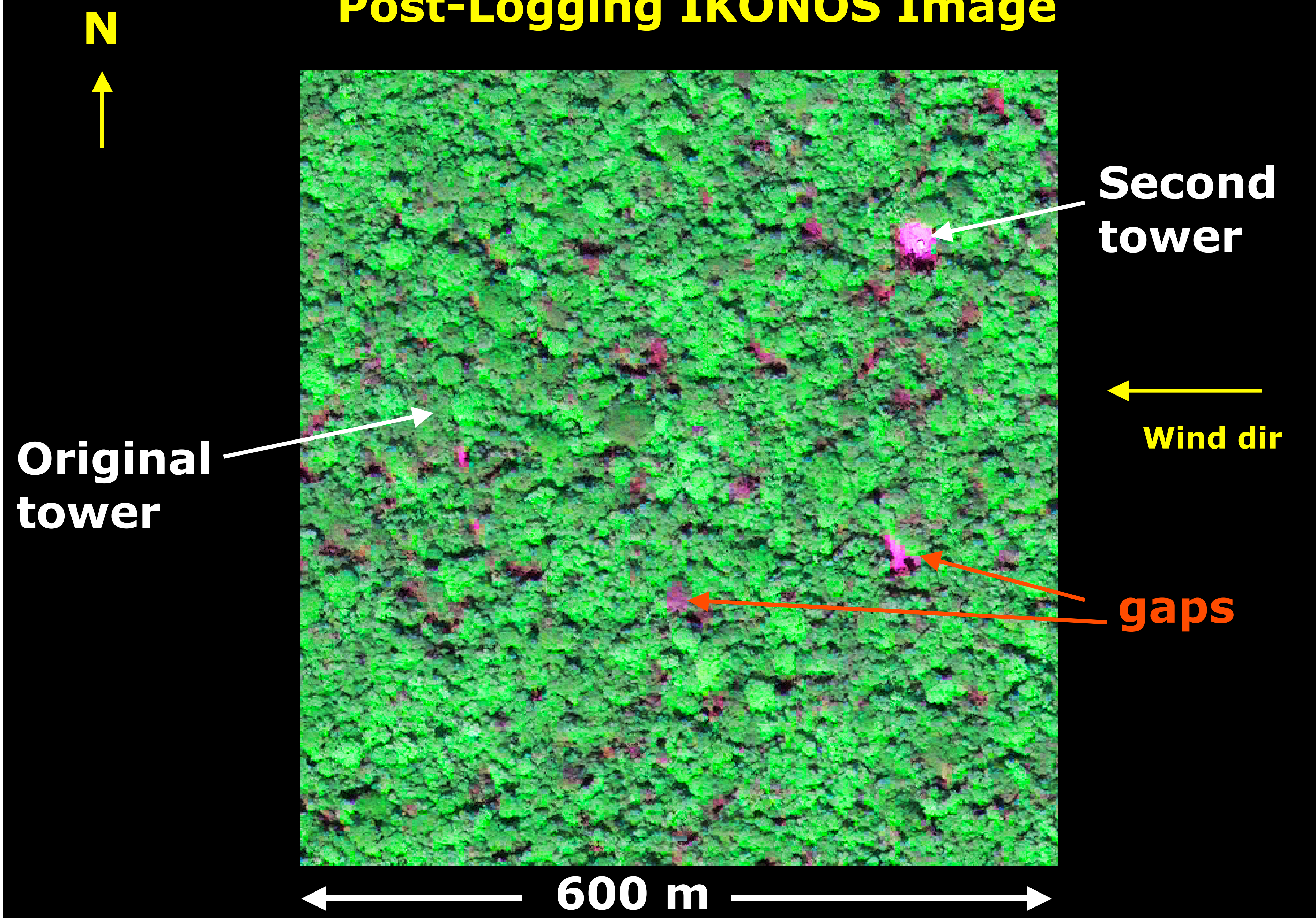
8% impacted by roads/skid trails

GAP MAP

- **10-15% gaps created**

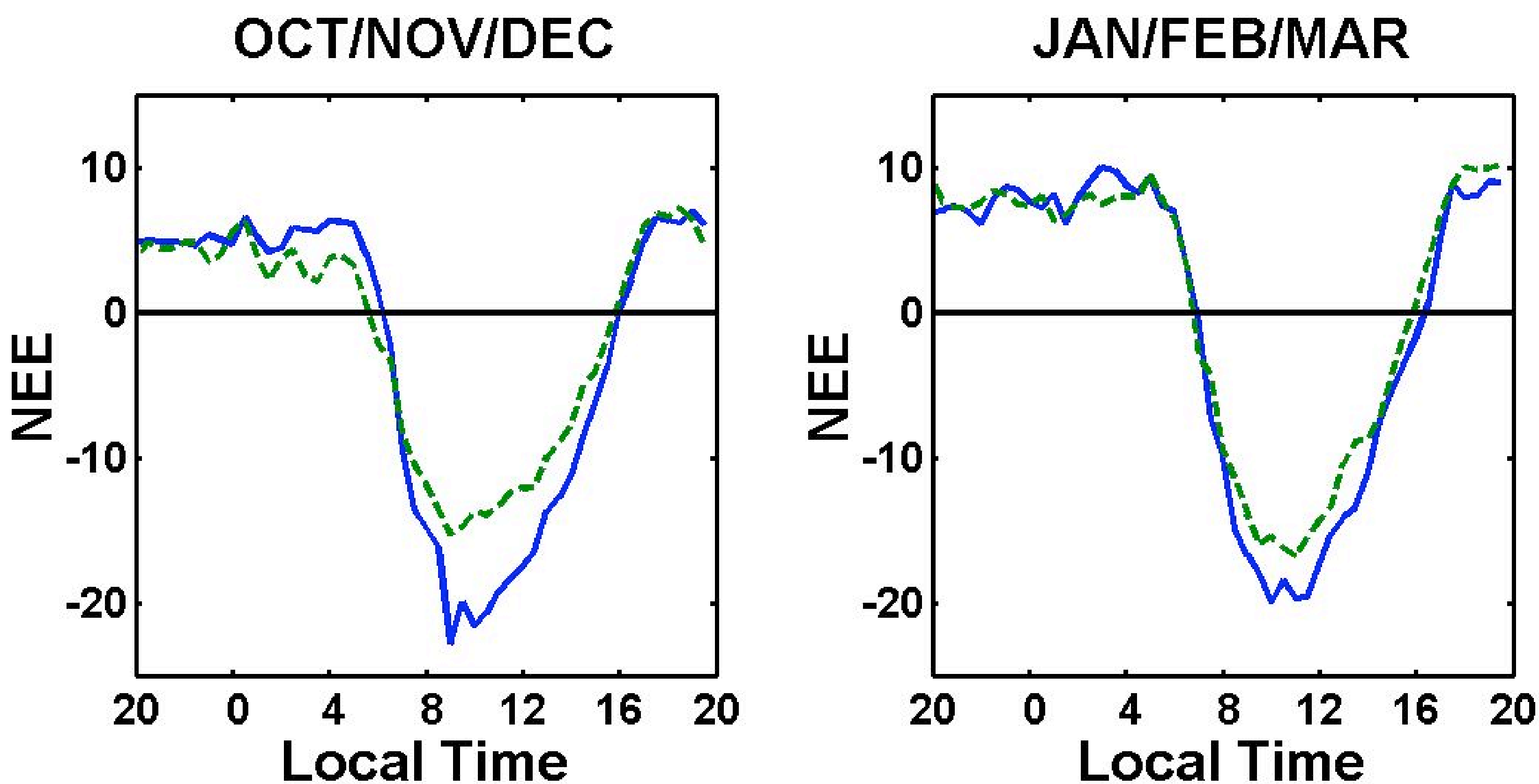


Post-Logging IKONOS Image



