Combination of different techniques and multi-scale approach to understand CO_2 budget in a temperate beech forest

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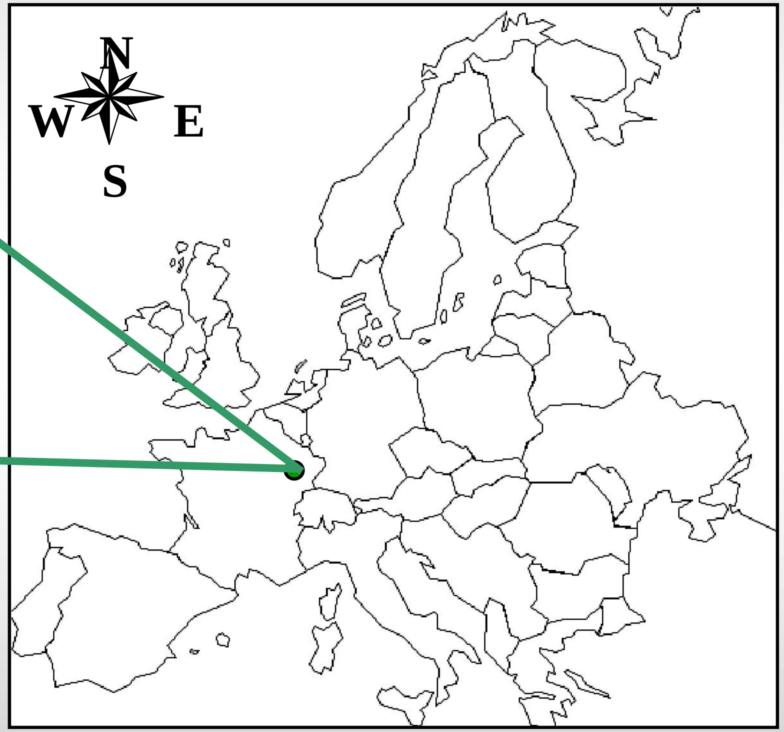
Context

Quantification C storage

Understanding C processes

European Beech (*Fagus Sylvatica*), French forest

Hesse site



Location

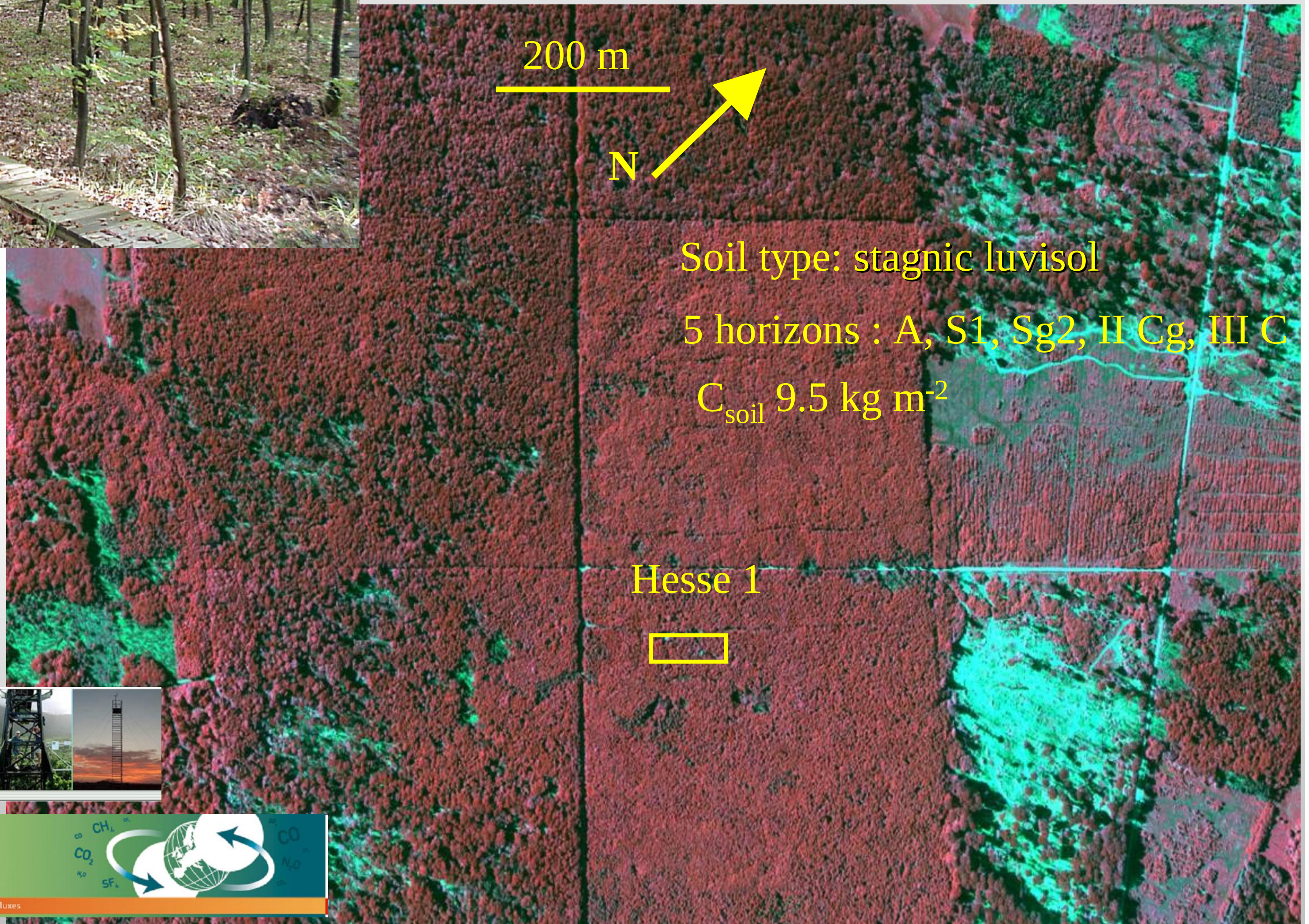
- 48°40’N, 7°05’E
- 65 km from Nancy (East)

Climate

- **Temperate**
- **Mean annual air Temp. : 10°C**
- **Mean annual Precip. : 950 mm**

Hesse site

- 90% beech
- 42 years old
- Height 19 m
- LAI : 7.5 -5
- Density ≈ 3000 n ha^{-1}
- Aerial biomass ≈ 100 t ha^{-1}



Material

IRGA (CO2)

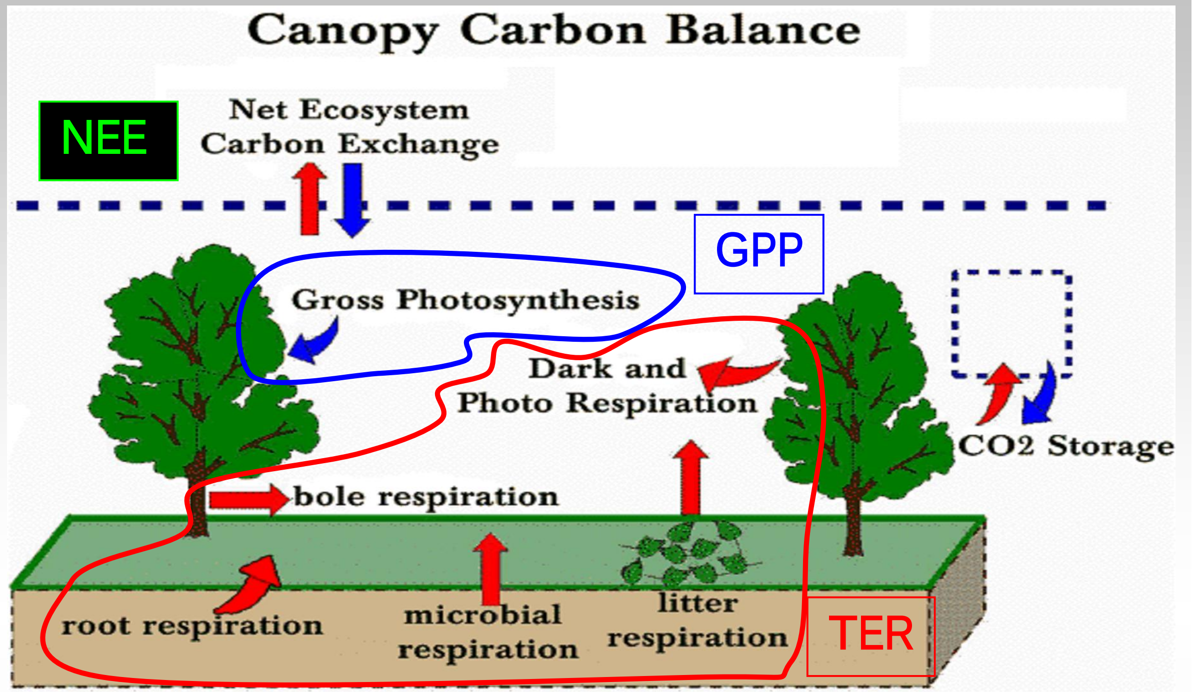
Automatic measurements :

