Research and methods in meteorological data collection

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ENVIRONMENTAL SENSORS

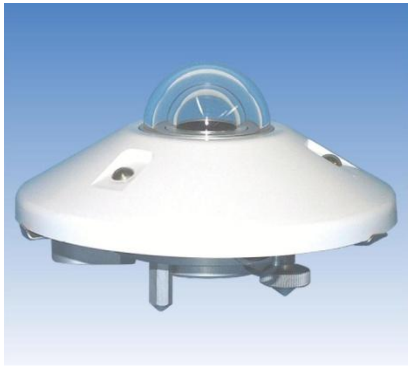
Air Temperature & RH

Wind Speed & Direction

Radiation

Pyrgeometer

Net Radiometer



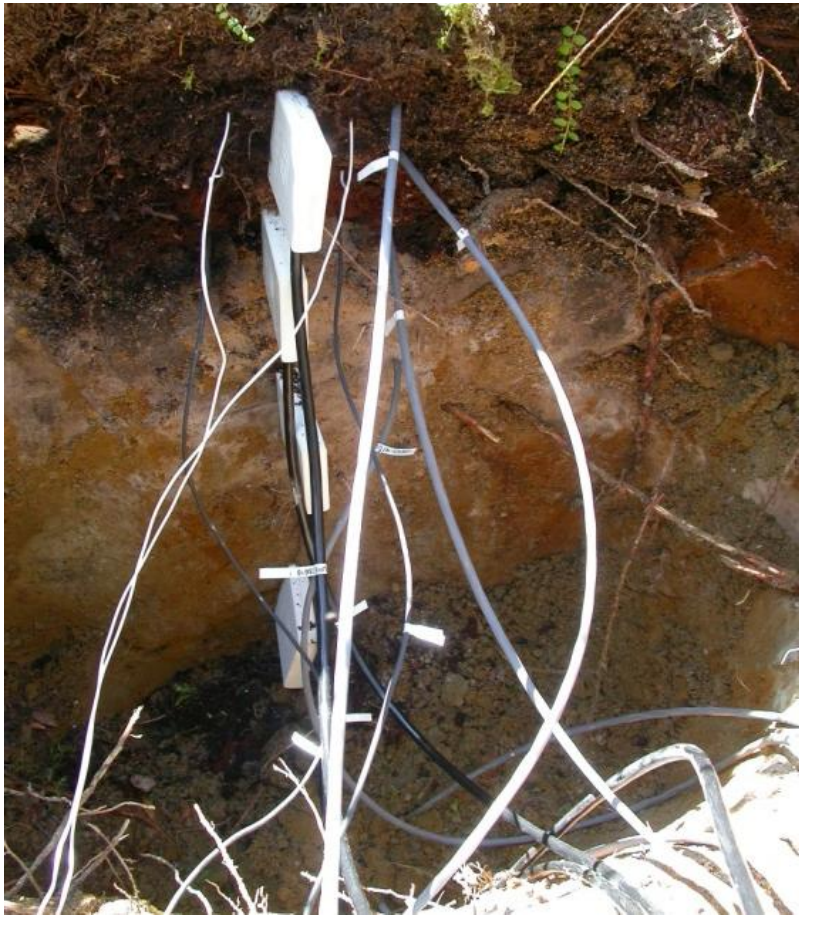
Pyranometer

Diffuse/Direct

PAR sensor

Soil Sensors

- Temperature
- Humidity
- Heat Flux



Precipitation Gauge

Tethersonde

- Vertical profiles
- Spatial transects

Other sensors

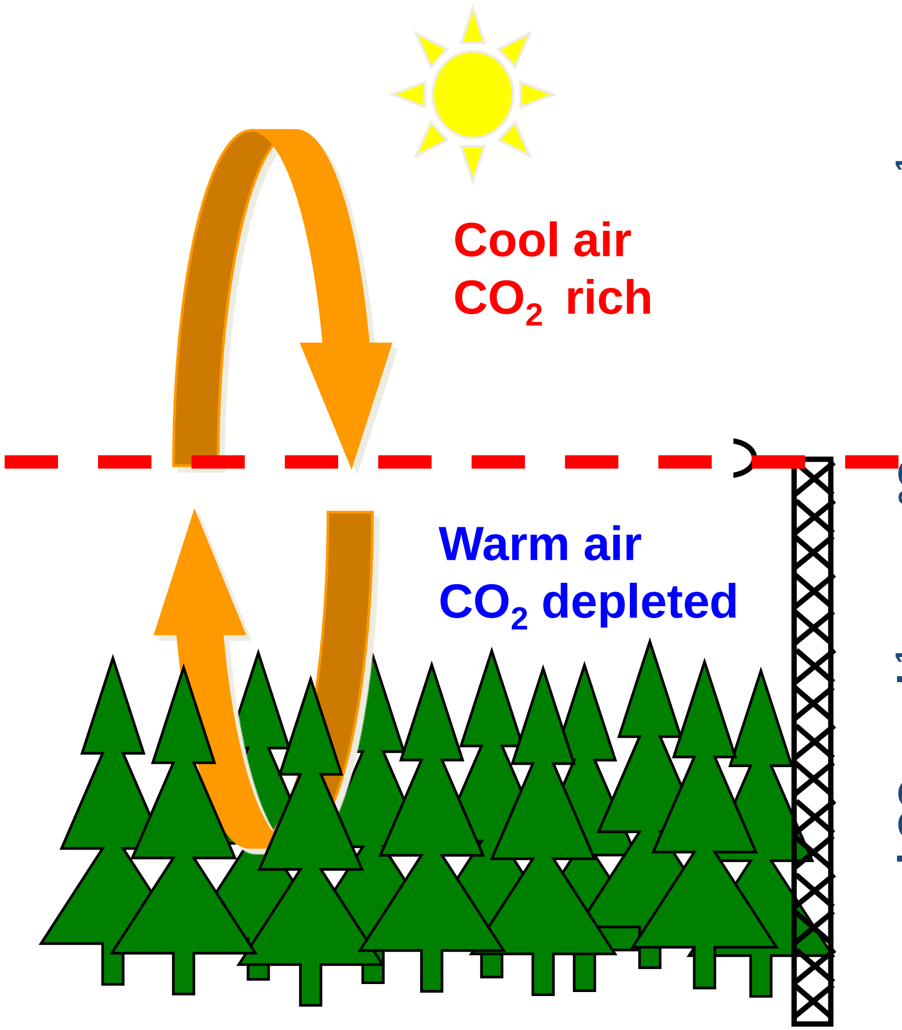
- Surface Temperature
- Water Table Depth
- Sonic Ranging Sensor
- Ceilometer
- Lidar
- Web cam

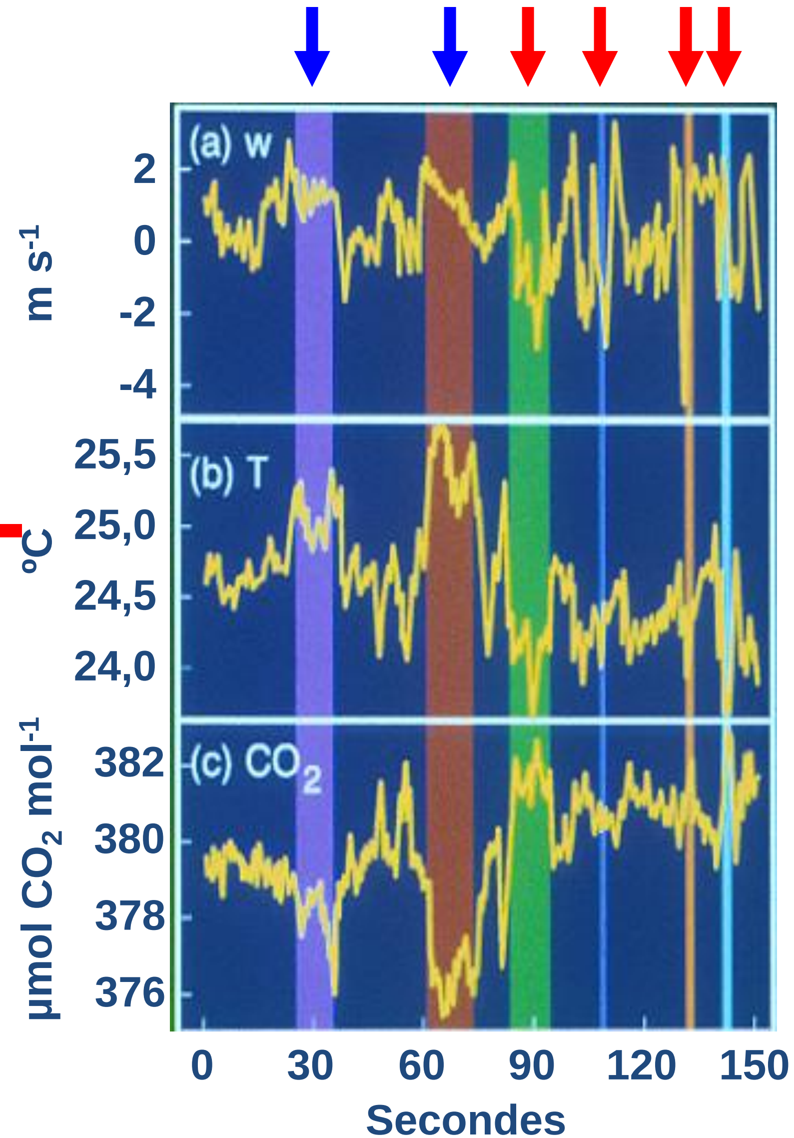
- Datalogger

EDDY COVARIANCE TECHNIQUE

What is Eddy Covariance?

Eddy covariance





Courtesy S. Wofsy/ M.-A. Giasson

eddy covariance

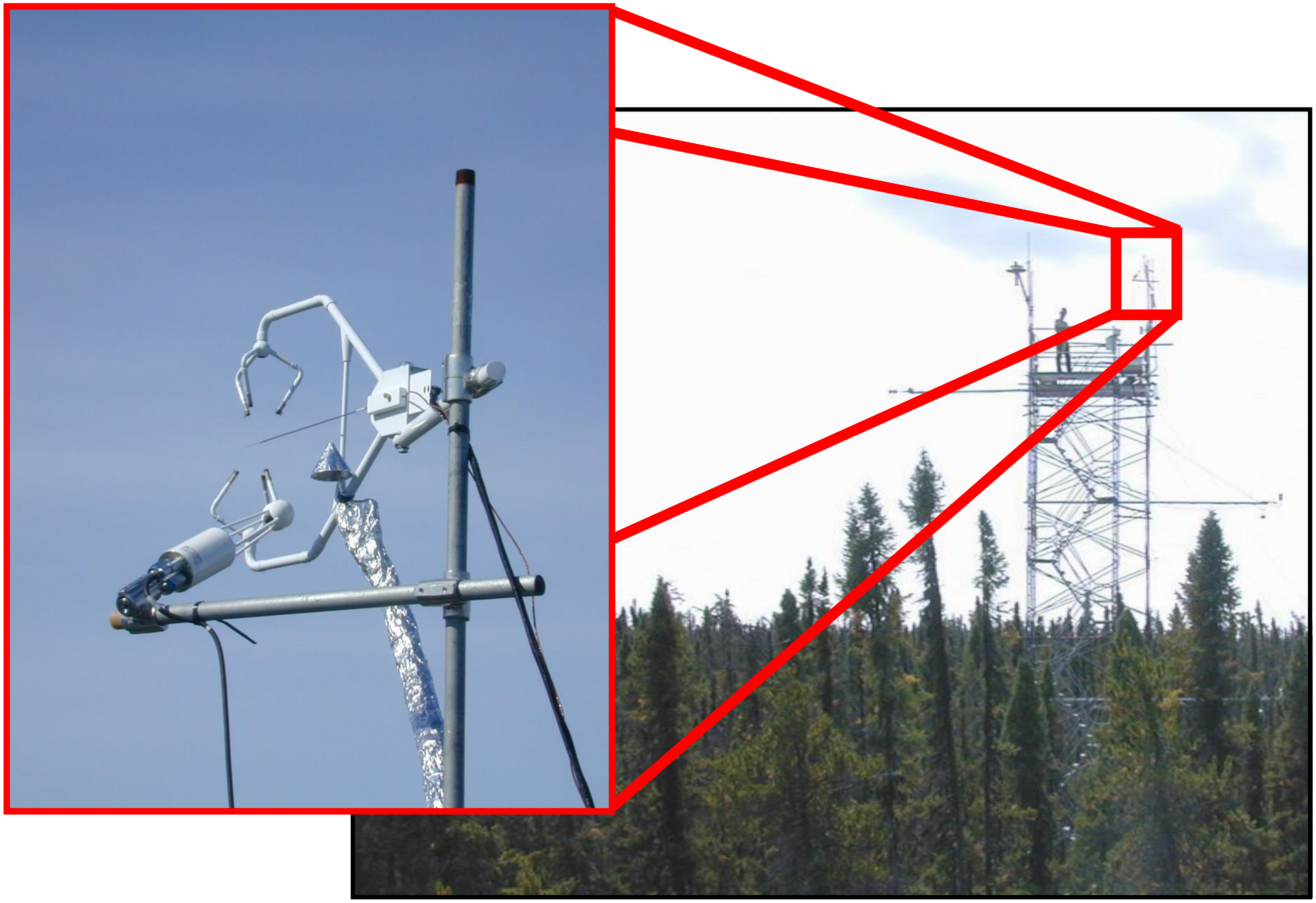
Exchange of CO_2 = Velocity X $[CO_2]$

$$F_{CO_2} = \sum_{i}^{n} \frac{(\overline{w} - w_i)X(\overline{CO_2} - CO_{2i})}{n}$$

$$\frac{\mu mol}{m^2\ s} = \frac{\cancel{m}}{s} \times \frac{\mu mol}{m^{\cancel{3}\ 2}}$$

g C m^{-2} yr^{-1} or ton of C ha yr^{-1}

Instrumentation



Sonic Anemometer – Design I

Metek USA1

Gill R3

symmetric head

Gill R2

asymmetric head

Campbell Scientific

CSAT3

Sonic Anemometer – Design II

Kaijo-Denki

ATI K Probe

Infra-Red Gas Analyser

Li-Cor LI-7500

Li-Cor LI-6262

Li-Cor LI-7000

Thermostatic enclosure

Storage Term

Why Eddy Covariance?