Average Daily Cycles of NEE

BLUE: PRE-LOGGING
GREEN: POST-LOGGING



Dry Season **Wet Season**

Cumulative NEE

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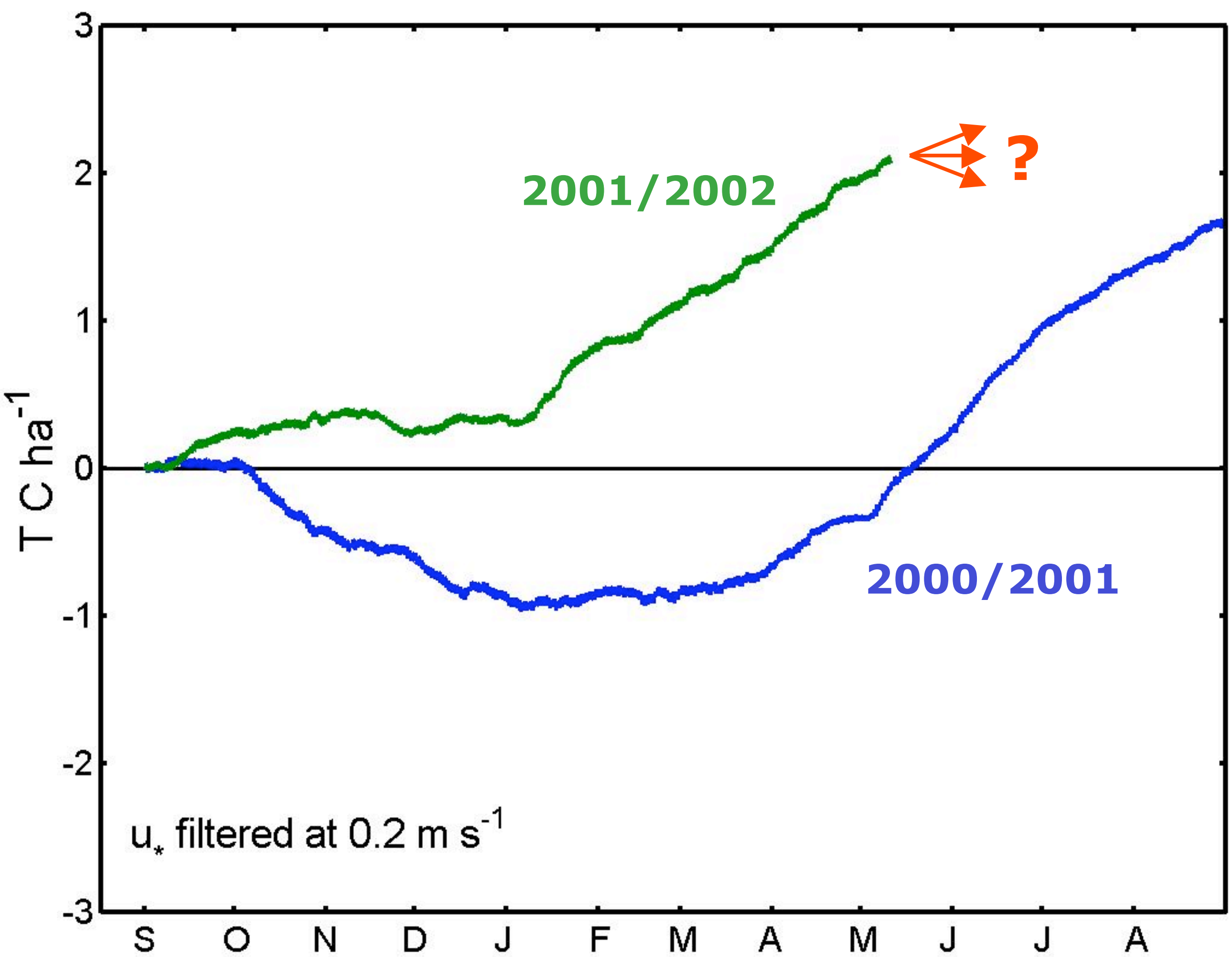