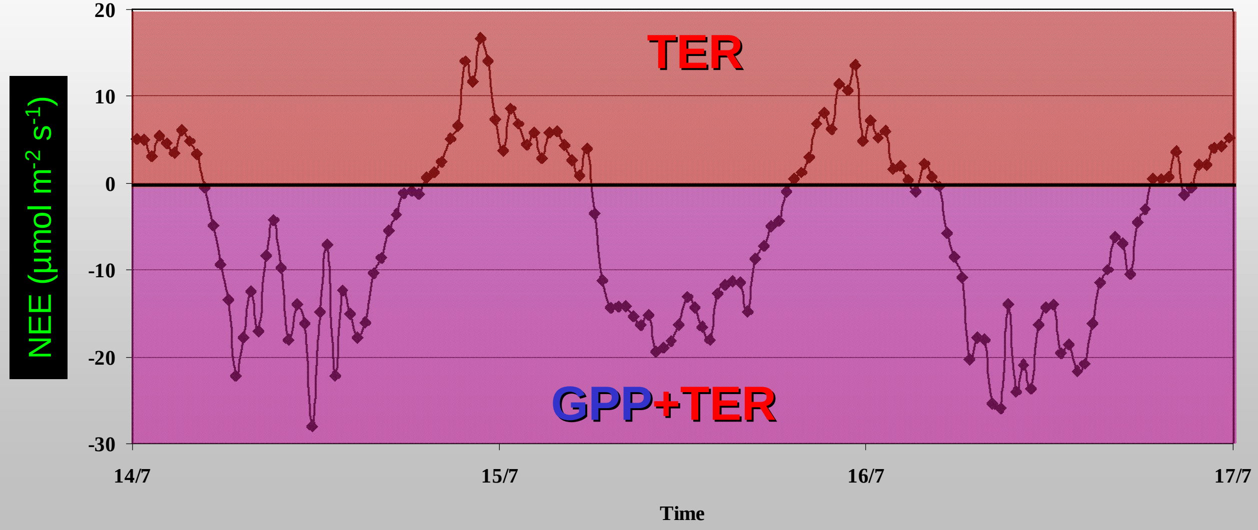
- Net Ecosystem Exchange NEE (Eddy Cov., 30 min)
- Micro-climate (T°, radiation, humidity, precipitations)
- Soil T° and water content
- Trunk circumferences (dendrometers) C biomass

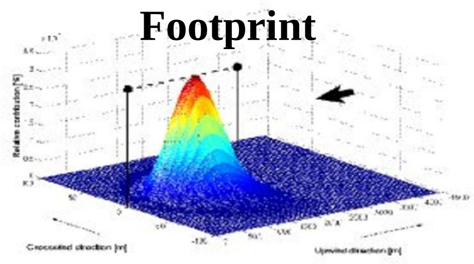
Measurement campaigns :

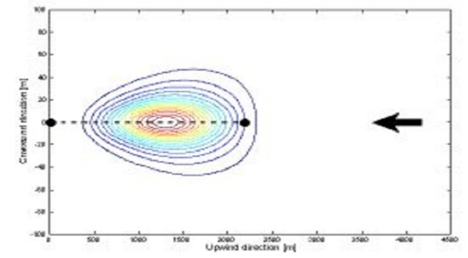
- Soil Respiration (Rs)
- LAI
- Aerial (Stems, leaves, fruits,…) and below ground (roots) Biomass
- Soil composition & characteristics (density, C & N contents…
- $\delta^{13}C$ of sampled materials (IRMS) and gaz (TDLS + IRMS)

NEE measurements









NEE partitioning : GPP – TER

GPP & TER have difference in response to changes in environnemental conditions

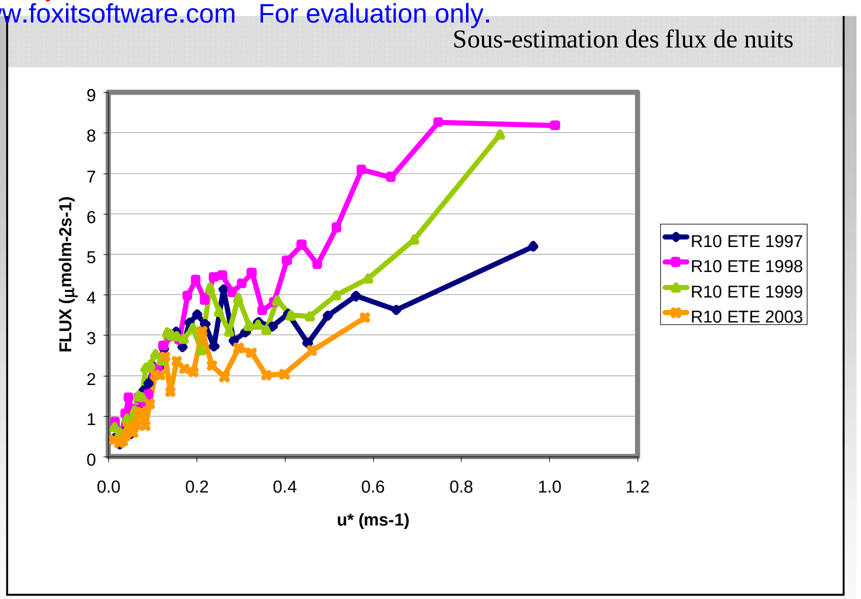
NEE partitioning

1st approach:

1. TER (t°, SWC) determination from night and leafless data
2. TER (t°, SWC) extrapolation to leafy daytime
3. Daytime :
   GPP = NEE (data) – TER (extrapolation)