- Scale-appropriate
  - Provides whole ecosystem estimates of net CO_2 exchange
- Direct measure of net CO_2 exchange between ecosystem and atmosphere (NEE)
  - Micrometeorological technique
- Area sampled (footprint) has longitudinal length scales of 100’s m to km’s
- Provides temporal scale measurements from minutes to years

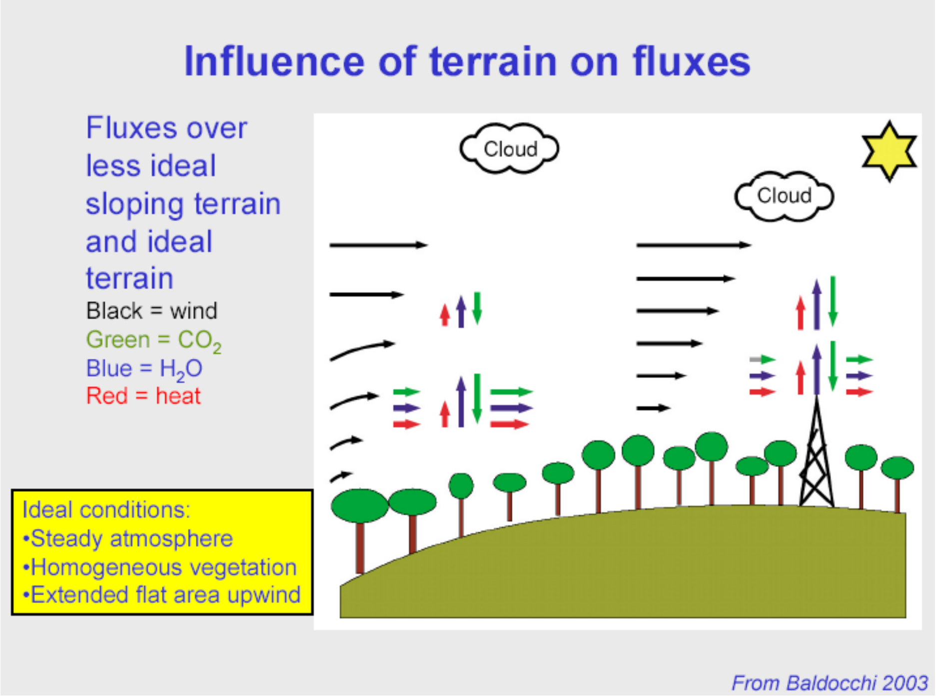
Baldocchi, 2003

Why Eddy Covariance?

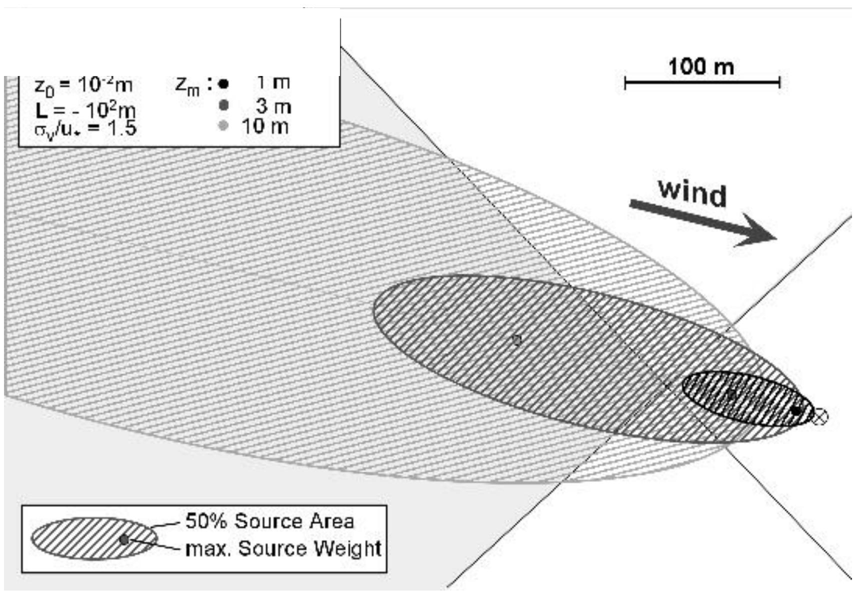
- Can be used to answer questions like:
  - How does the ecosystem respond to perturbation?
  - If we use paired systems we can assess management decisions

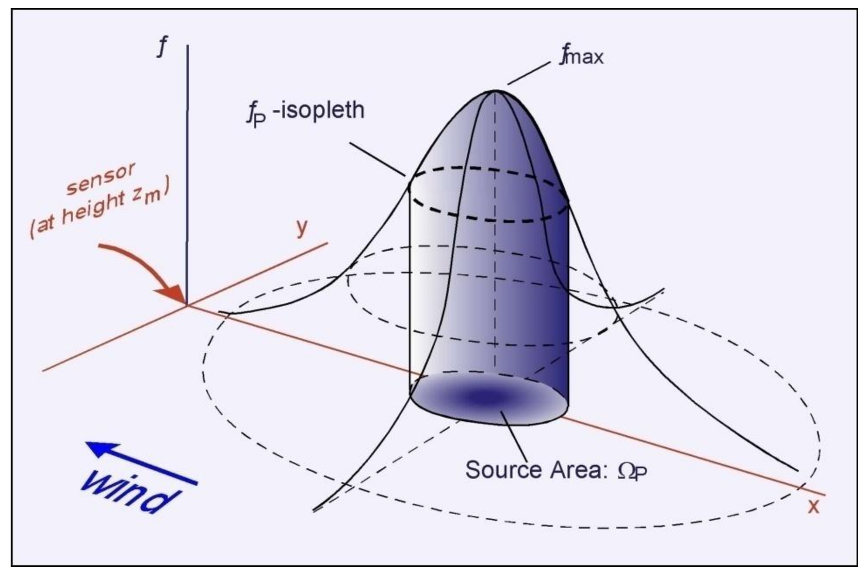
Why not use it everywhere?

- Requires:
  - Flat terrain
  - Large homogenous upwind surface
    - Horizontal homogeneity: udc/dx=0; dFx/dx=0
    - Upwind fetch ~100 x height of canopy
  - Steady environmental conditions
    - Steady-state conditions: dc/dt=0



What are we measuring? (Source areas / flux footprints)





From: Dr. HaPe Schmid

EC Data Processing

1) Processing of the high frequency data to get 30-minute averages of CO_2 fluxes

2) Data Quality Control

3) Gap filling of missing data

EC Data Quality Control

- **Main reasons why data are rejected**
  - Obstruction of the IRGA path (e.g. Precipitation)
  - Low turbulence at night
  - Extreme values
  - Wind coming from undesired sector

Missing EC Data

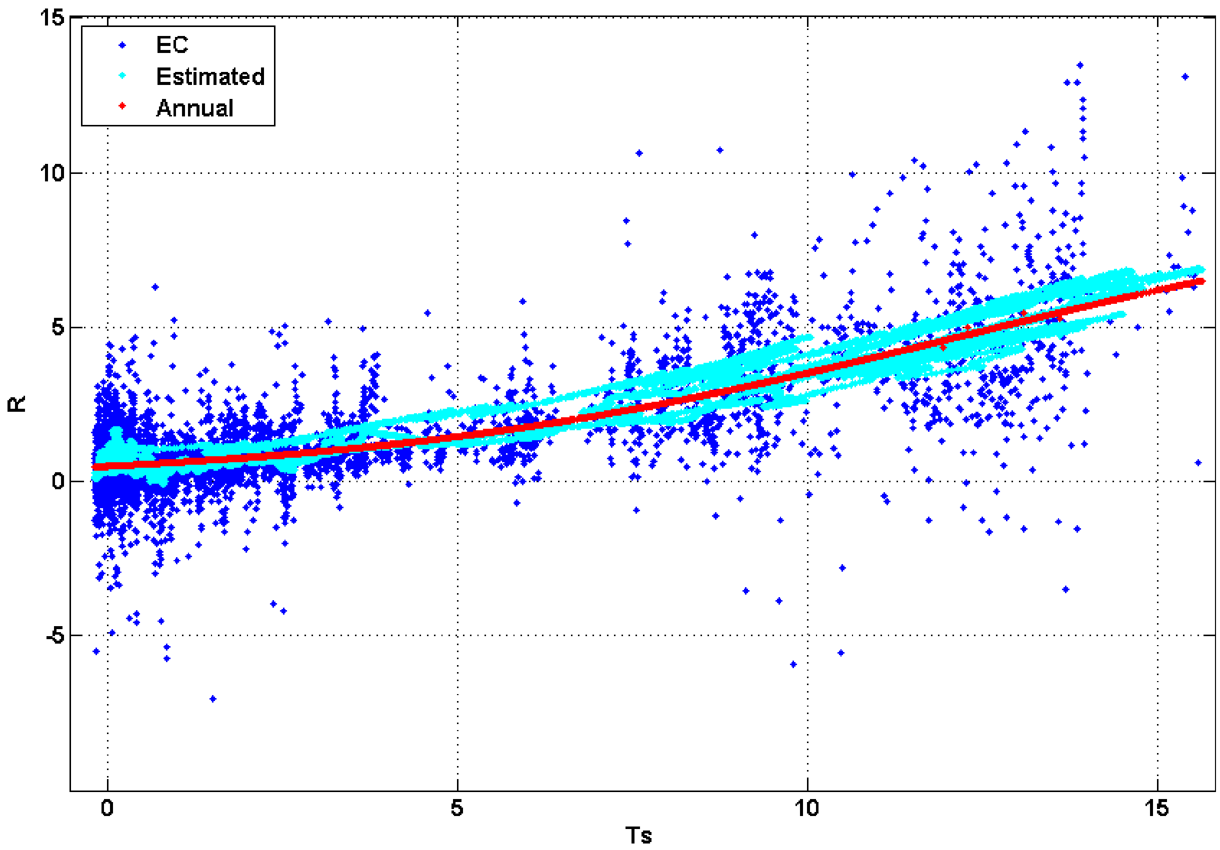
- **Gaps in the data occur due to various reasons**
  - Rejection following quality control requirements
  - Power failure
  - Maintenance and repairs of instrumentation

Filling the Gaps

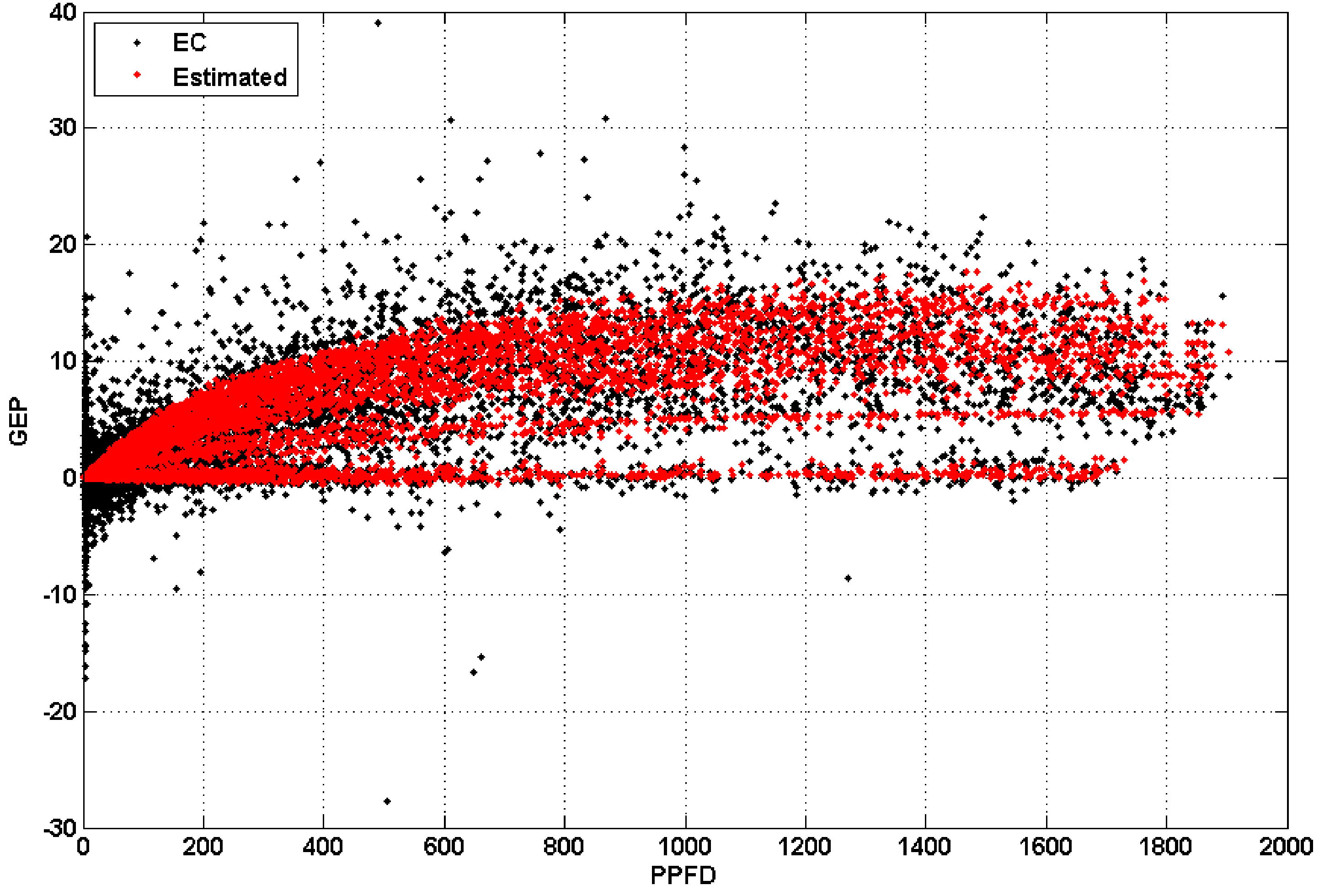
- **Small gaps (≤ 4 half-hours):**
  - Linear interpolation

- **Longer gaps (> 4 half-hours):**
  - *Forest Ecosystems* (*NEE = ER – GEP*)
    - **Ecosystem Respiration (ER):** Relationship between night-time NEE vs soil temperature
    - **Gross Ecosystem Production (GEP):** Relationship between measured GEP and radiation
  - *Hydroelectric Reservoir*
  - *Urban Environment*