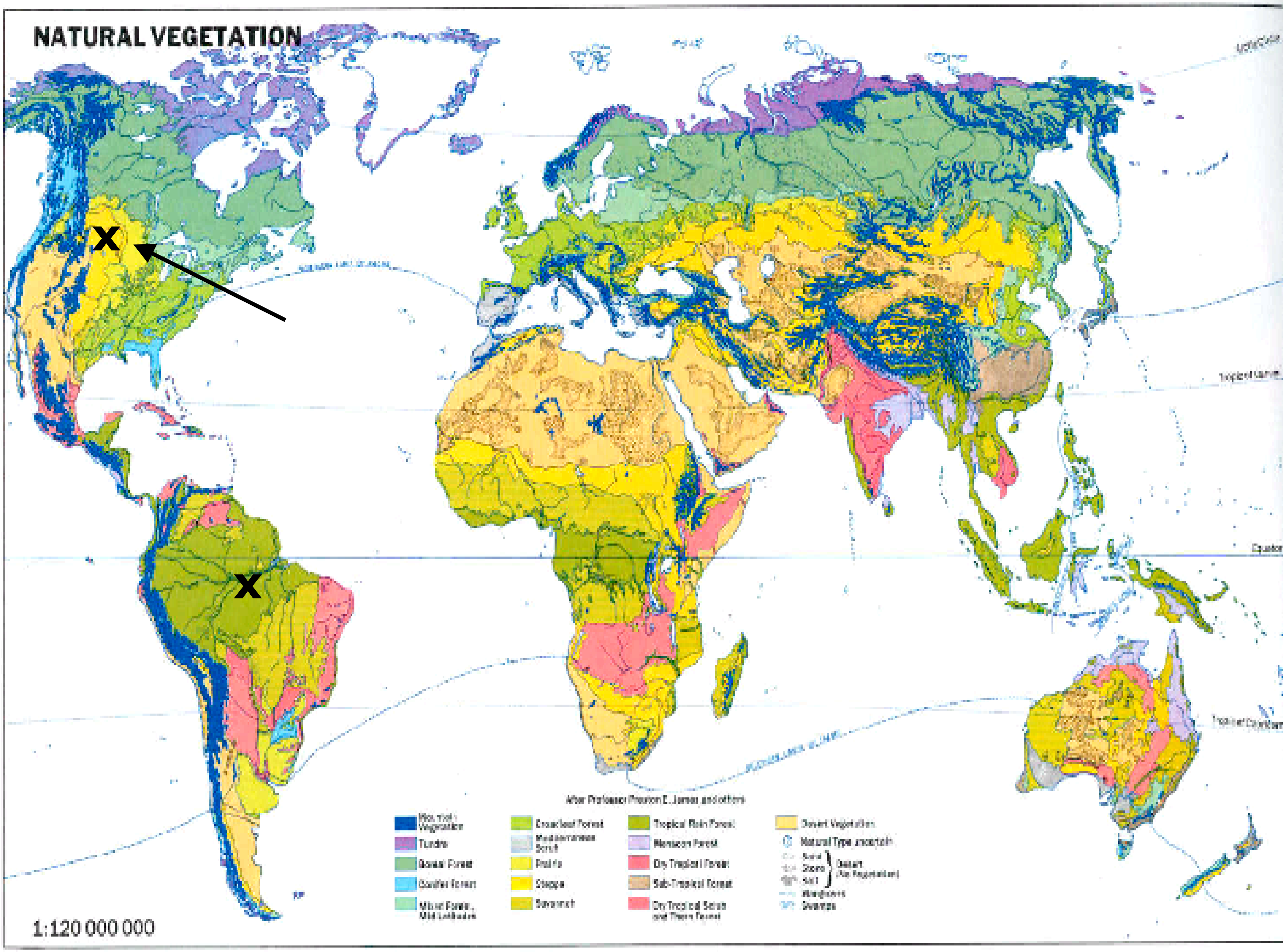
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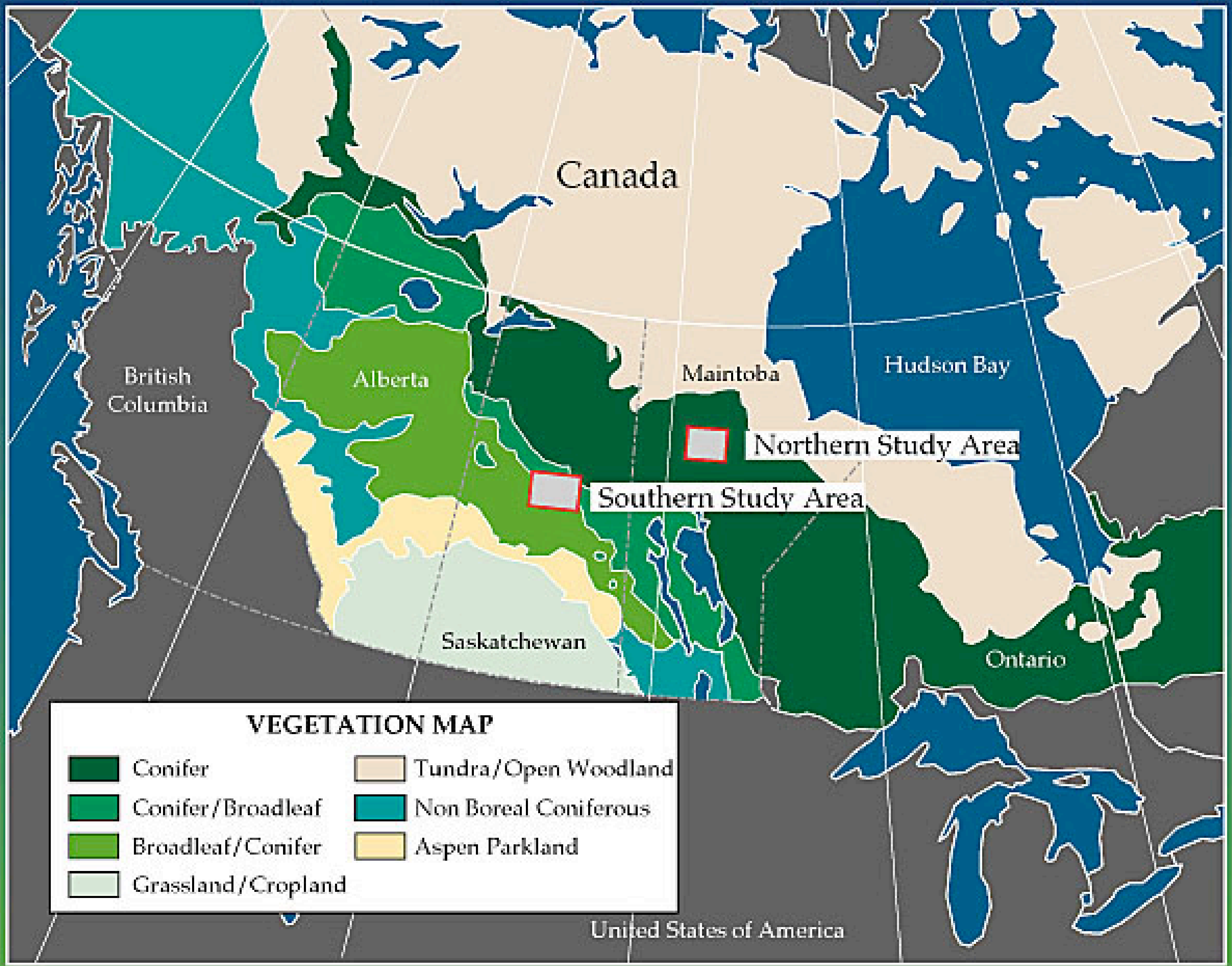