2nd approach: Combining 2 equations

1. NEE = GPP + TER
2. NEE $*\delta^{13}C_{NEE}$ = GPP $*\delta^{13}C_{atm}$ + TER $*\delta^{13}C_{TER}$



1st Approach Uncertainties

EC anomalies

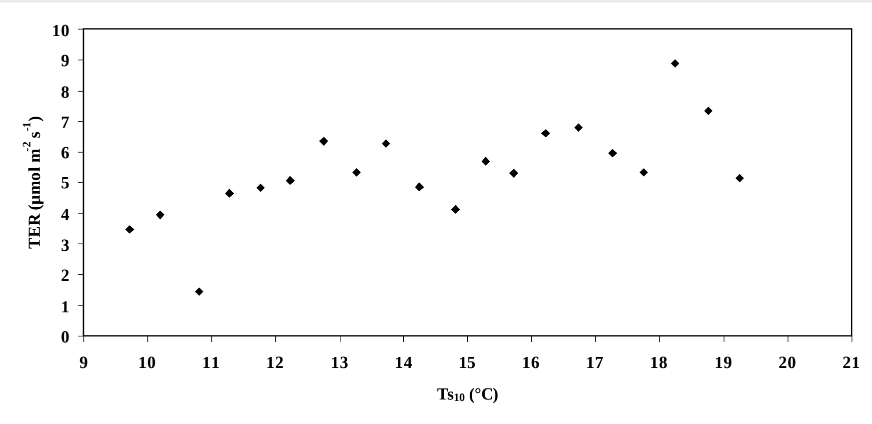
Low turbulence (u*<<) periods

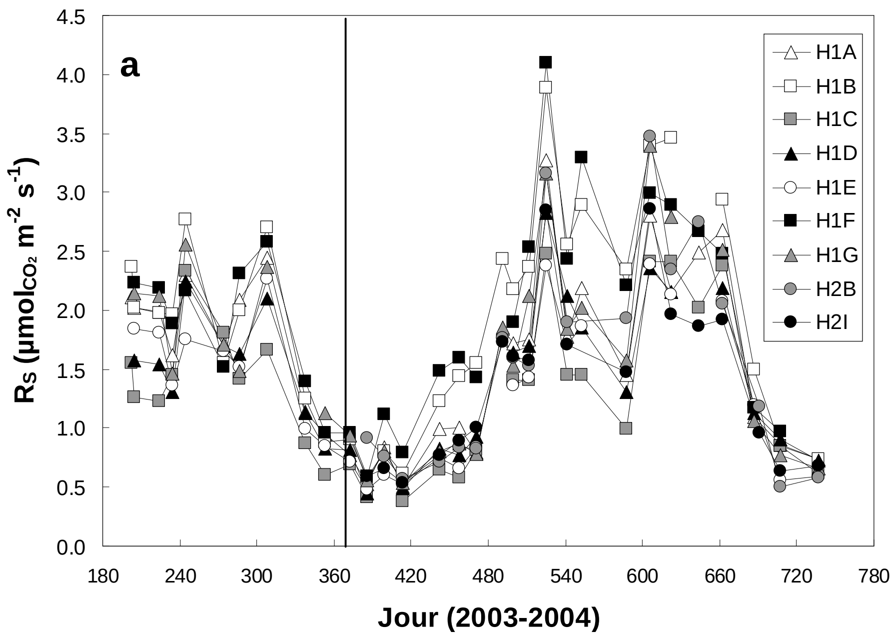
Large uncertainty on TER (t°, SWC)
TER (Ts_{10}, SWC_{10}): $R^2 < 0.1$
(Longdoz et al., 2008)

Footprint fluctuations (WD, WS, u*)
+
TER (Rs) spatial variability

TER (Ts_{10}, SWC_{10}) validity

Improvement Rs model





Rs spatial variability

$$R_s = R_{10} \cdot Q_{10}^{\left(\frac{T_{10}-10}{10}\right)} \cdot \exp(-\exp(a - b \cdot SWC))$$