R_{eco} vs T_s

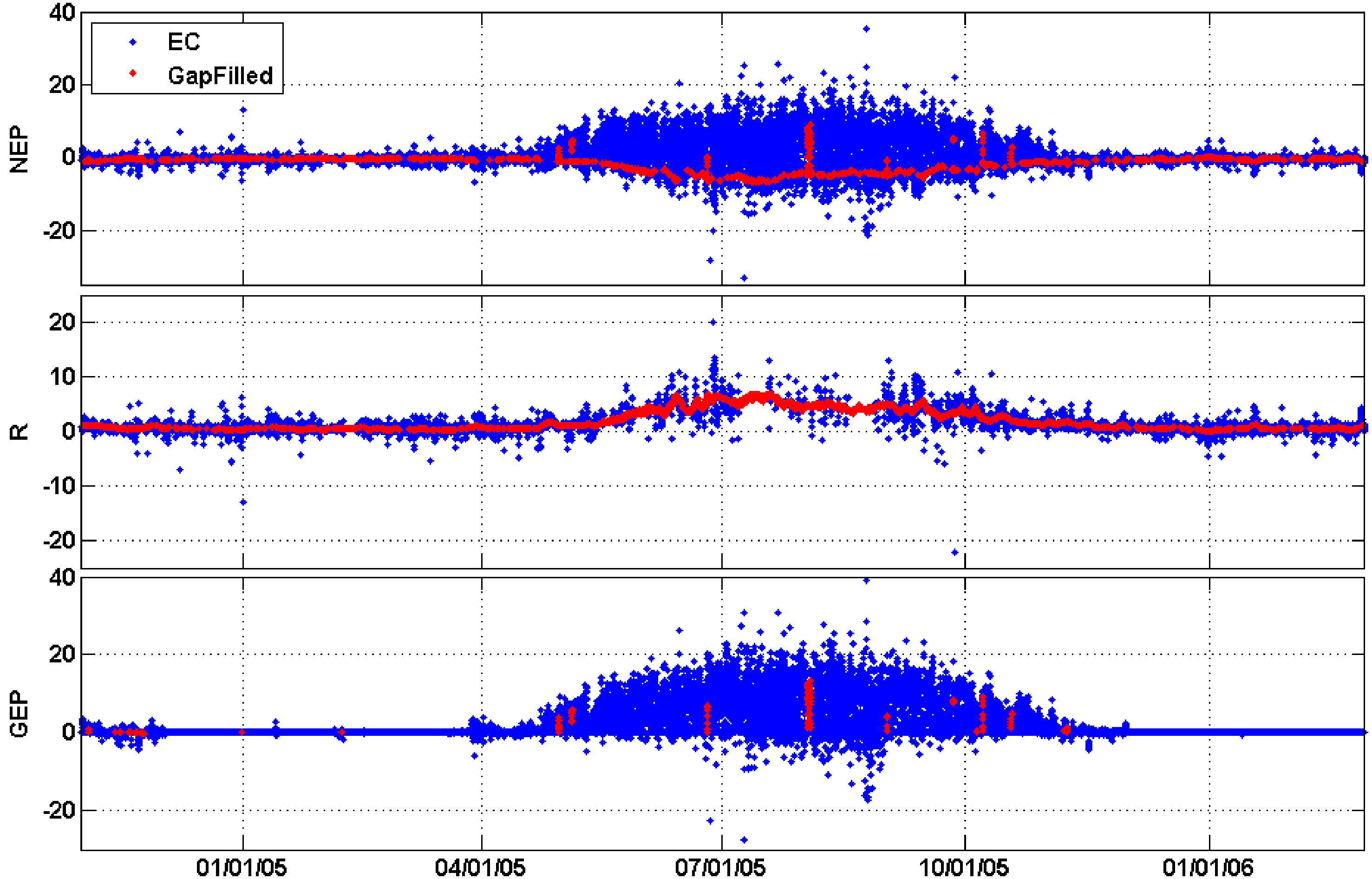


GEP vs PPFD



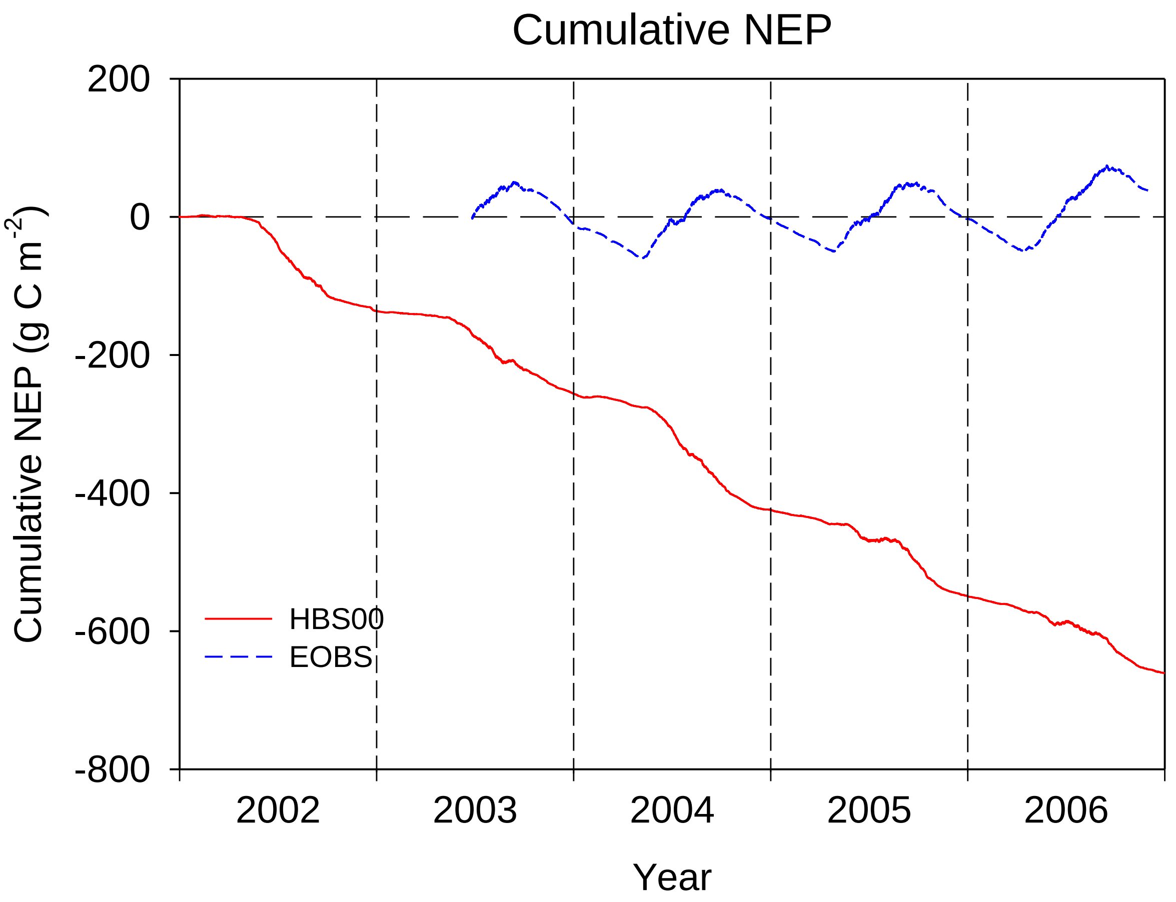
EC
Estimated
GEP
PPFD
40
30
20
10
0
-10
-20
-30
0
200
400
600
800
1000
1200
1400
1600
1800
2000