Canada
British Columbia
Alberta
Maintoba
Hudson Bay
Northern Study Area
Southern Study Area
Saskatchewan
Ontario
United States of America
VEGETATION MAP
Conifer
Conifer/Broadleaf
Broadleaf/Conifer
Grassland/Cropland
Tundra/Open Woodland
Non Boreal Coniferous
Aspen Parkland

LS48.032

Fire plays an integral role in boreal forest ecosystems

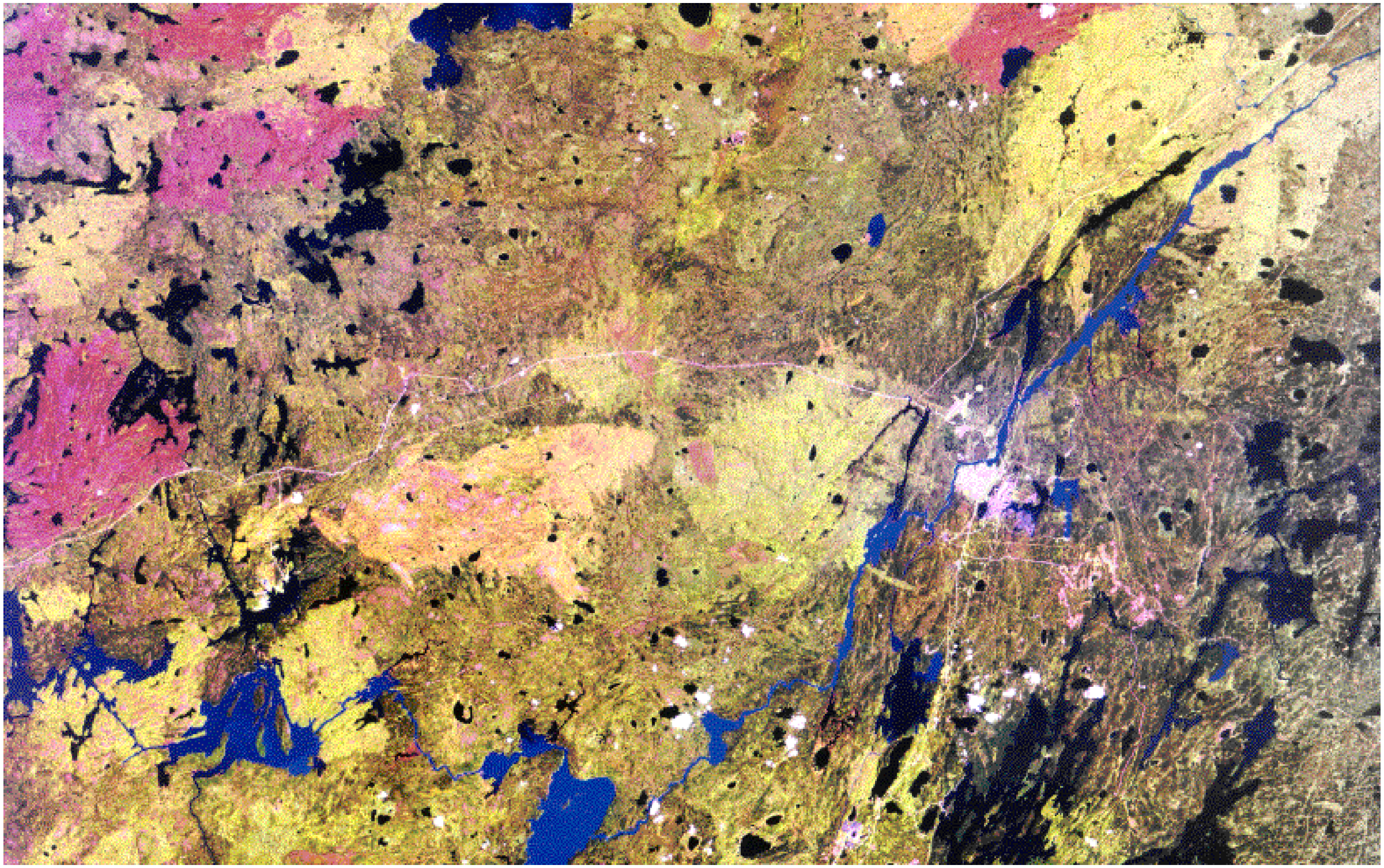
Lightning-induced fire in a stand of black spruce between BOREAS NSA and Churchill in 1994

Dominant disturbance in many regions

Fire returns every 50 to 200 years

Maintains boreal landscape as spatial mosaic of forest patches in different successional stages