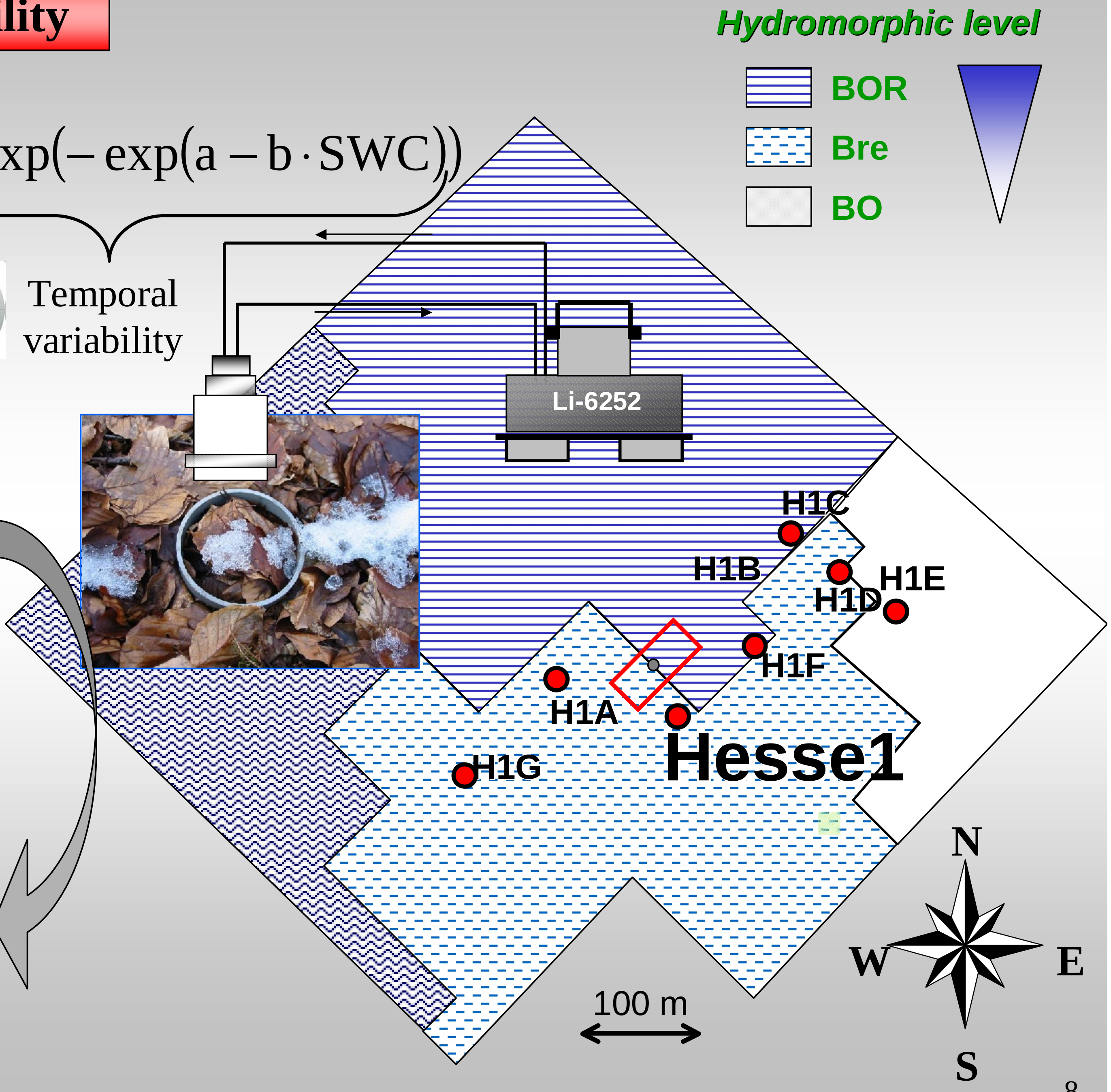
Temporal variability

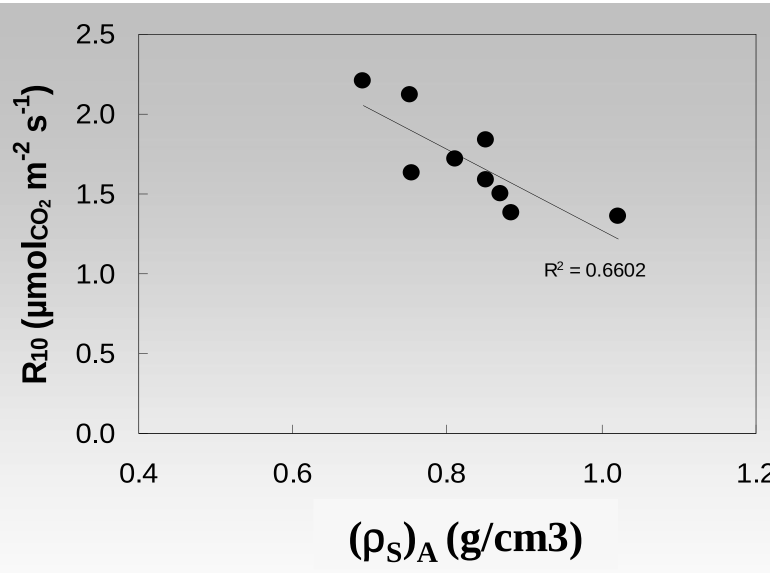
Above & belowground characteristics

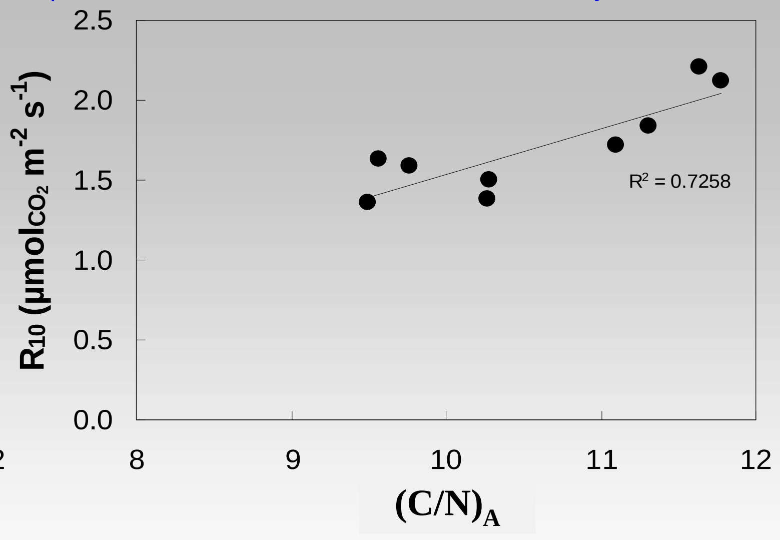
$(\rho_S)_A$
soil bulk density of the A layer

&

$(C/N)_A$
ratio of carbon to nitrogen content of A layer





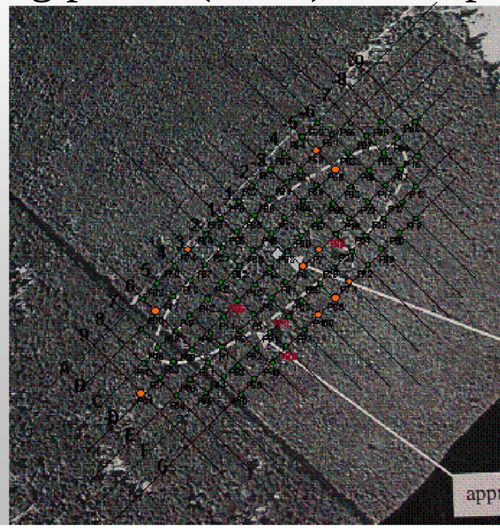


$$R_{10} = -1.47 \cdot (\rho_S)_A + 0.19 \cdot \left(C/N\right)_A$$

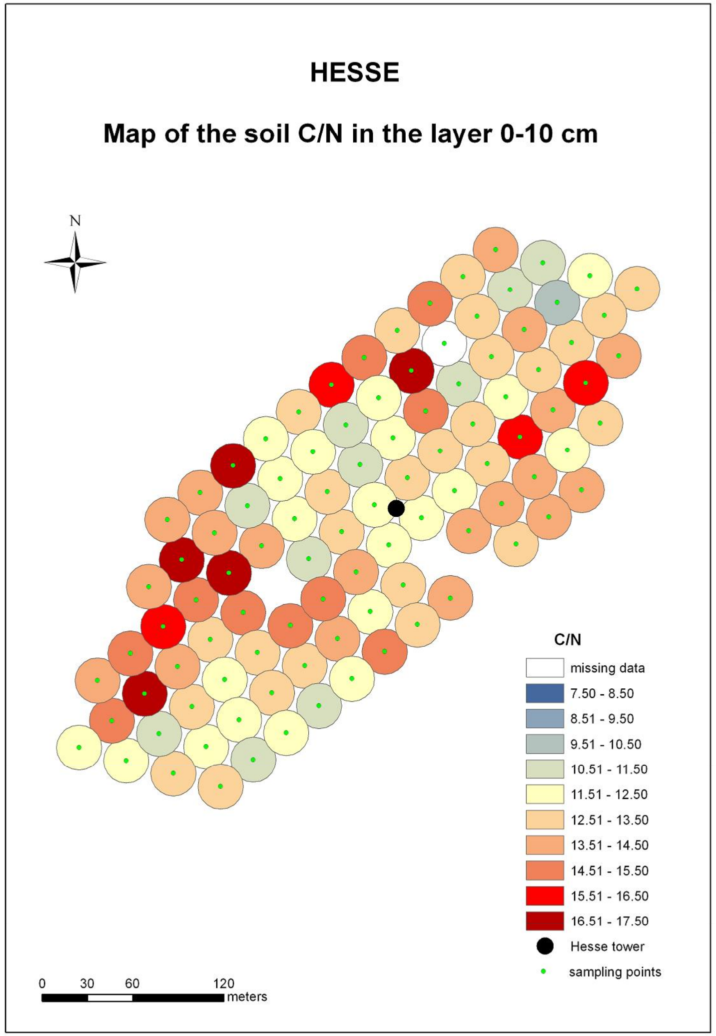
(R^2 = 0.87)

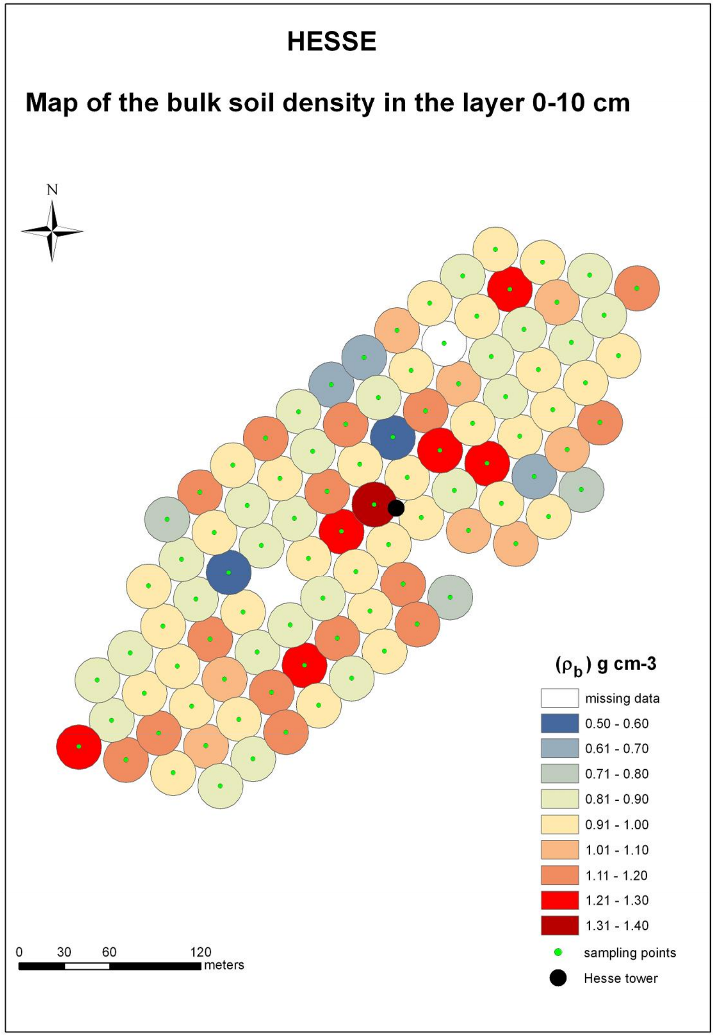
Soil sampling for **$(\rho_S)_A$** and **$(C/N)_A$** mapping