Gap filled data

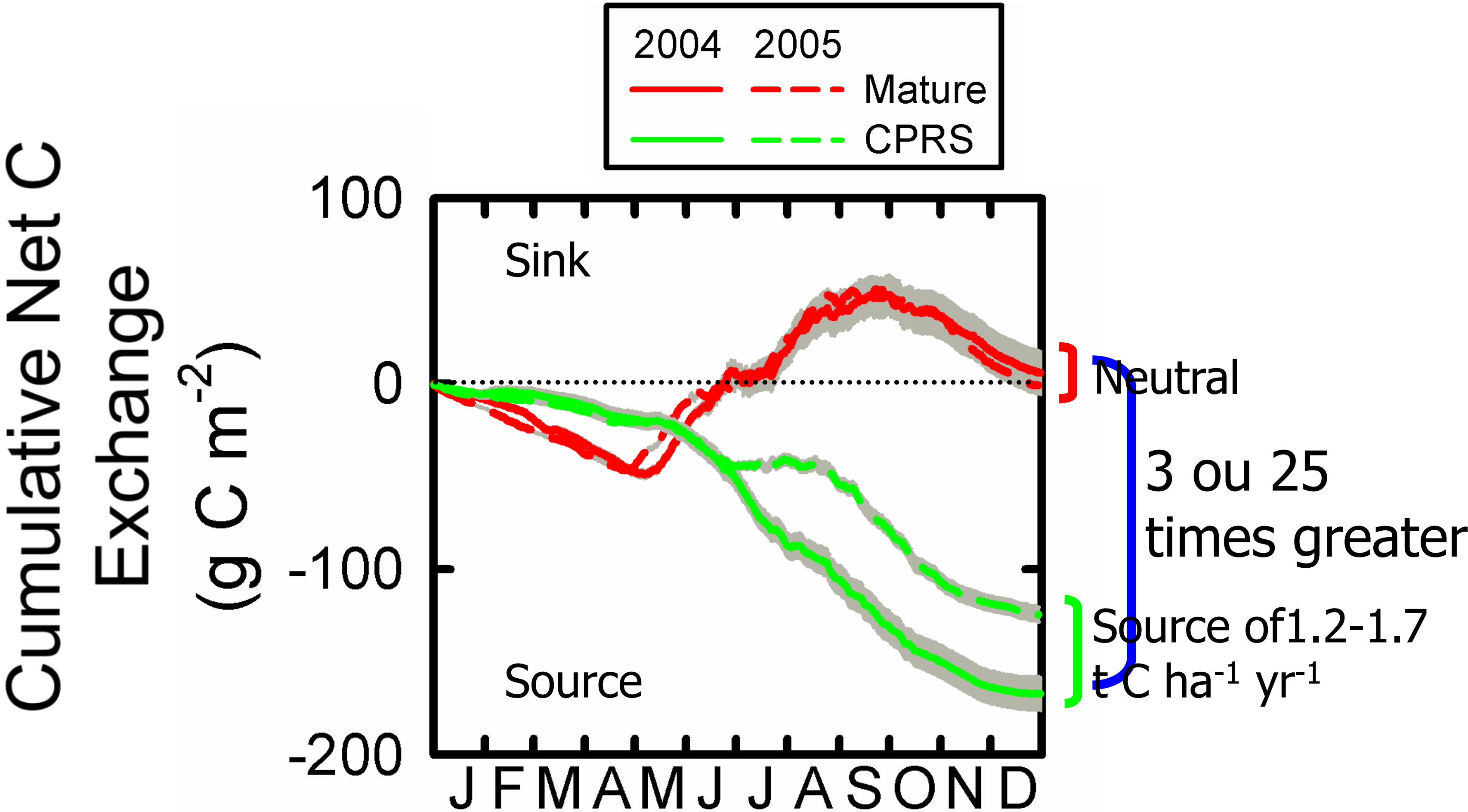


Harvested vs Mature Forests

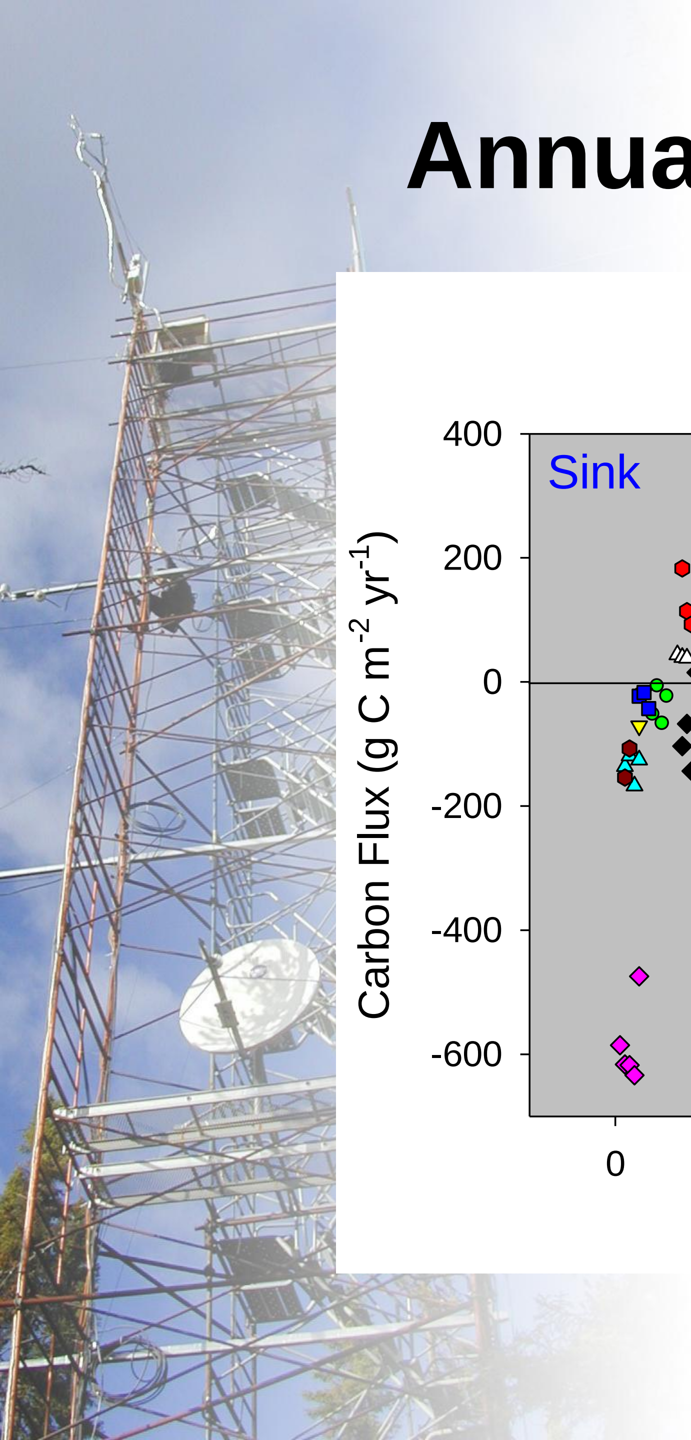
Cumulative NEP

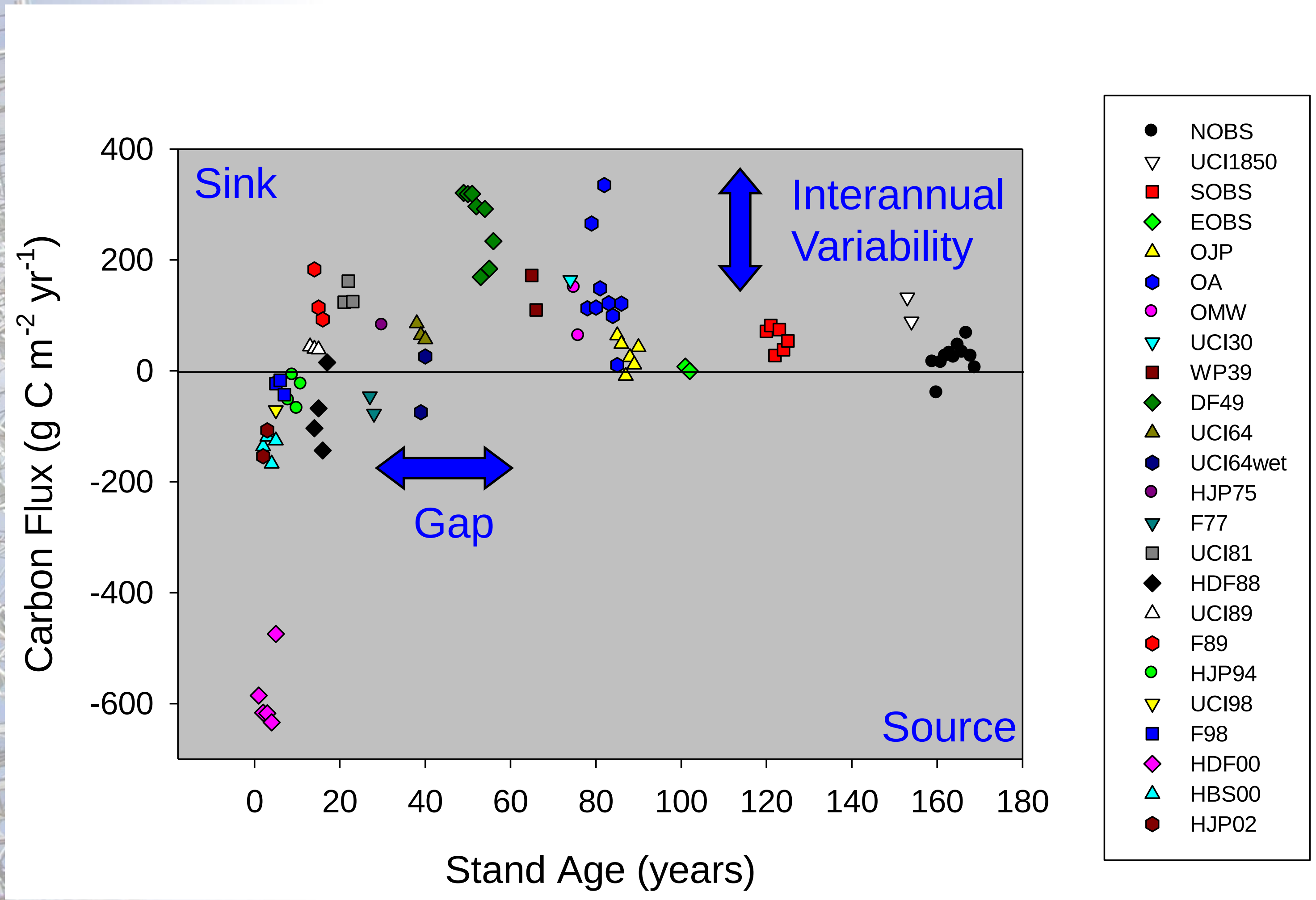


Harvested vs Mature Forests

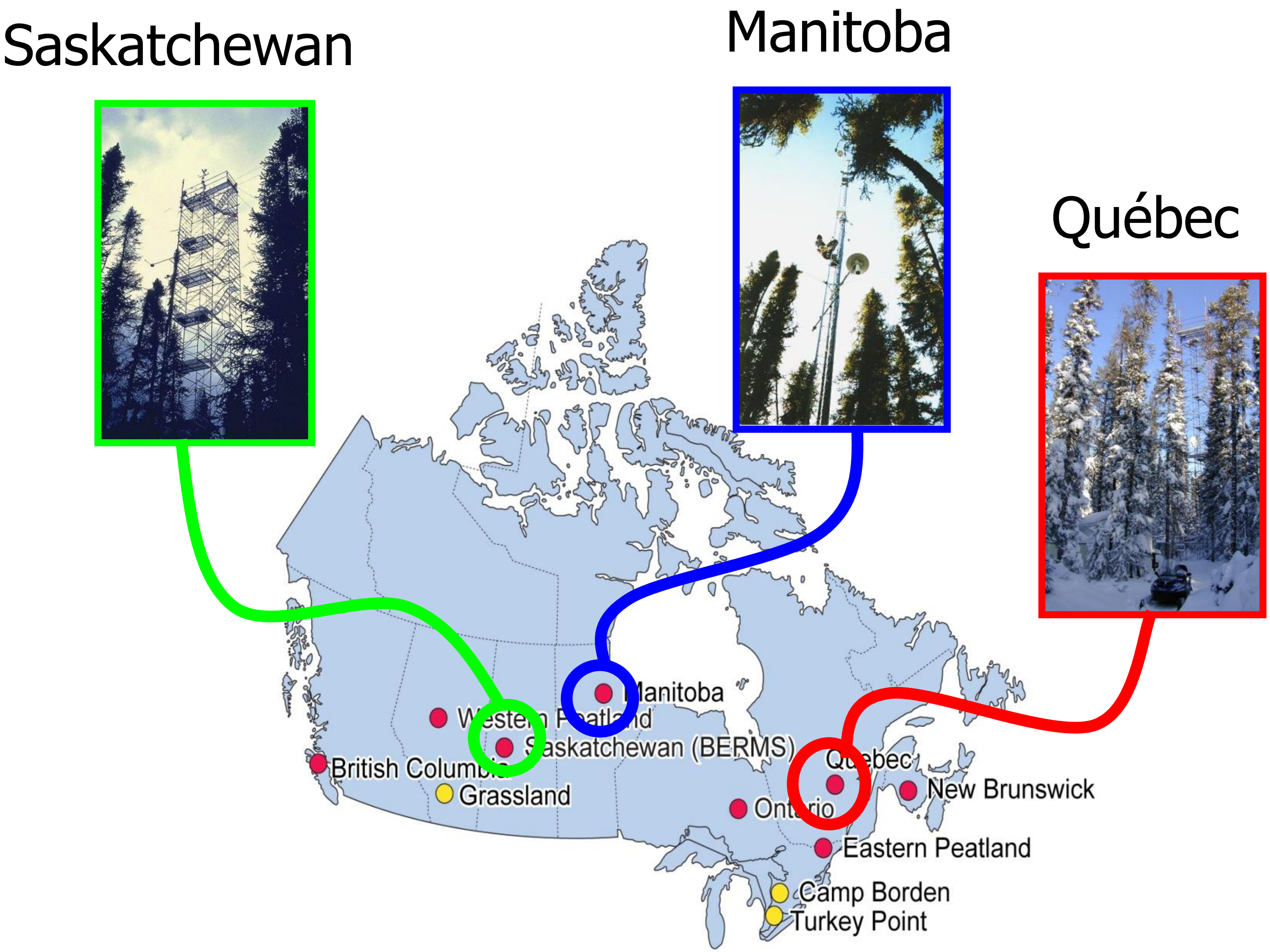


Annual Carbon Budgets





Cross-Site Comparaison



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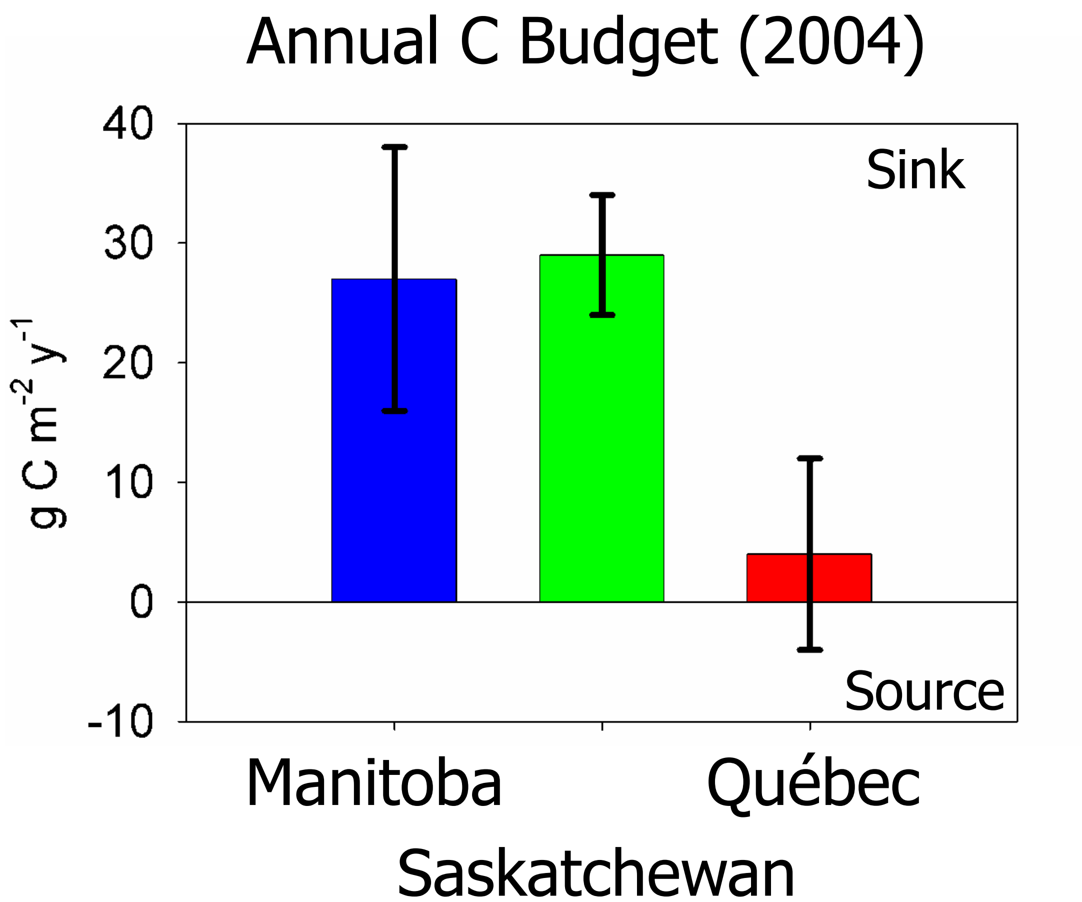
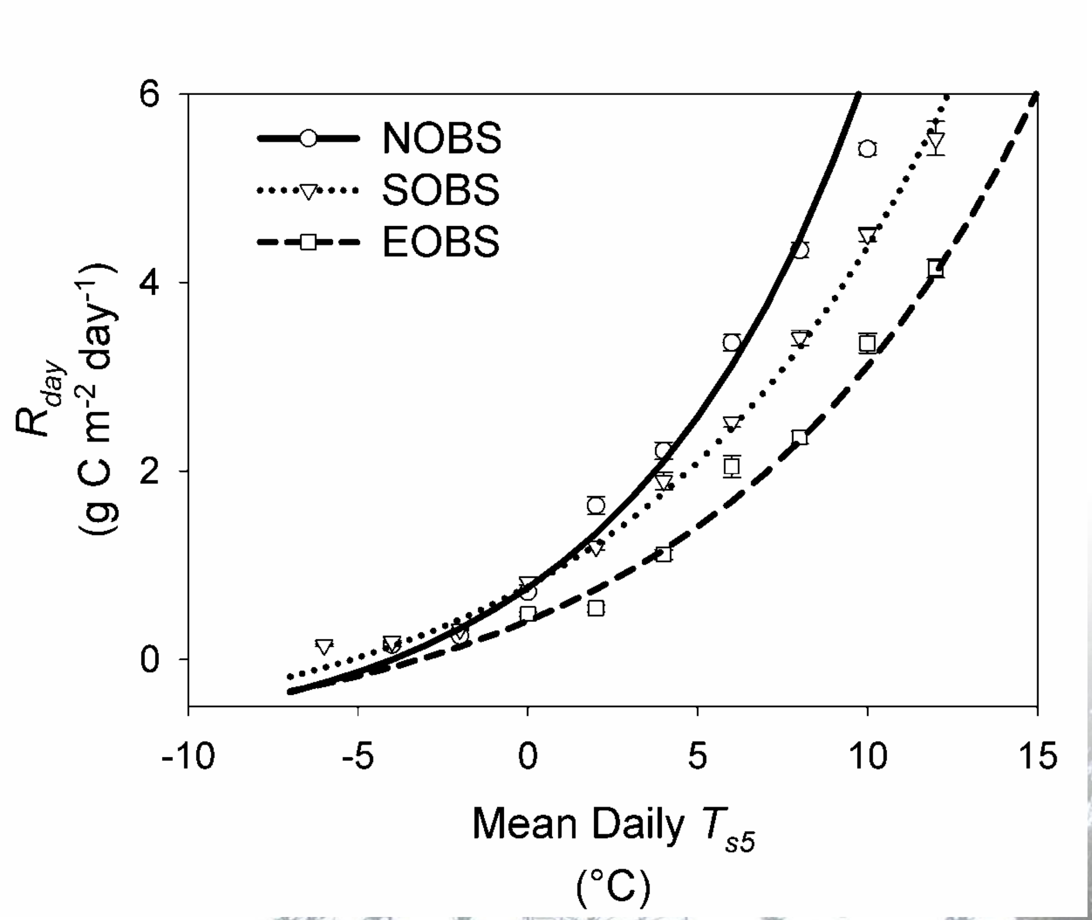
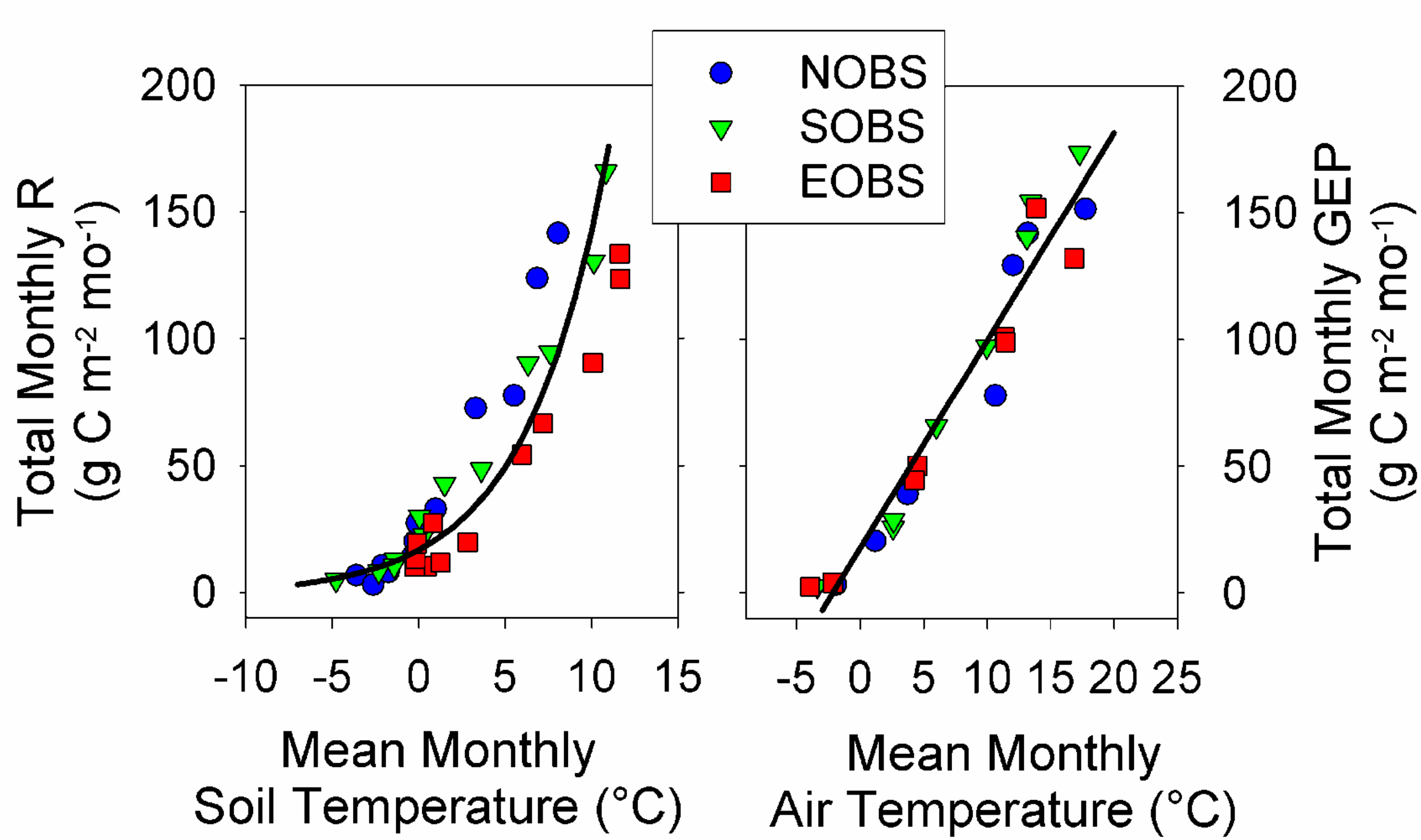