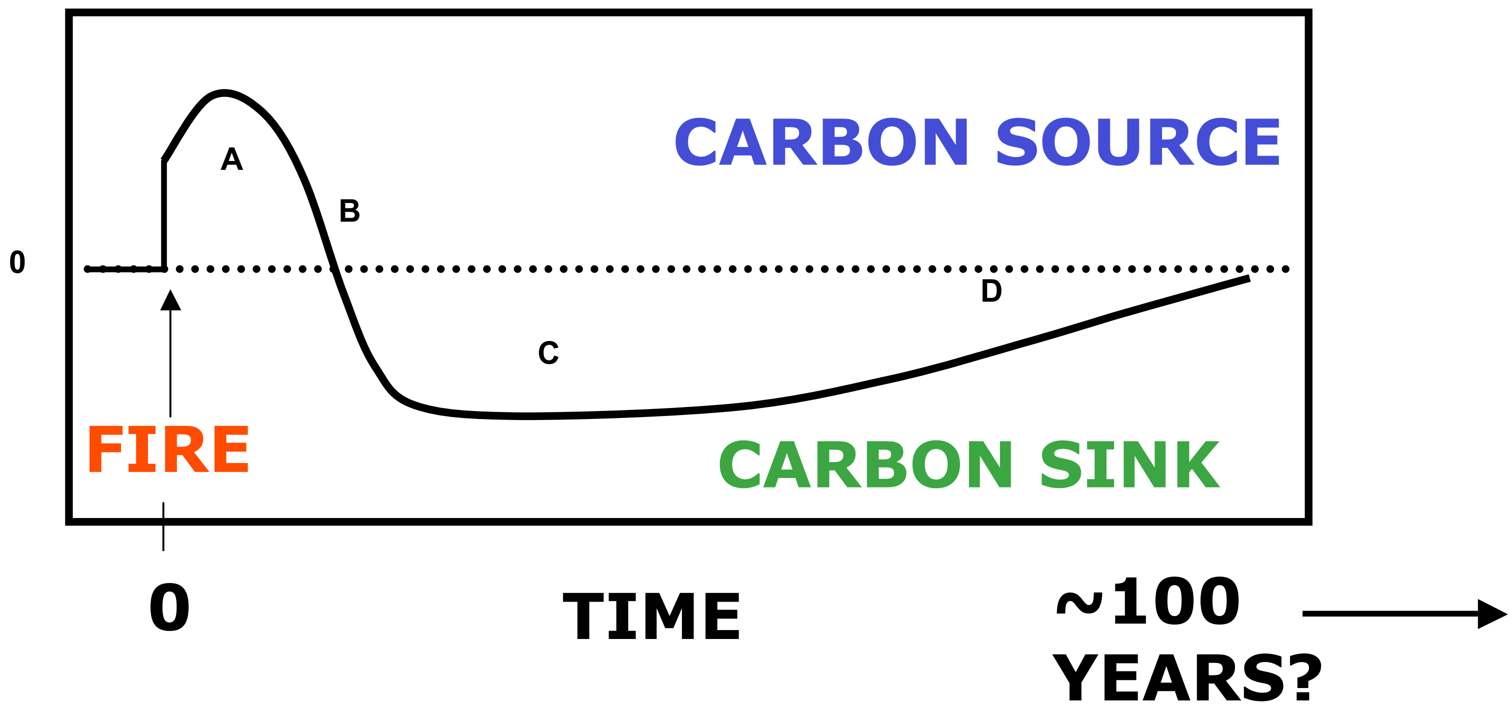
BOREAS-Northern Study Area Fire history- TM July 25, 1990



Scale 50 km

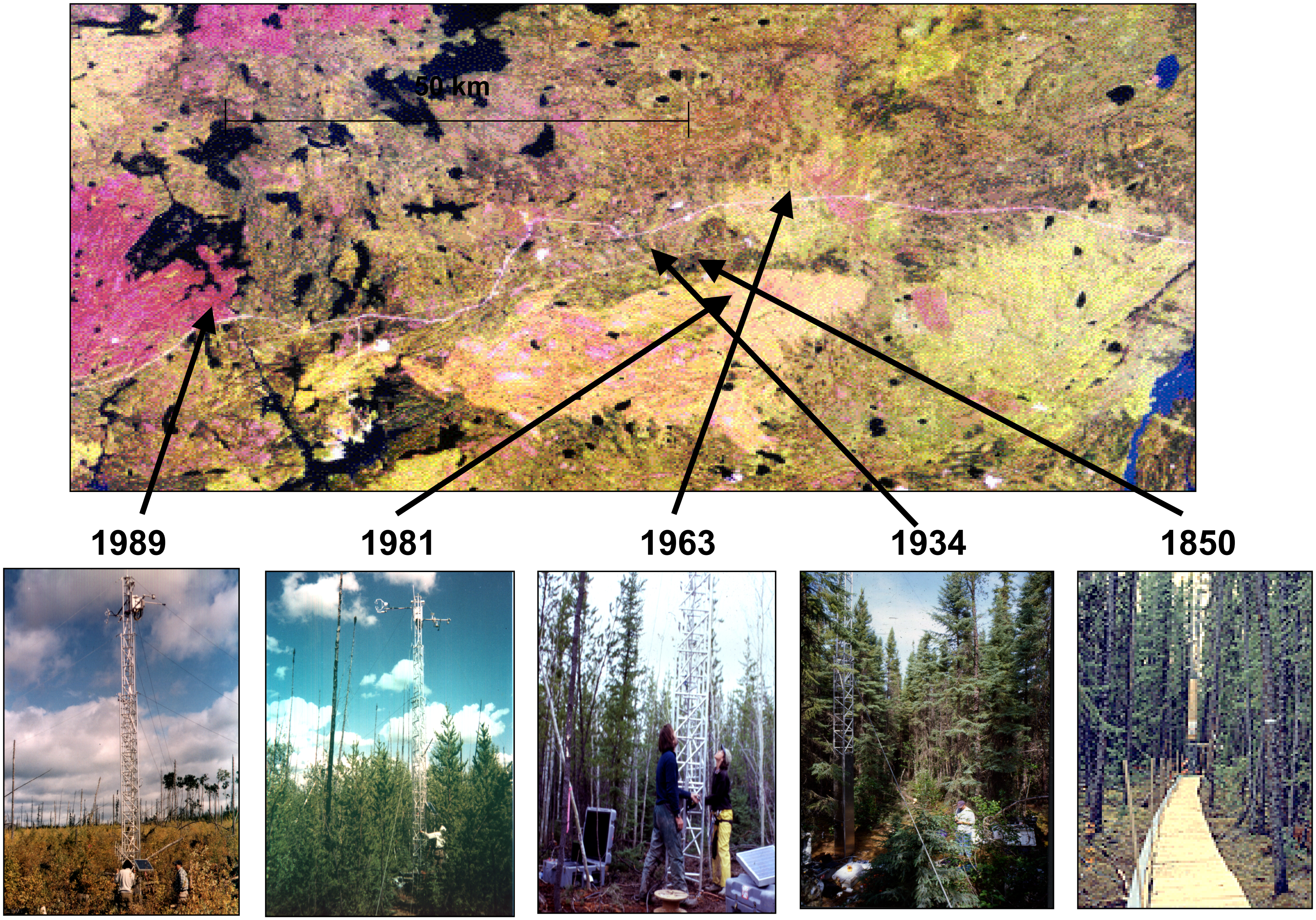
Objective

How does forest CO_2 cycle recover after **fire**?