Soil sampling points (>100) in footprint area



Rs spatial variability





$$R_{10} = -1.47 \cdot (\rho_S)_A + 0.19 \cdot \left({}^{C}\!/_{N} \right)_A$$

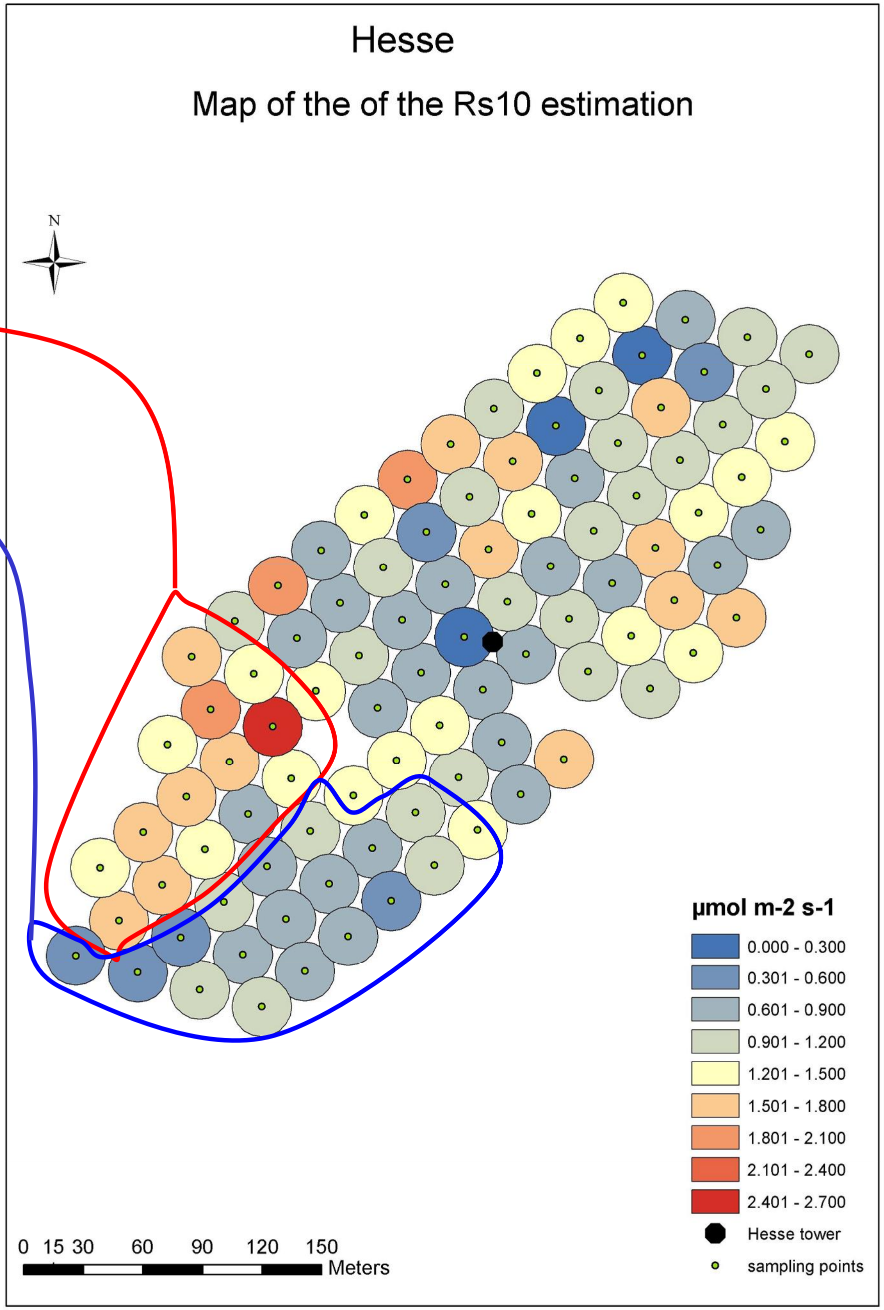
Rs spatial variability

"Hot area" at West-South-West

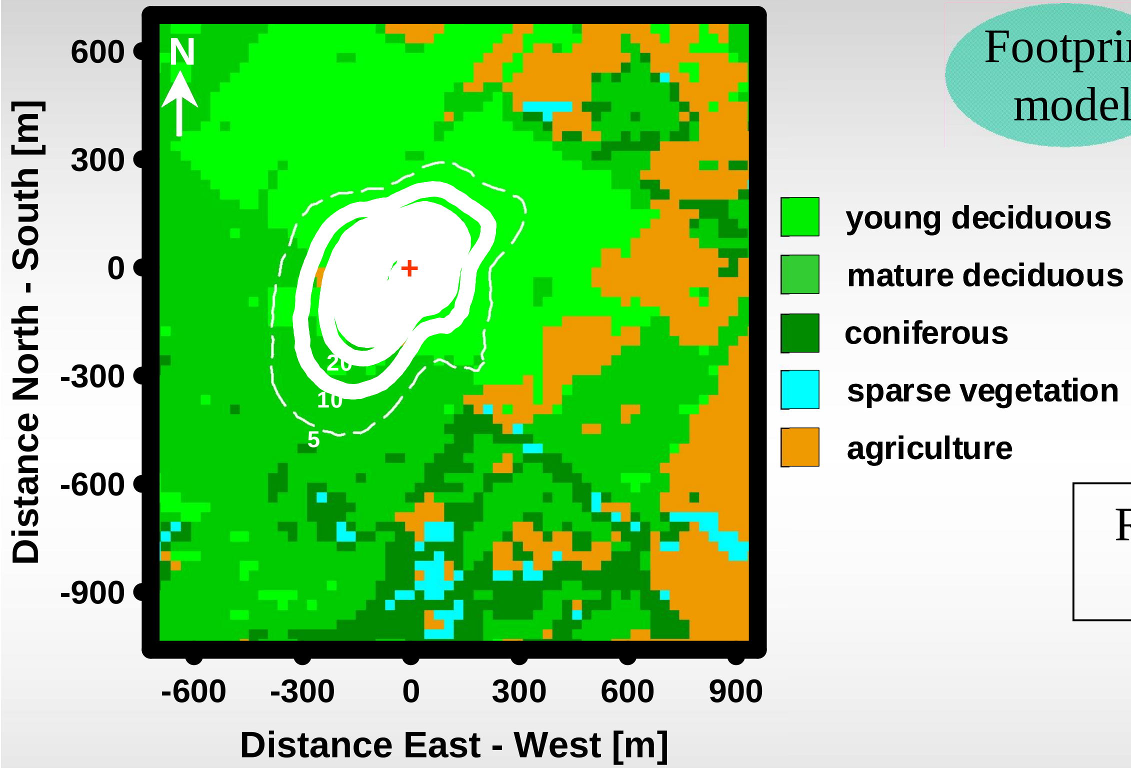
"Cold area" at South-West

Confirmed by first analyse of EC-TER data

ANOVA with 45° Sectors
significant difference (p=0.029)



Rs spatial variability



R_{10} map

T°s & SWC

Footprint model

Rs map

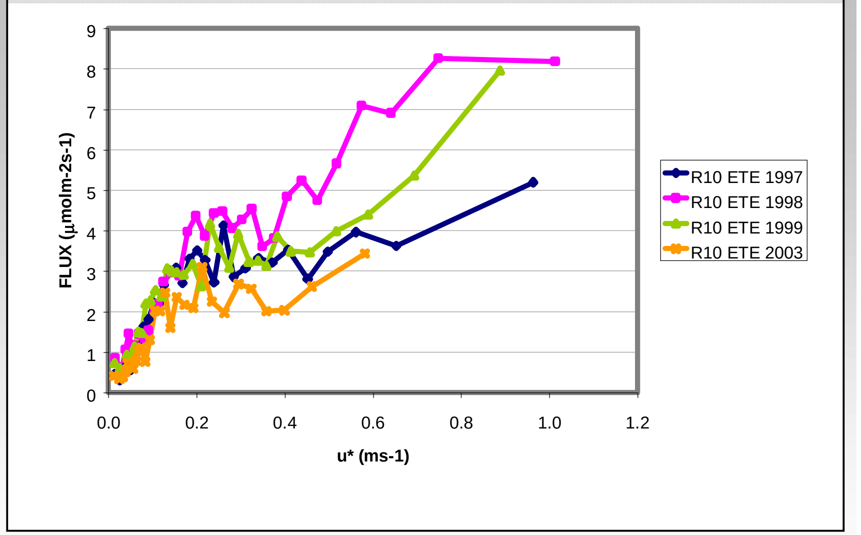
Rs contributions to TER

Estimations of TER temporal fluctuations due to Rs spatial variability

Rs spatial variability

1st Approach Uncertainties

Sous-estimation des flux de nuits



Large uncertainty on TER (t°, SWC)
TER (Ts_{10}, SWC_{10}): $R^2 < 0.1$
(Longdoz et al., 2008)