Cross-Spruce Comparison

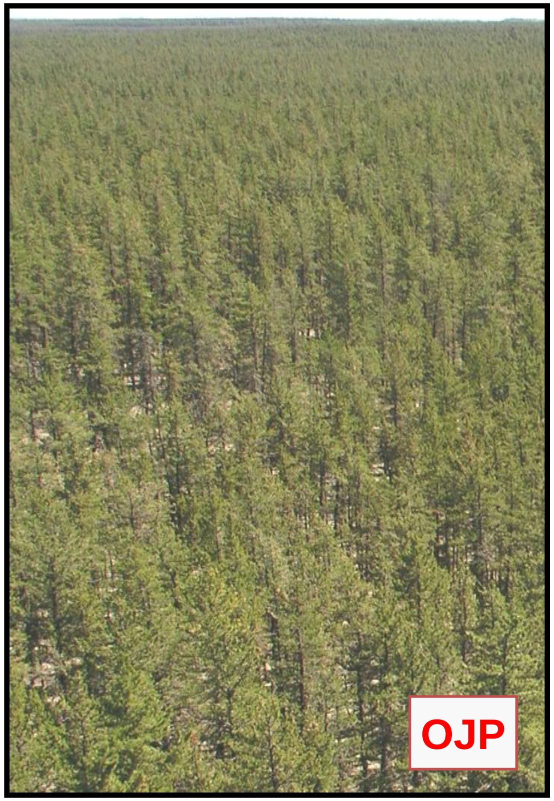


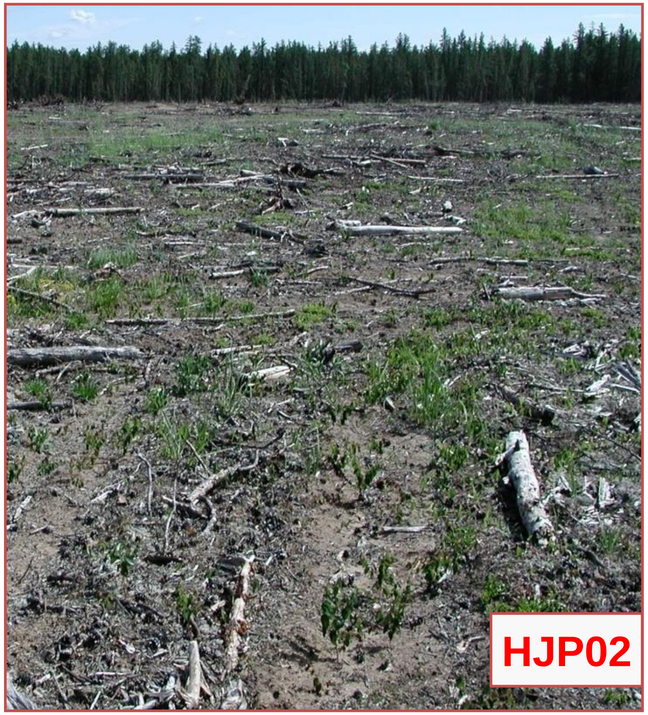
Cross-Spruce Comparison



BC FLUX STATION
CHRONOSEQUENCE OF 3 DOUGLAS-FIR STANDS

Planted	2000	1988	1949
Height (m)	0.8	3-8	30-35

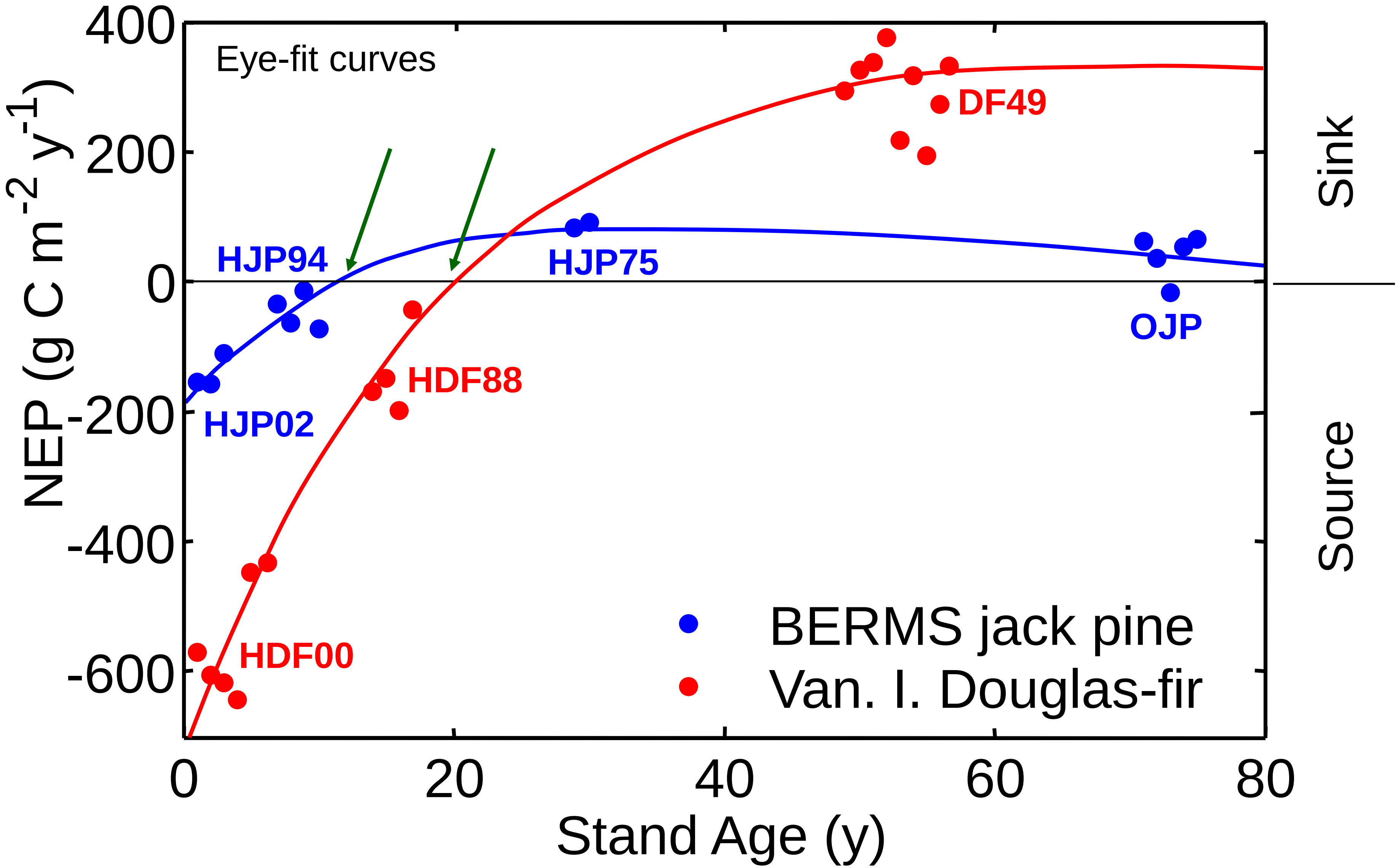




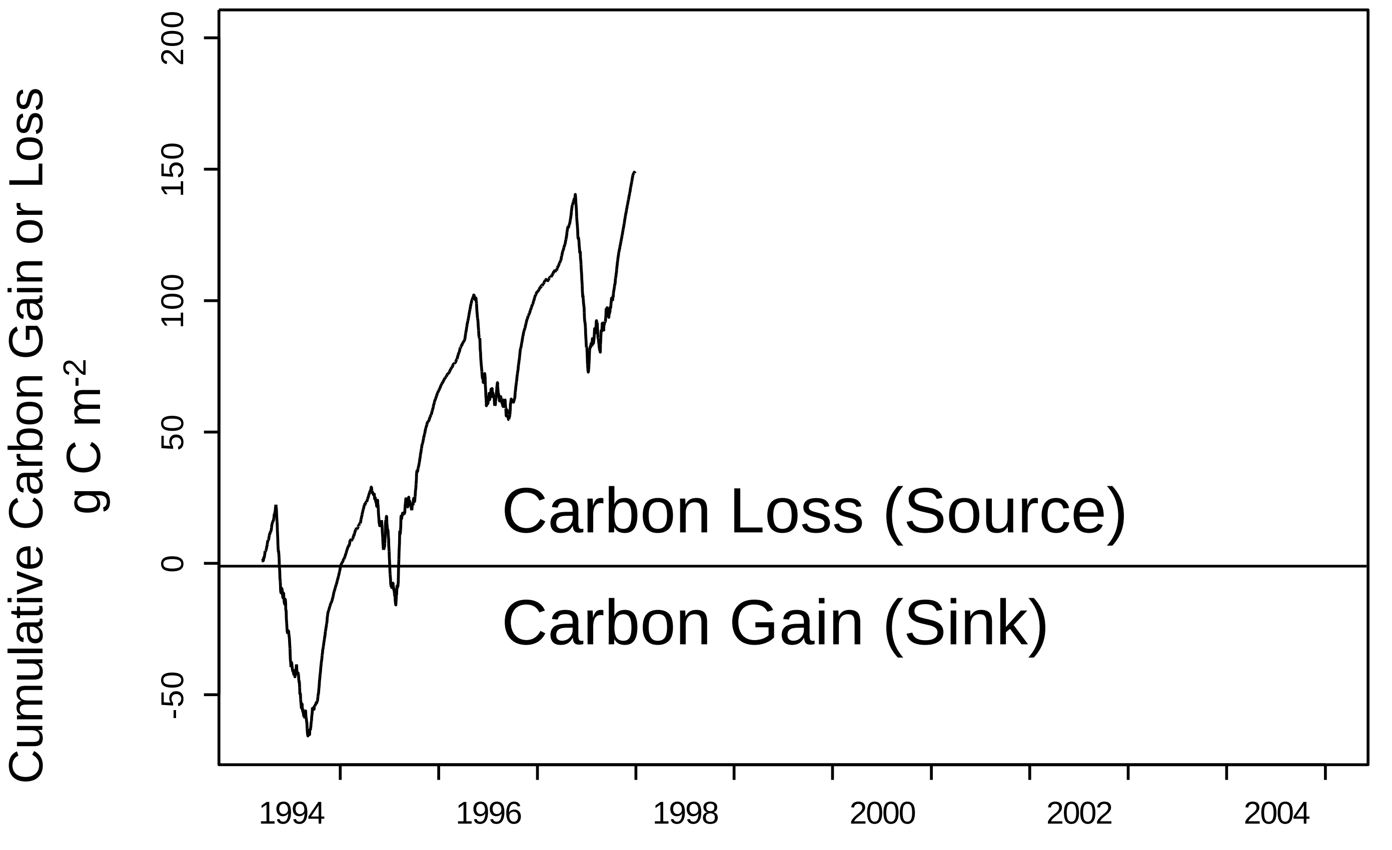
BERMS JACK PINE CHRONO-SEQUENCE

	Age (y)
OJP	75
HJP75	31
HJP94	12
HJP02	4

ANNUAL NEP FOR BERMS JP AND BC FLUX STATION DF CHRONOSEQUENCES



Northern Old Black Spruce, Manitoba



(Wofsy et al. Harvard)