Odum 1969, Gorham et al. 1979, Sprugel 1985, Schulze et al. 2000

BOREAS NSA-Chronosequence Study



1989 burn:
11 years after fire

1930 burn:
~70 years after fire

Experimental design: 7 identical, solar powered, automated towers running year round

Temperatures are -40 C in winter, +40 C in summer

Logistical challenges

Solar power

Sunlight

Summer - ~20 hours
Winter - ~ 4 hours

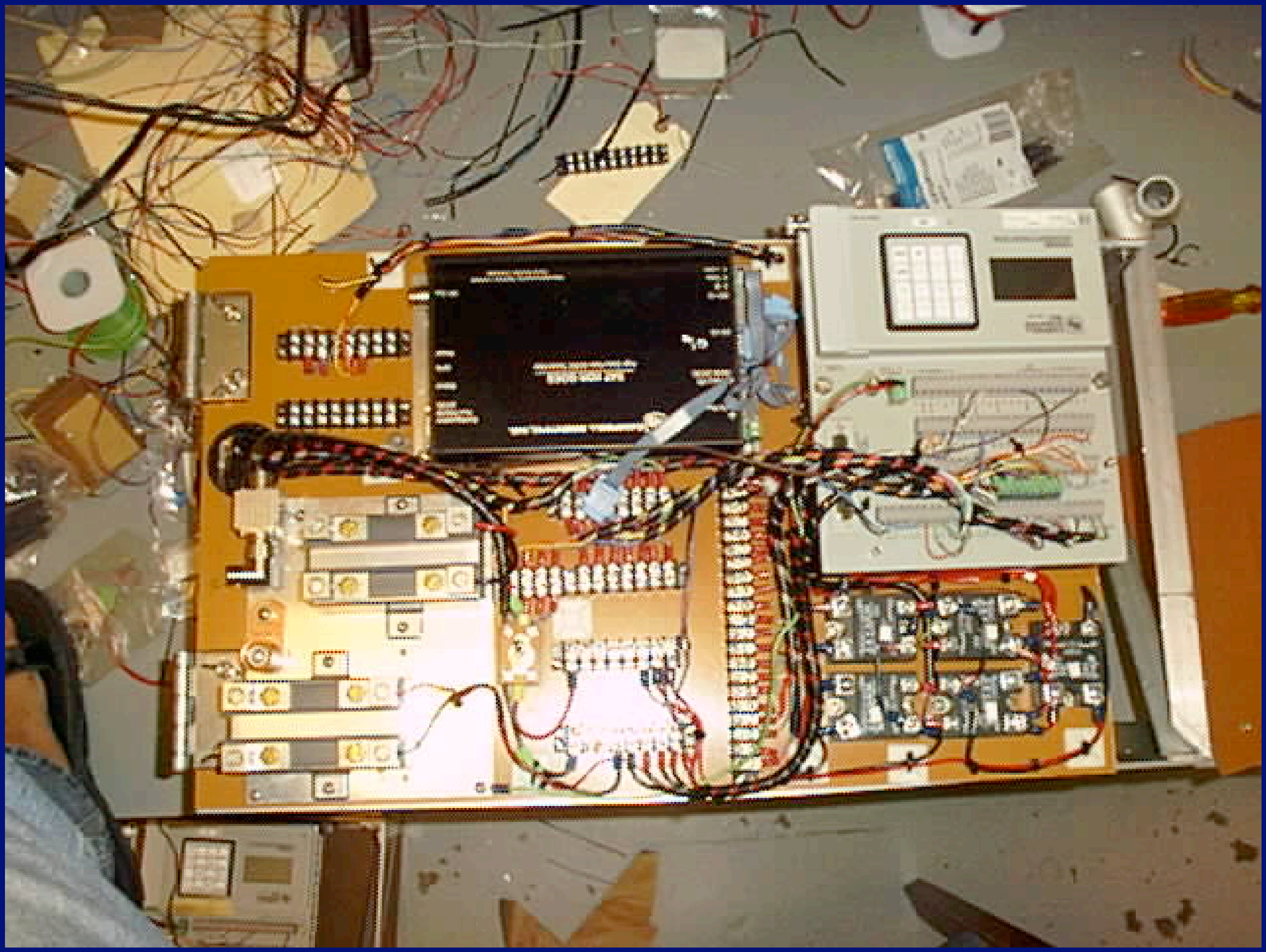
Logistical challenges

Sites are several km from nearest road

Logistical challenges

Access to sites during 6 months of winter is limited.

Data is transmitted via GOES satellite link, every 3 hours



Logistical challenges

Equipment box is buried beneath soil, and covered by snow during winter.

Box temperature remains about 20 C when ambient temp is -40 C.