Footprint fluctuations (WD, WS, u*)
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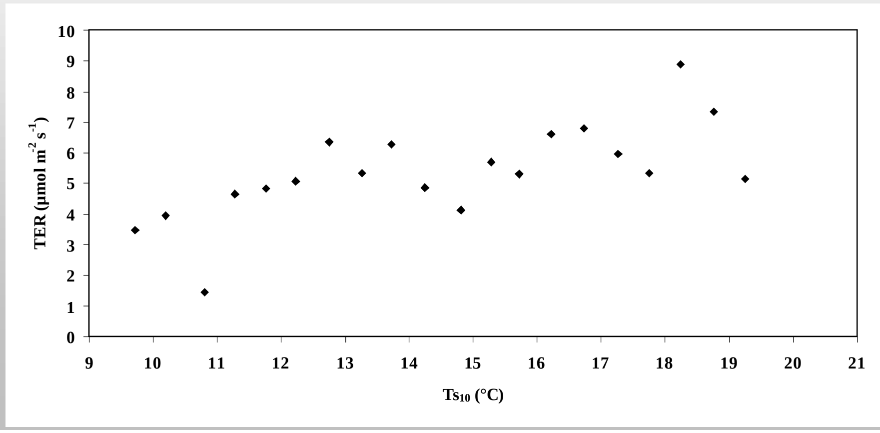
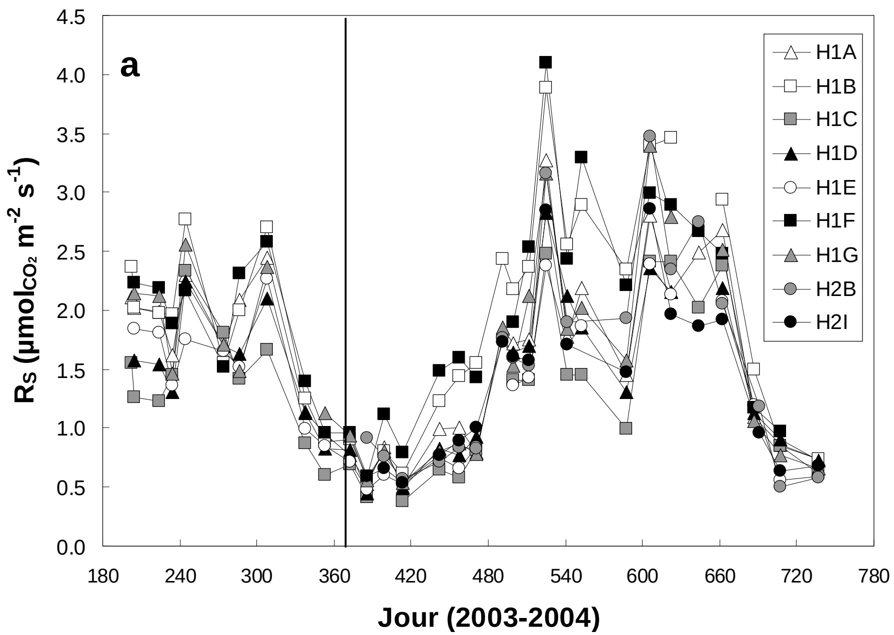
Improvement Rs model

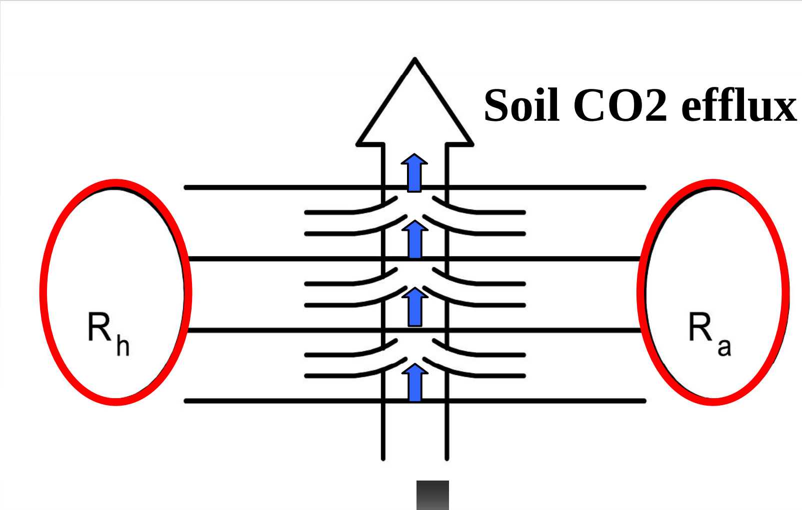




Improvement of Rs model

Also necessary to have better understanding of the C processes in forest

Differentiate
Production & Transport



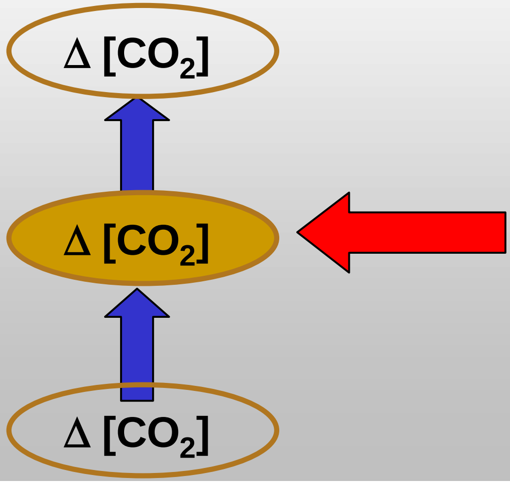
Better description of the **Production** processes