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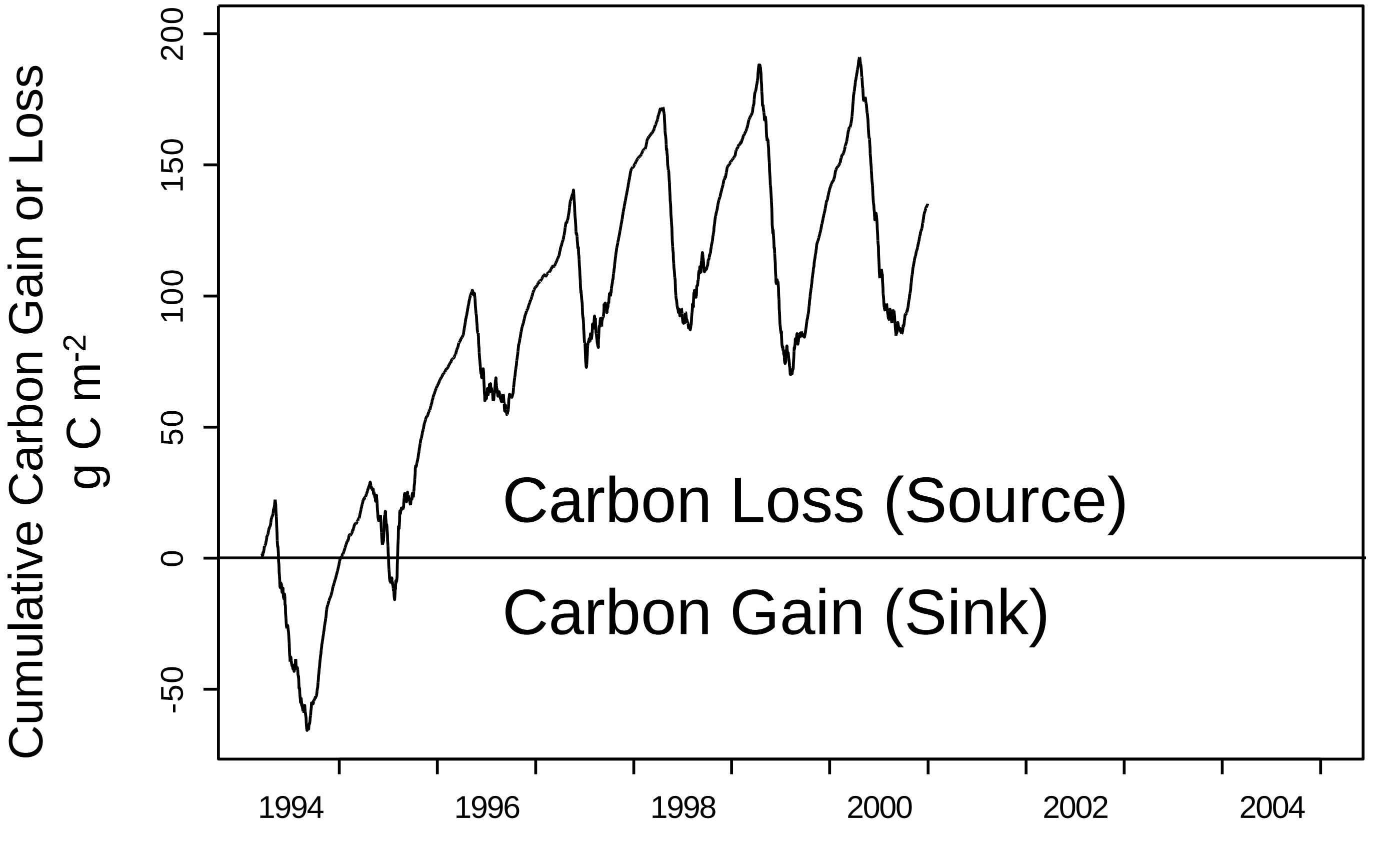

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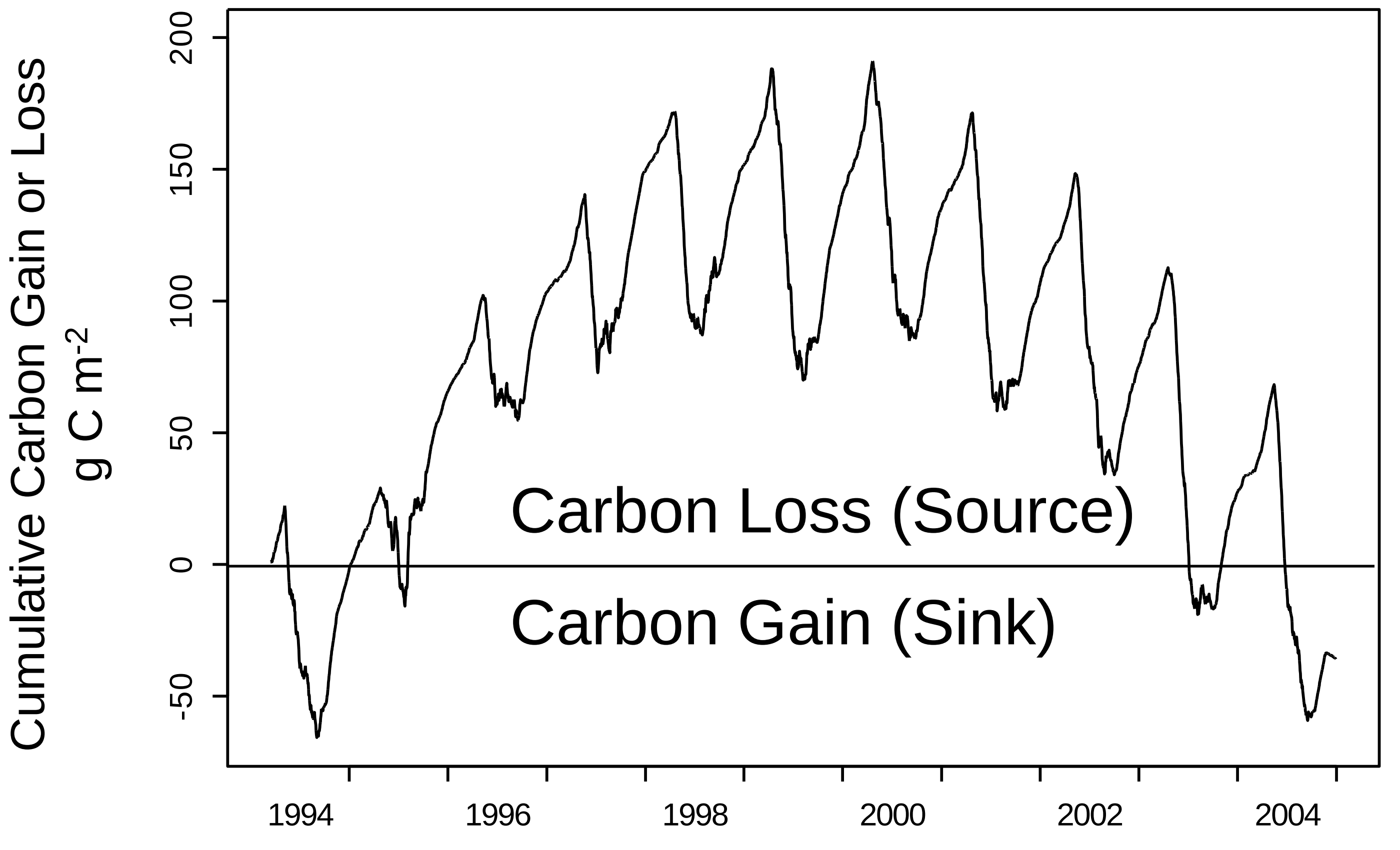
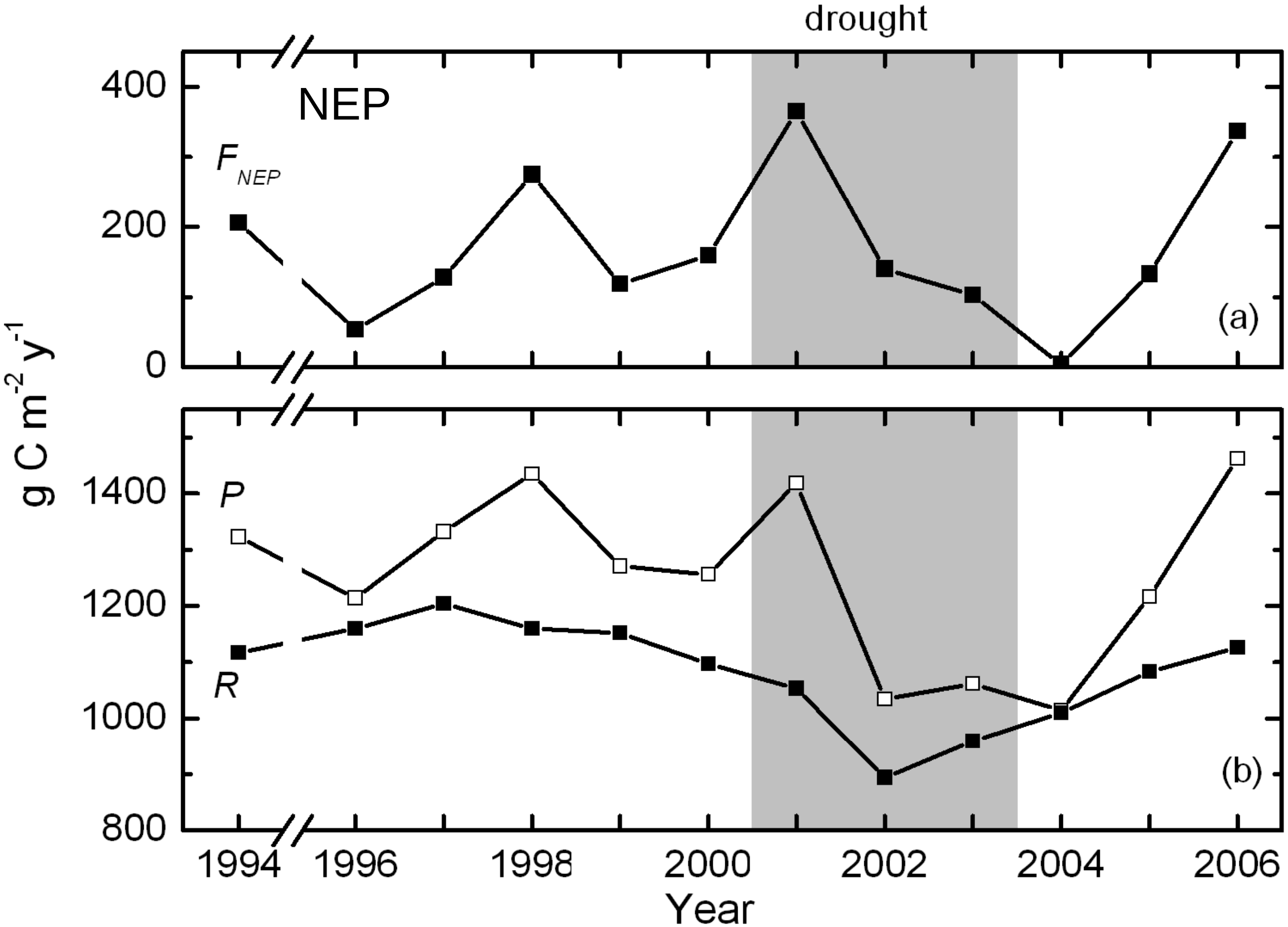


(Wofsy et al. Harvard)