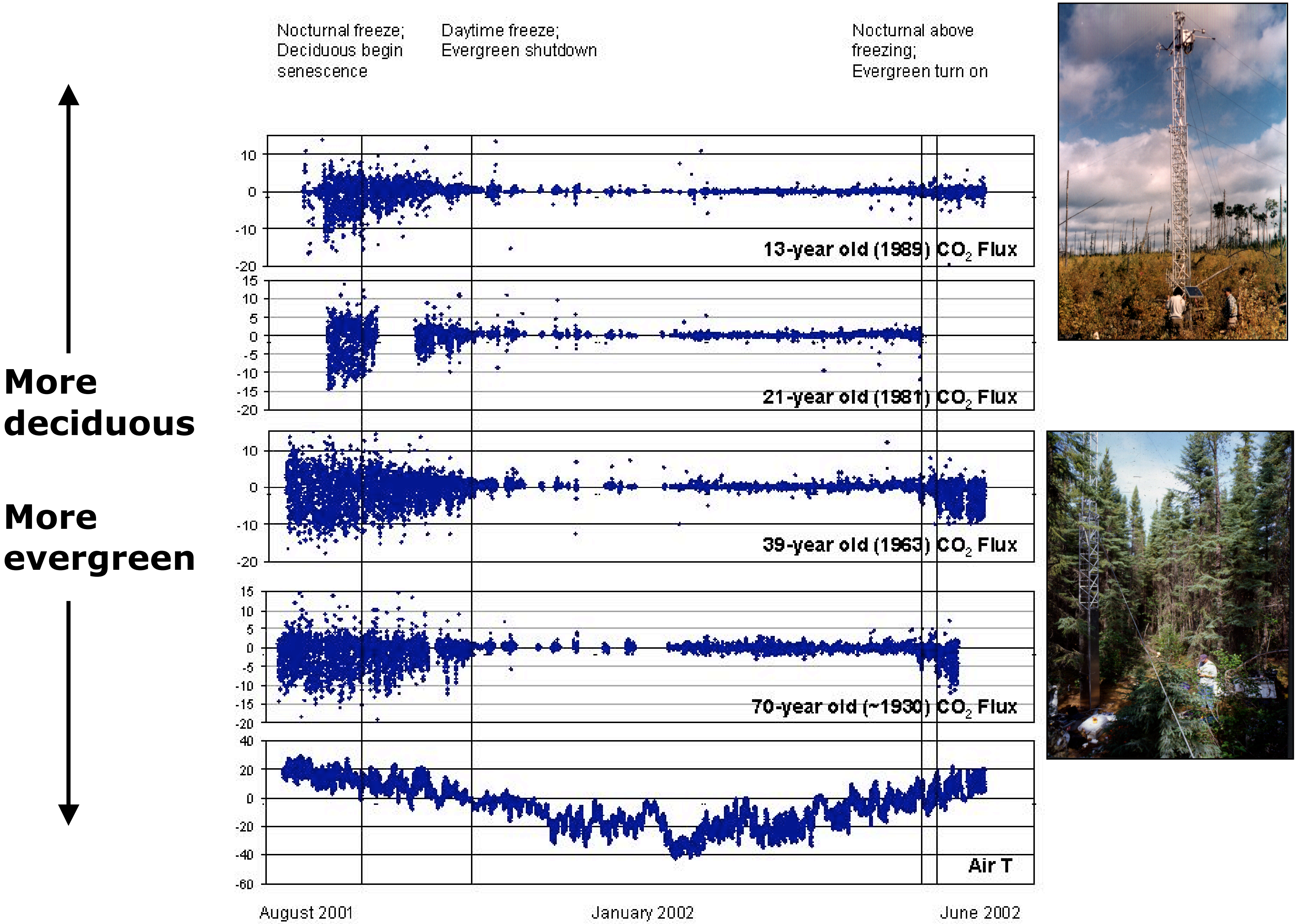
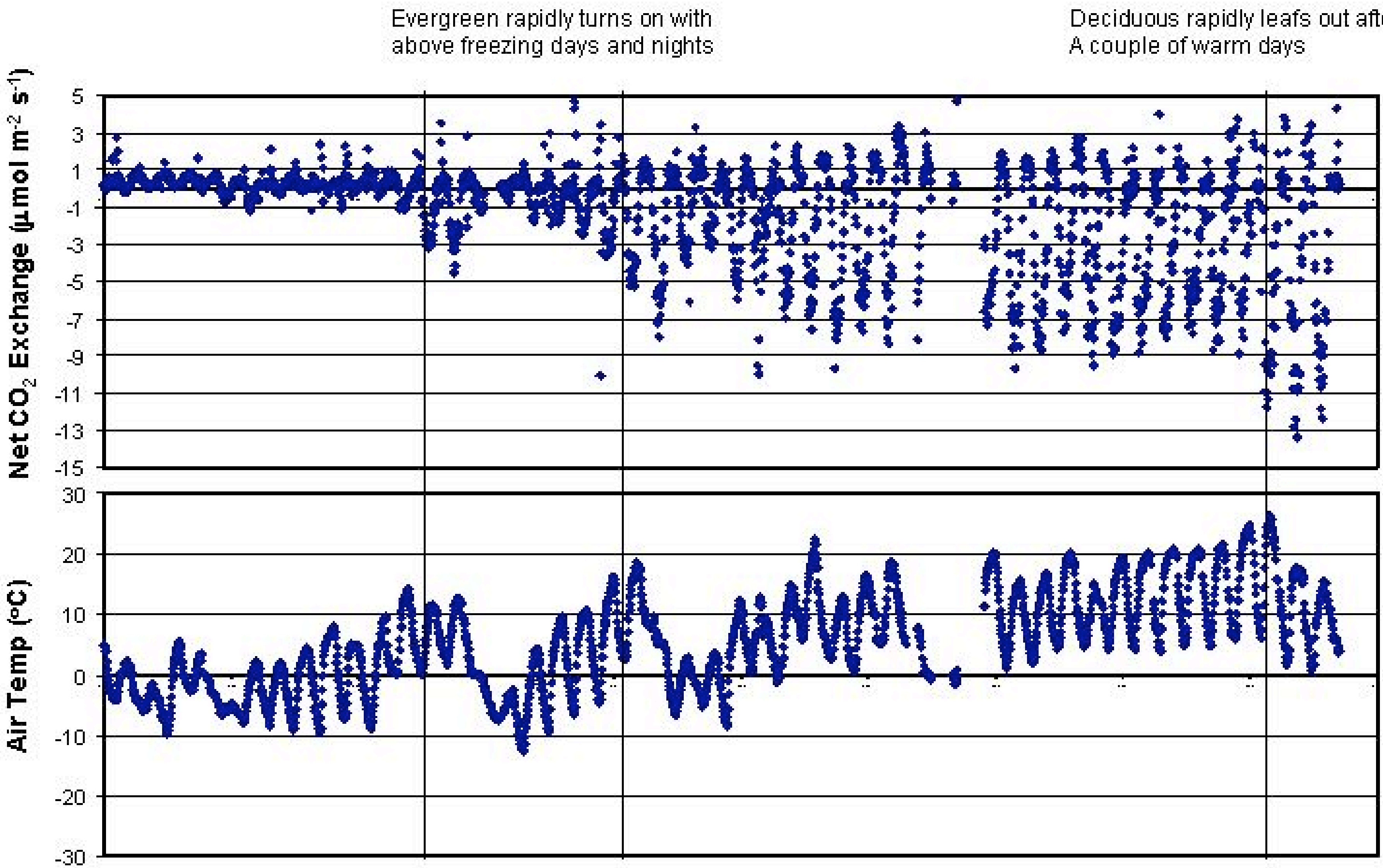
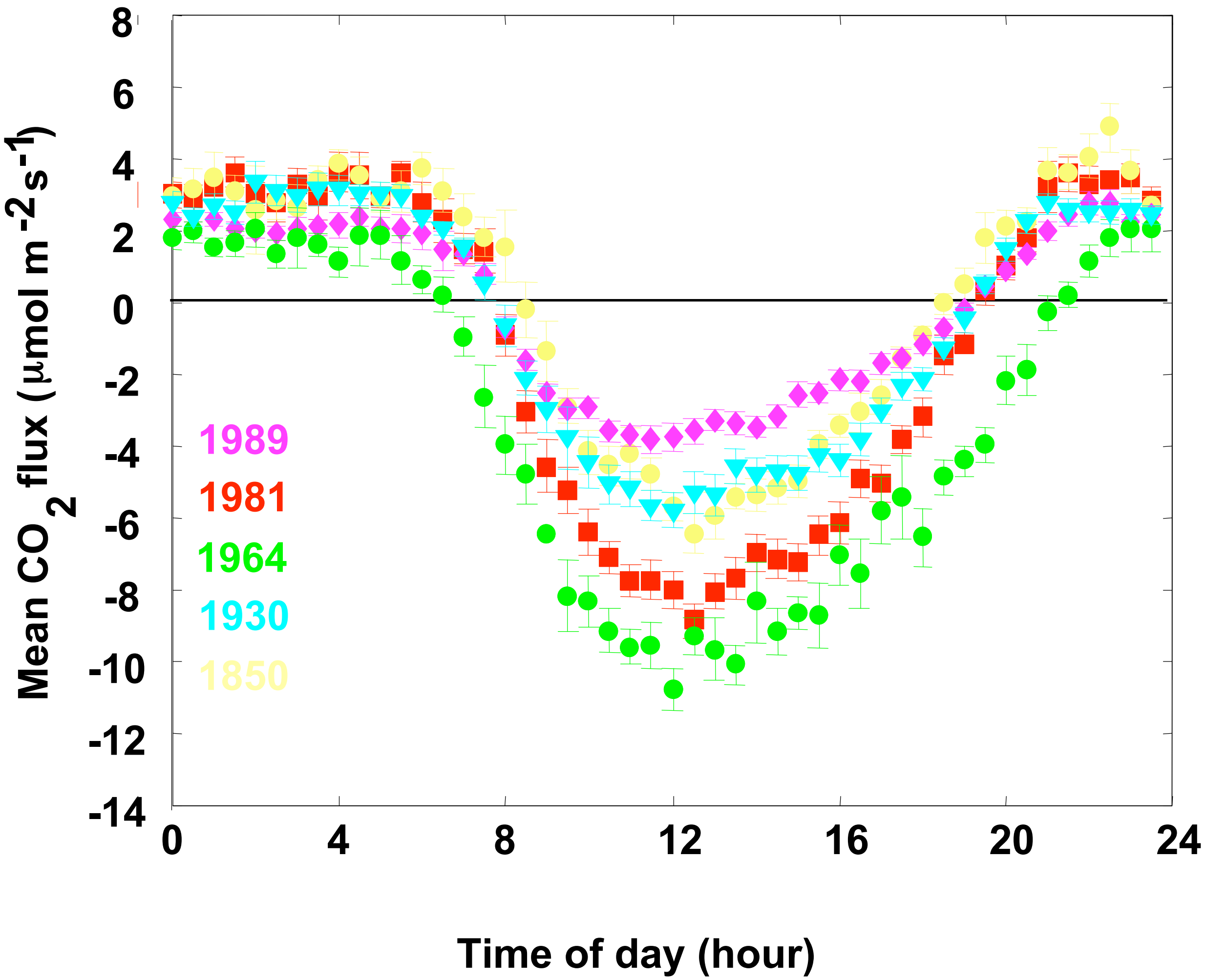