Differentiate sources and their behaviour

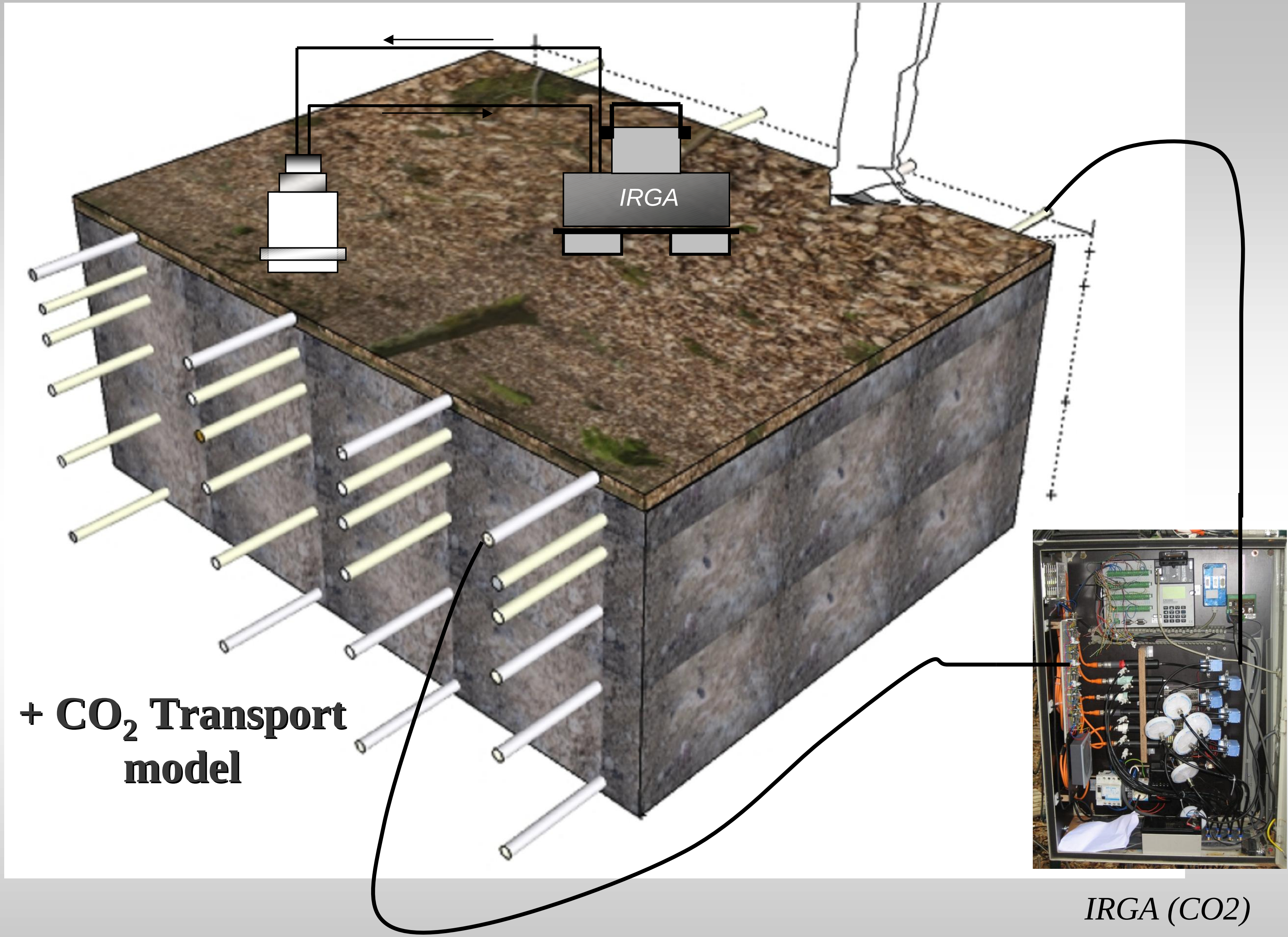
Important vertical profile

response to environmental conditions

Better description of the **Transport** processes



Need for CO_2 concentration measurements in the different layers



+ CO_2 Transport model

IRGA (CO2)

To be continued in the Caroline Plain Talk

Improvement of Rs model

2nd Approach Uncertainties

2nd approach: Combining 2 equations

1. NEE = GPP + TER
2. NEE $*\delta^{13}C_{NEE}$ = GPP $*\delta^{13}C_{atm}$ + TER $*\delta^{13}C_{TER}$

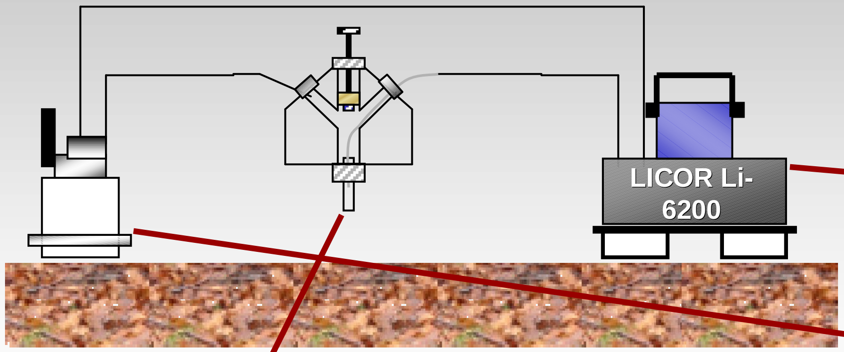
Large uncertainty on $\delta^{13}C_{TER}$ (EC)

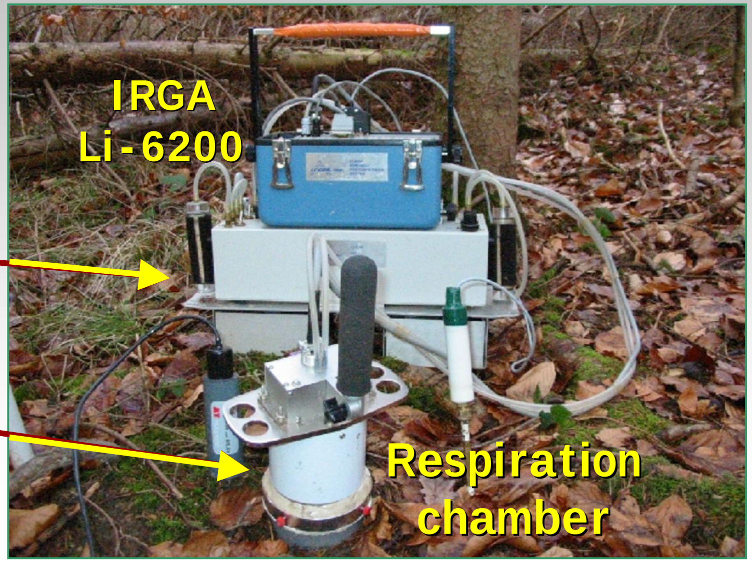
Footprint fluctuations
+
$\delta^{13}C_{TER}$ ($\delta^{13}C_{Rs}$) spatial variability

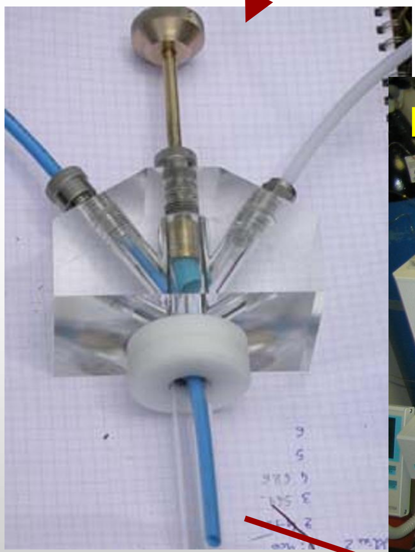
$\delta^{13}C_{TER}$ ($\delta^{13}C_{Rs}$) temporal variability