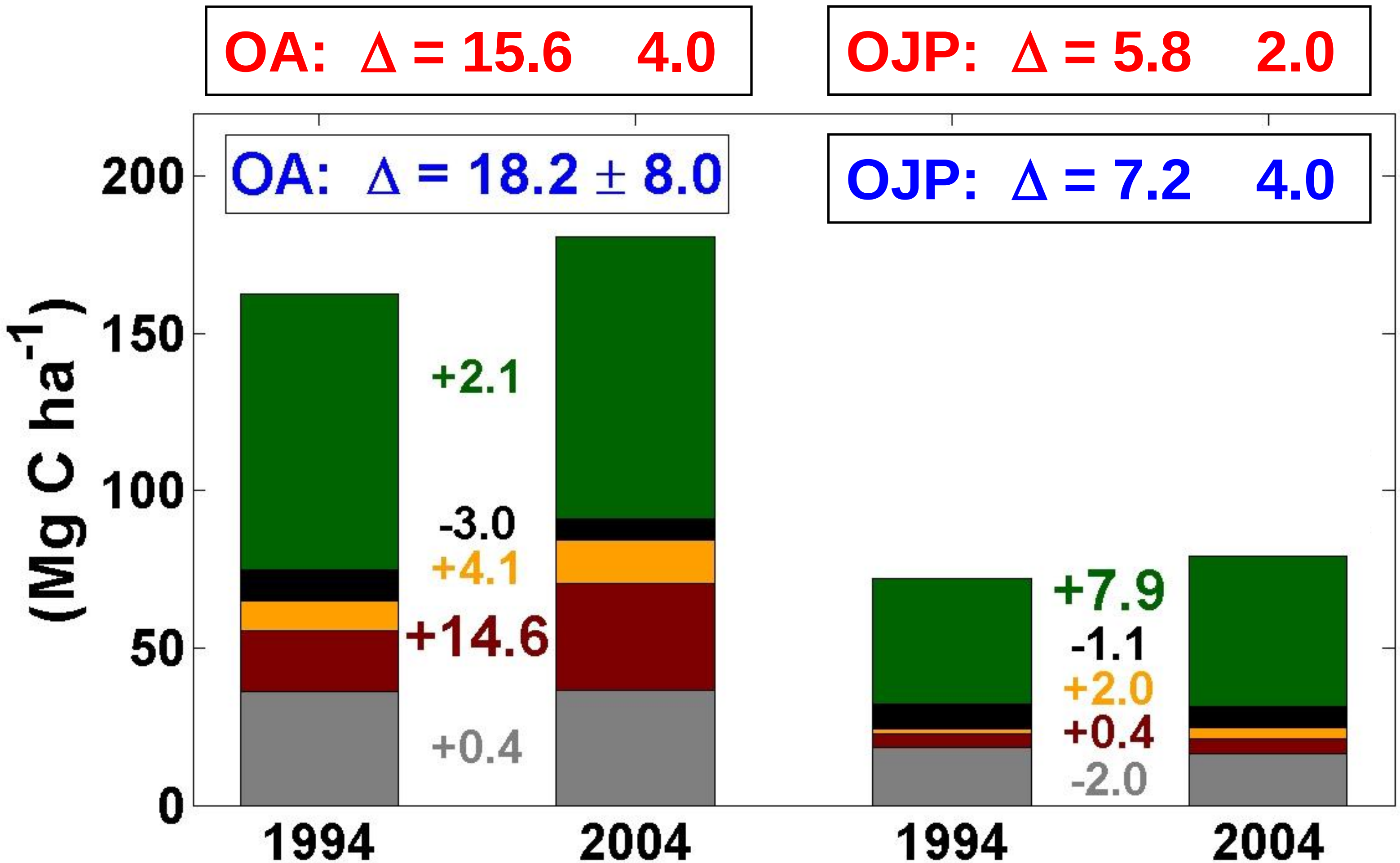
Old Aspen, Saskatchewan



Measured Carbon Stock Changes

BERMS SOA and SOJP Sites, 1994 to 2004

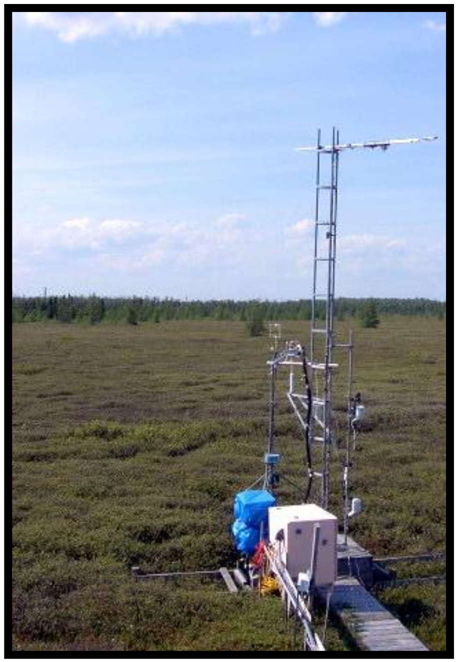
Vis-à-vis Eddy-Covariance NEP ($Mg\ C\ ha^{-1}$):



(Theede, Barr, Black, McCaughey, Gower)

Peatlands

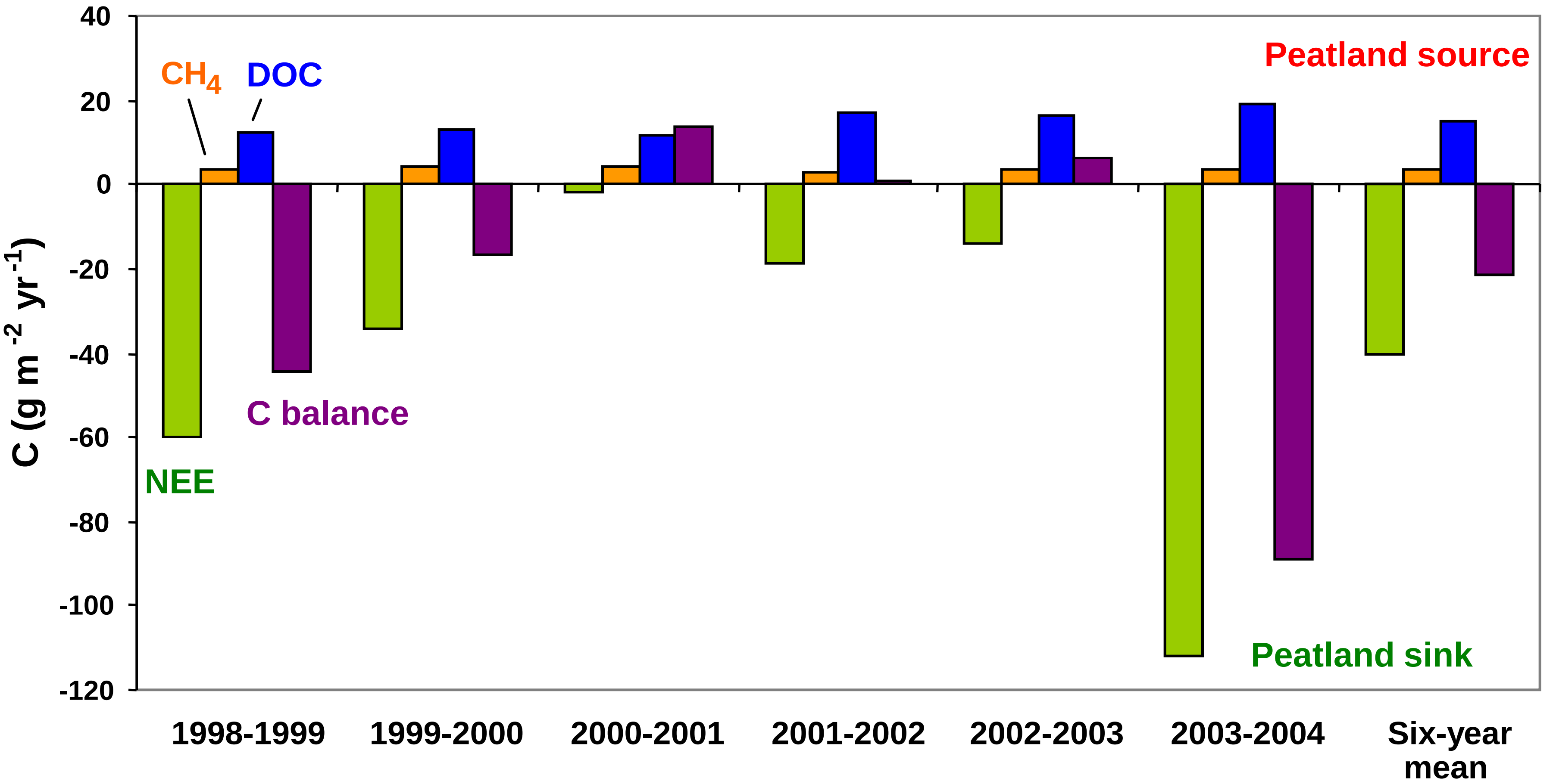
Ombrotrophic Shrub Bog (EP), Ontario



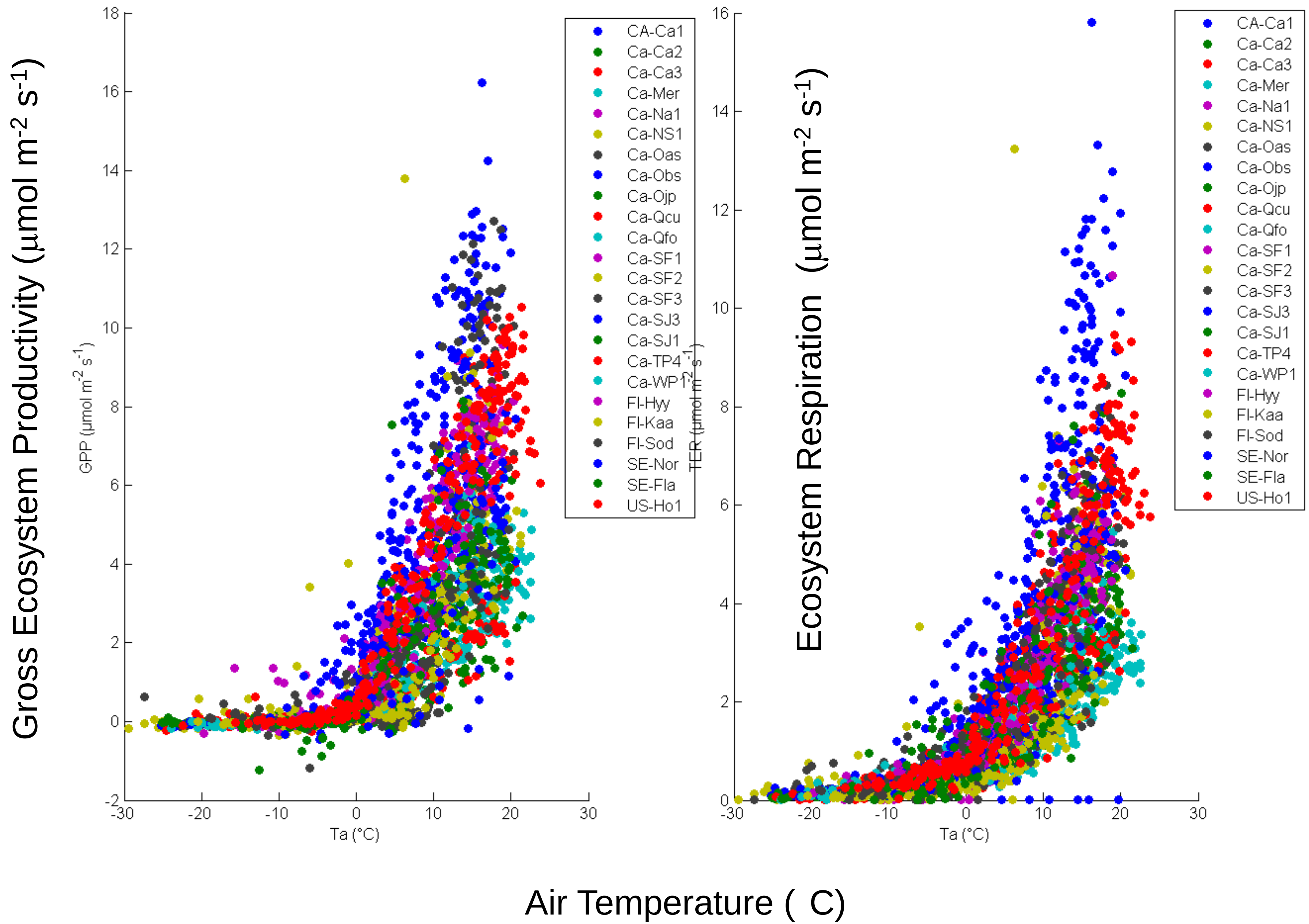
Drought-Prone Southern Fen (SFEN), Sask.

Minerotrophic Treed Fen (WP), Alberta

Six-year C balance of the Mer Bleue Peatland



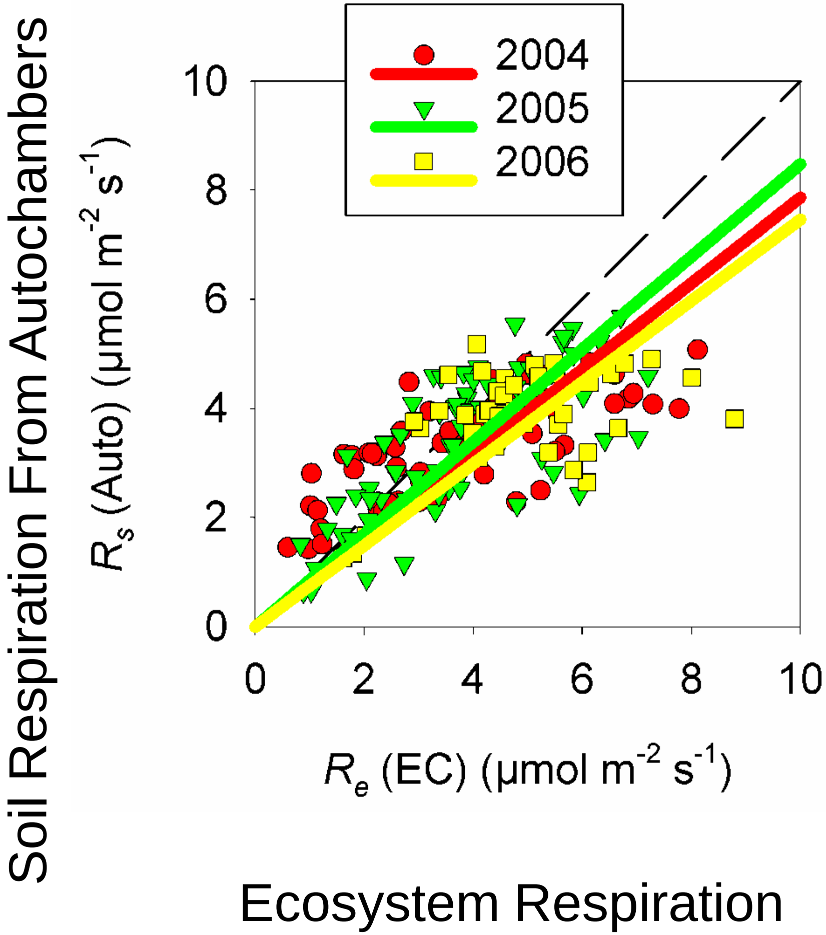
Boreal Forests in Canada, US, Finland, and Sweden