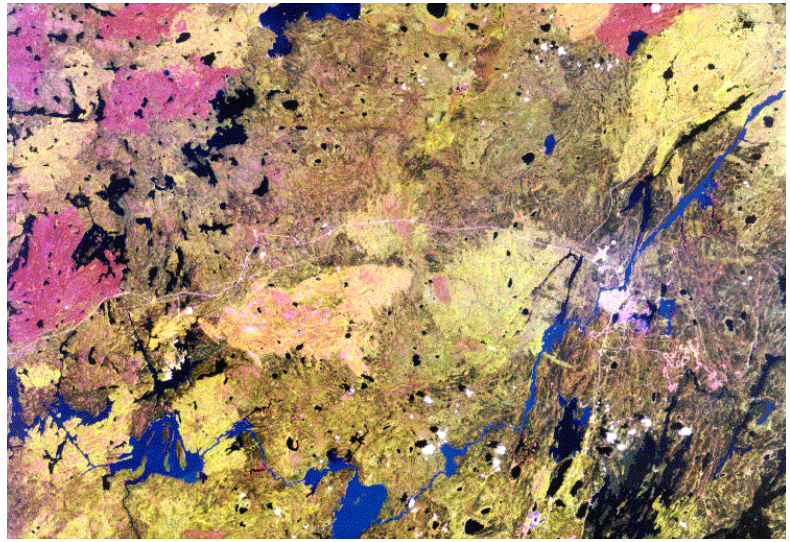
Figure 1 Goulden et al. DOE-TCP progress report June 2002

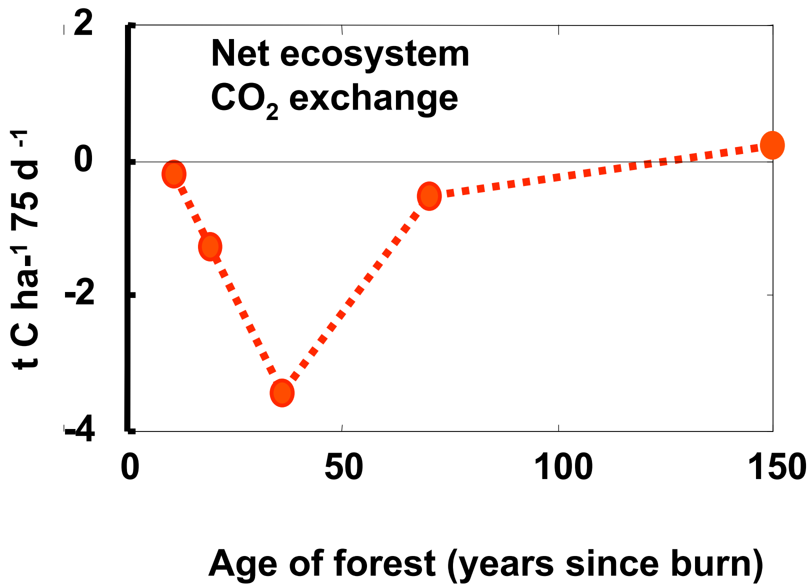
Spring 2002 at 39-year old stand (mix of evergreen and deciduous)



Comparison of Summer Diurnal CO_2 fluxes
Pilot Study 1999, 2000







Net ecosystem
CO_2 exchange
t C ha-1 75 d -1
2
0
-2
-4
0
50
100
150
Age of forest (years since burn)

Conclusions

- **Eddy covariance, within the context of a well designed experiment, is suited for studying disturbance.**

- **Preliminary data indicate that selective logging in a tropical forest has a modest, transient affect on carbon exchange**

- **Preliminary data indicate that time since recovery has a large impact on boreal stand carbon balance**

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