OTHER USEFUL SYSTEMS

Automated Chamber
ForestFloor CO2 Exchange

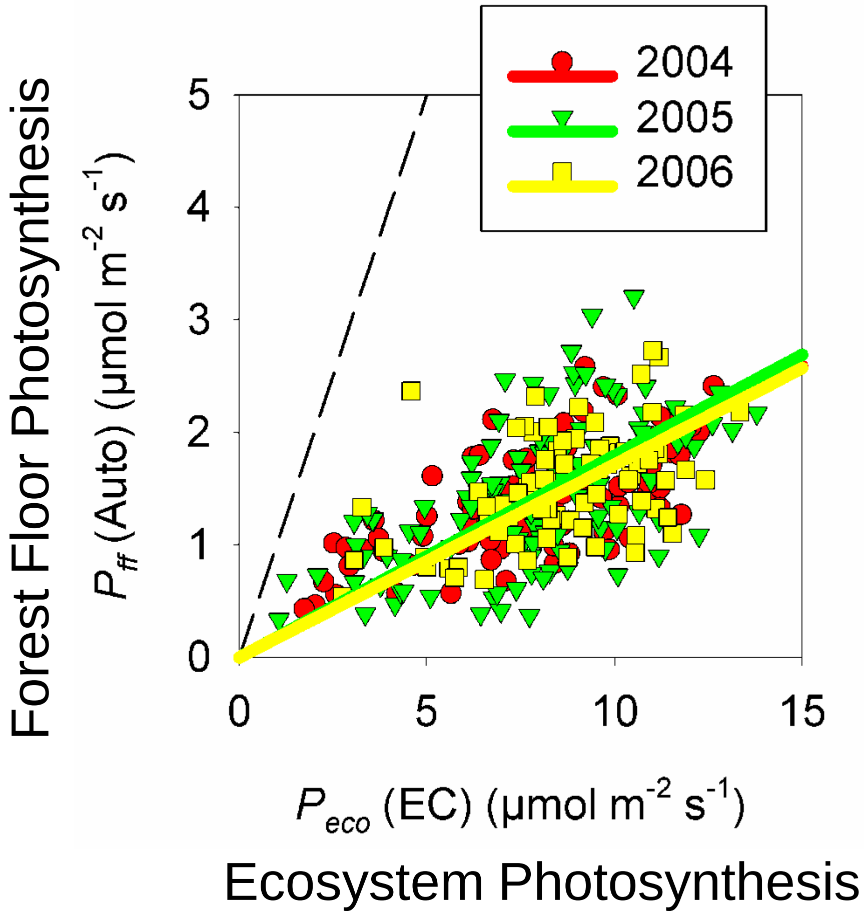
Forest Floor Gas Exchange
Mature Site



Slope = ~0.8 to 0.9

The soil accounts for ~80% to 90% of ecosystem respiration at EOBS

Forest Floor Gas Exchange
Mature Site



Slope = ~0.2

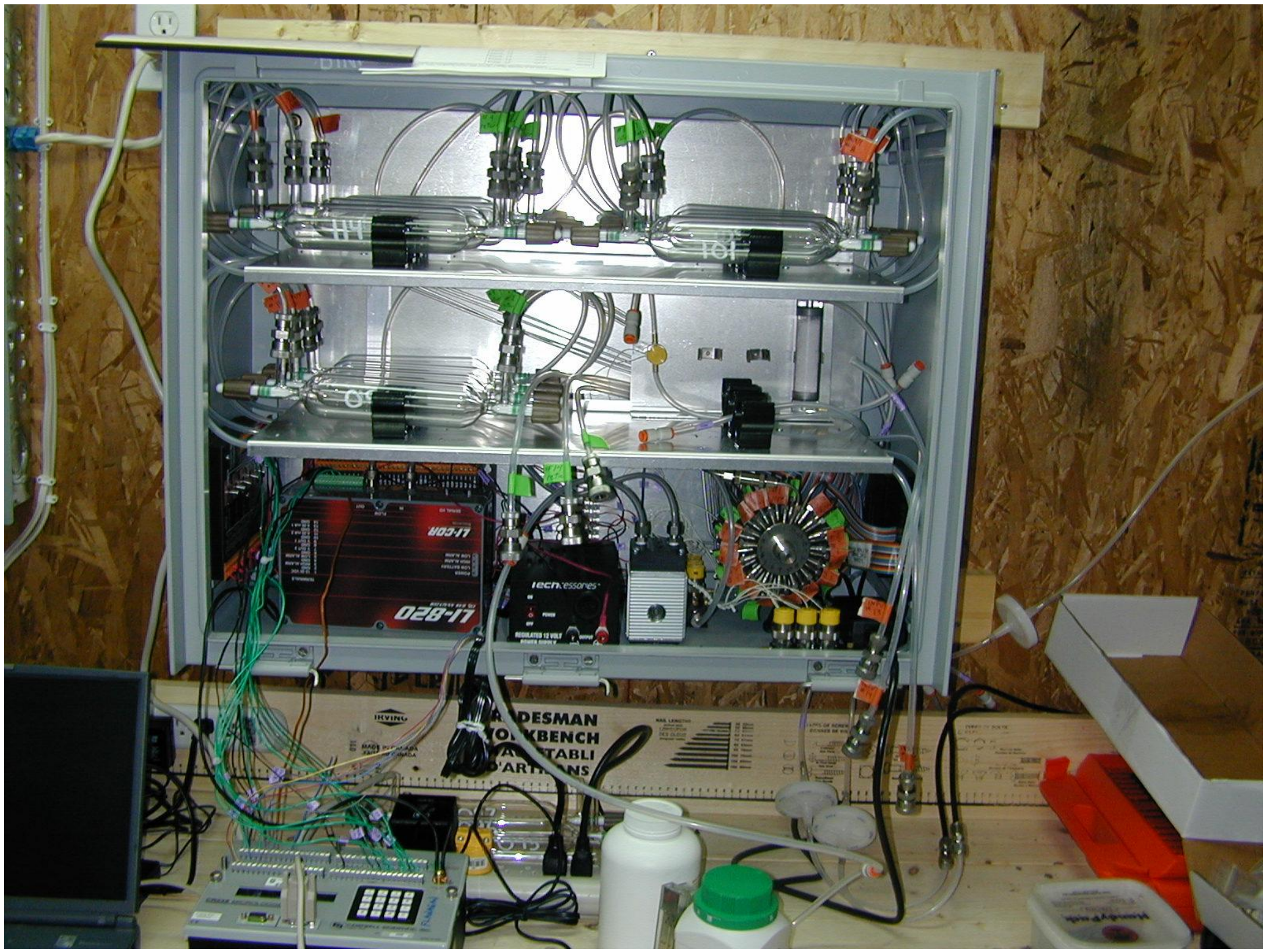
The forest floor accounts for ~20% of ecosystem photosynthesis at EOBS.

Other Systems

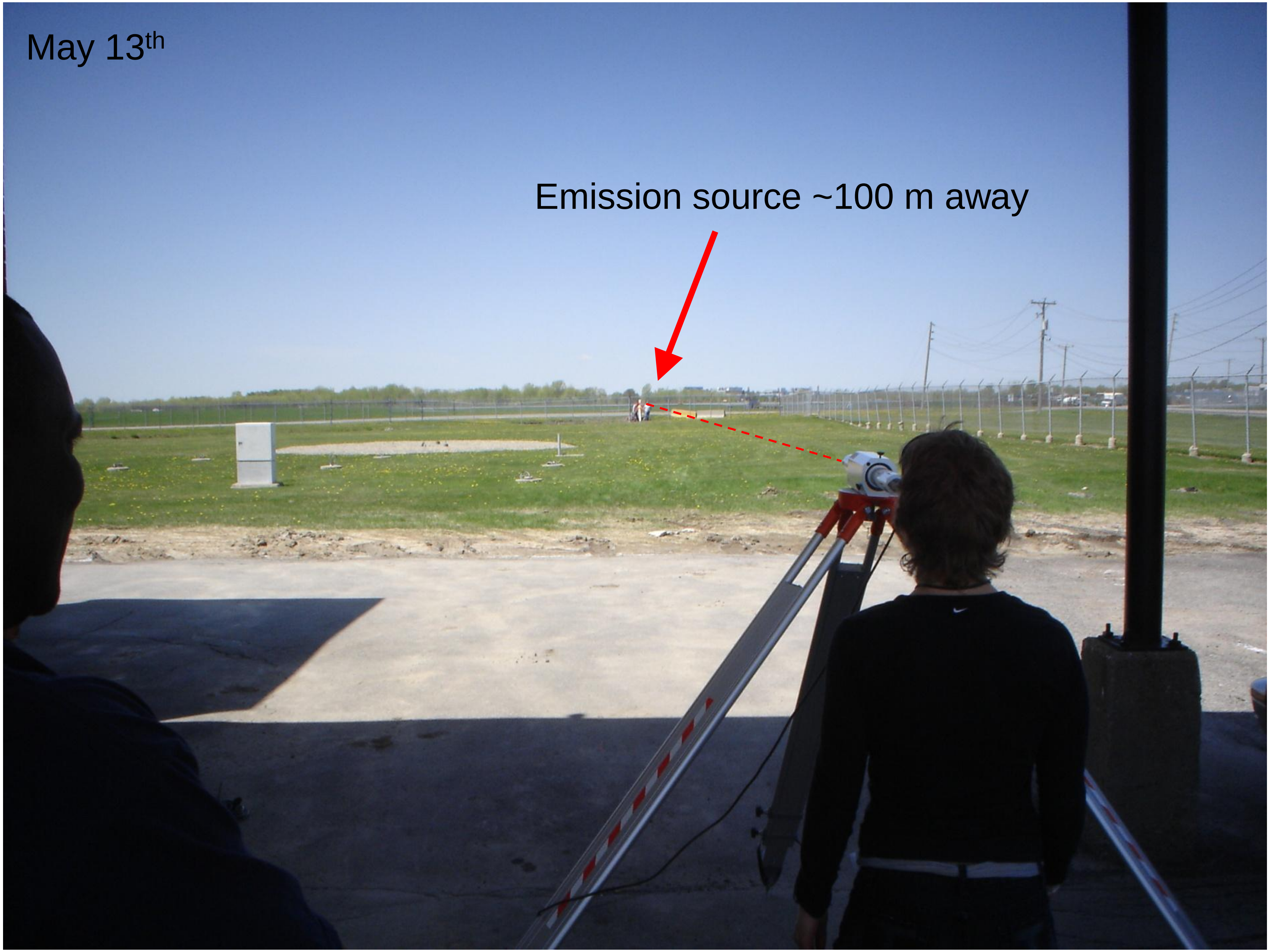
LI-8100

LI-6400XT

Automated Air Sampling Robot Isotope Analysis

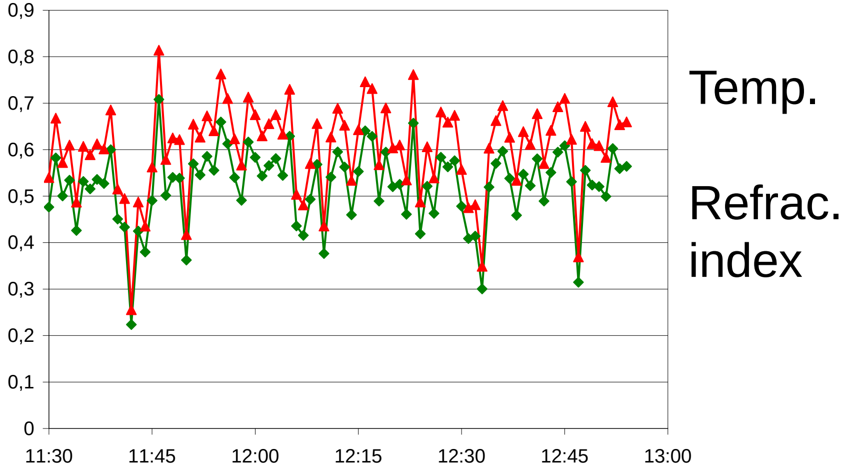


Informations from scintillometer

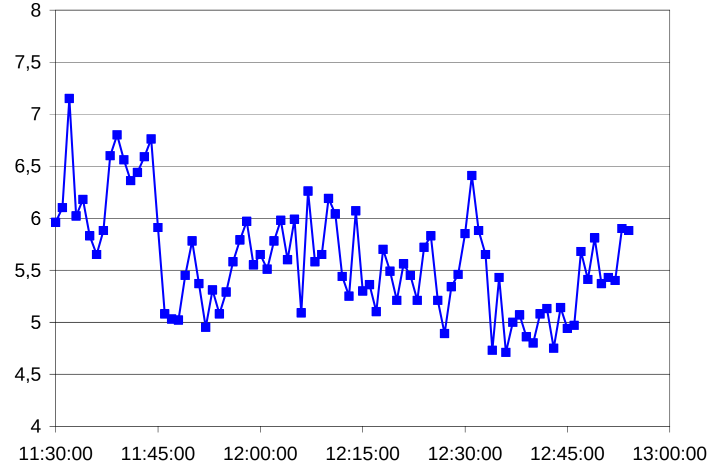


Informations from scintillometer

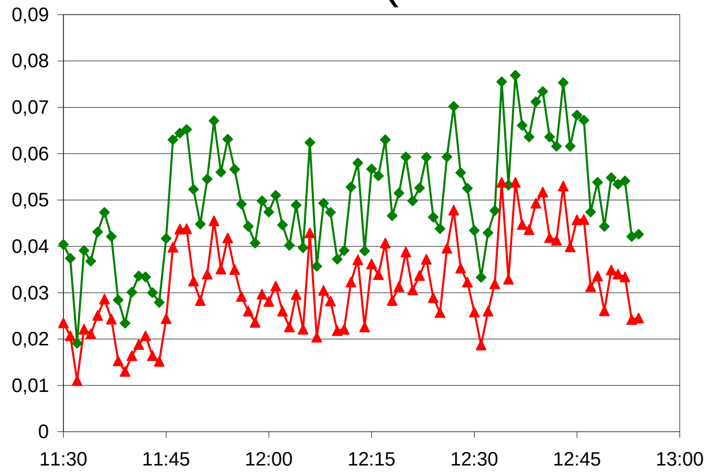
Structure function constant



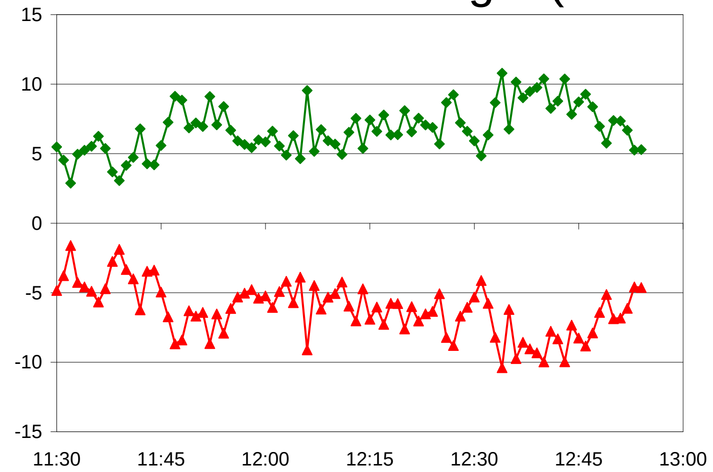
Inner scale refrac. index



Momentum flux (stable/unstable)



Monin-Obukhov length (stable/unstable)



Informations from scintillometer