$\delta^{13}C_{Rs}$ spatio-temporal variability

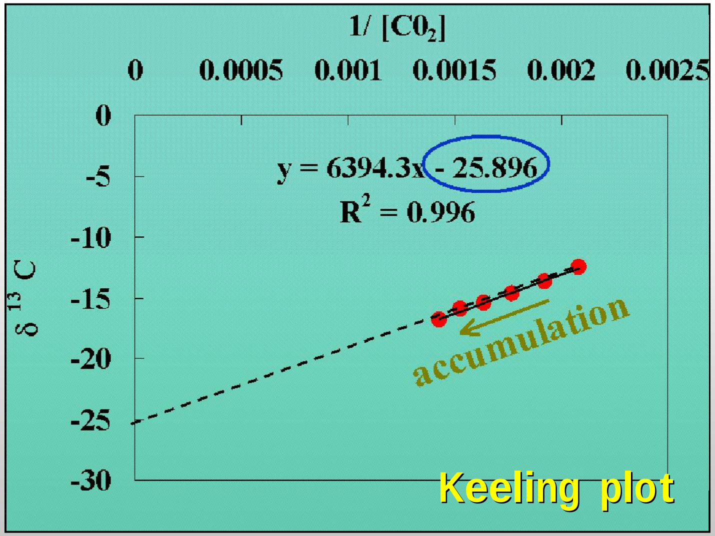
Soil Keeling Plot



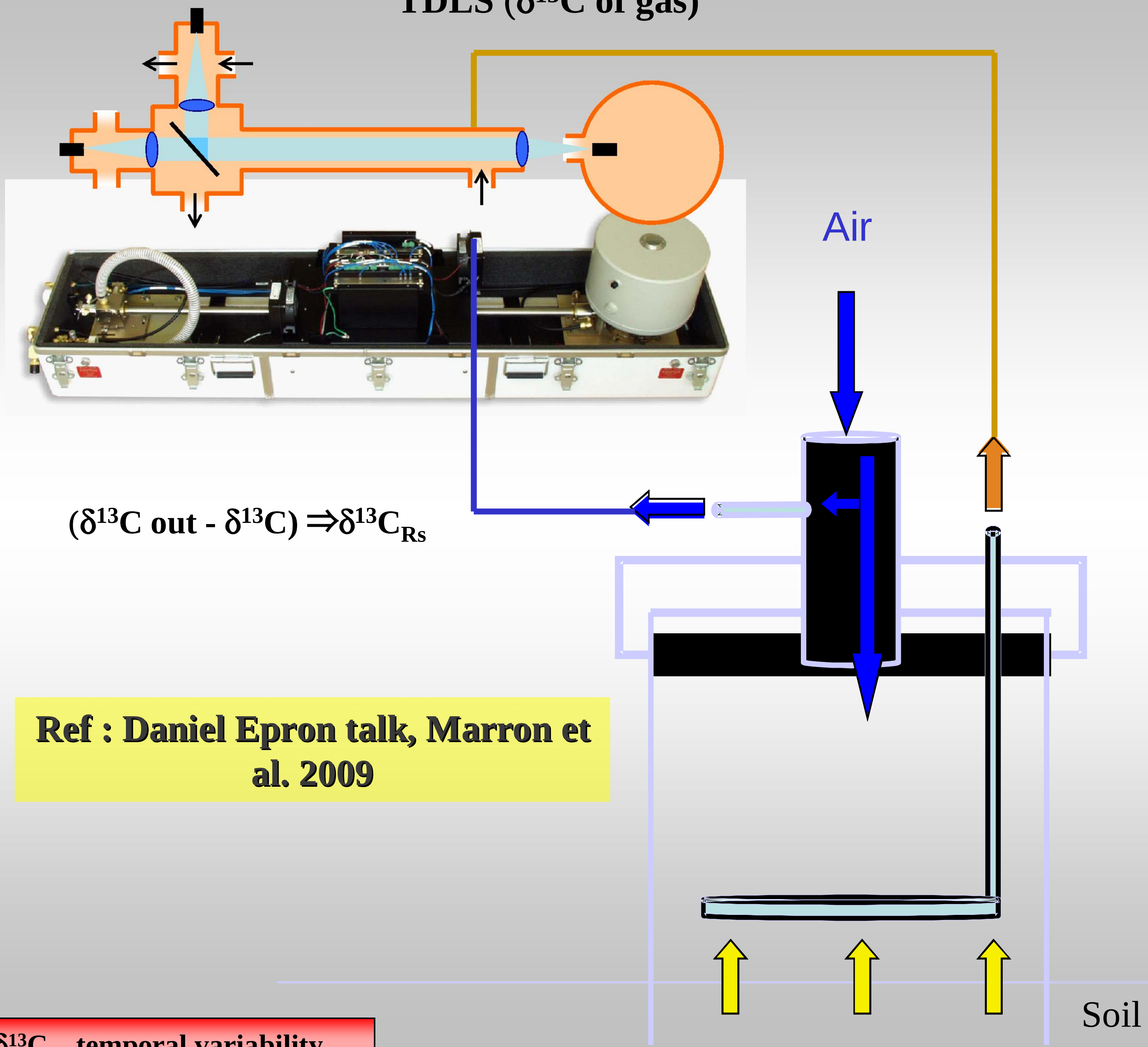




Sampling chamber



$\delta^{13}C_{Rs}$ spatial variability

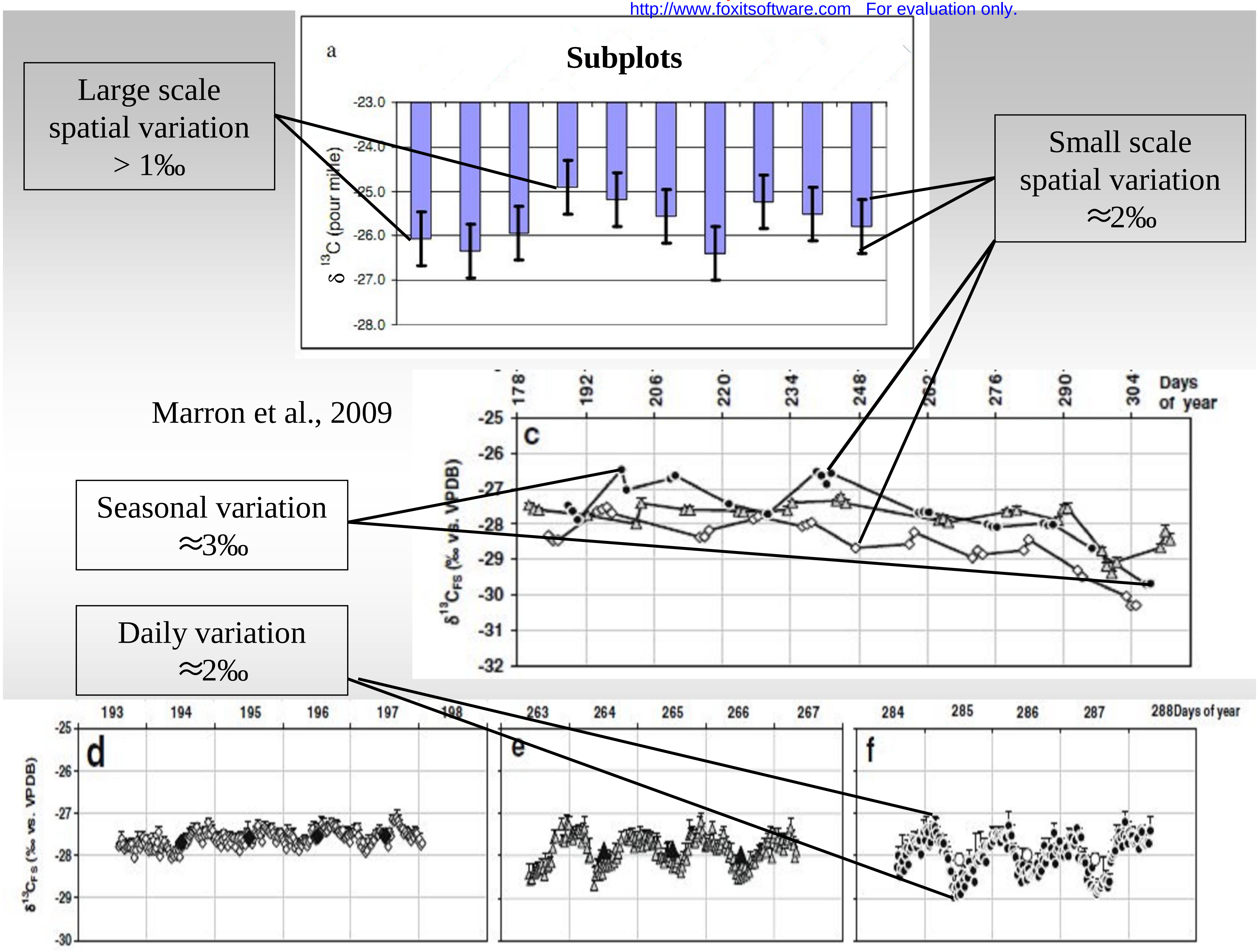


$(\delta^{13}C\ out - \delta^{13}C) \Rightarrow \delta^{13}C_{Rs}$

Ref : Daniel Epron talk, Marron et al. 2009

Soil chambers

$\delta^{13}C_{Rs}$ temporal variability


Large scale spatial variation > 1‰
a
Subplots
δ 13C (pour mille)
-23.0
-24.0
-25.0
-26.0
-27.0
-28.0
Small scale spatial variation ≈2‰
Marron et al., 2009
Seasonal variation ≈3‰
Daily variation ≈2‰
c
Days of year
178
192
206
220
234
248
276
290
304
δ 13CFS (‰ vs. VPDB)
-25
-26
-27
-28
-29
-30
-31
-32
d
e
f
193
194
195
196
197
198
263
264
265
266
267
284
285
286
287
288
Days of year
δ 13CFS (‰ vs. VPDB)

Use of $\delta^{13}C$ as tracer : C transfer, allocation-source partitioning
(Daniel Epron talk)

More knowledge about ^{13}C discriminations
(**$\delta^{13}C$ Production** & **$\delta^{13}C$Transport)**

$\delta^{13}C_{Rs}$ Spatio-temporal variations from –25‰ to -30 ‰

Complex climatic determinism
(SWC 4 to 5 days before)

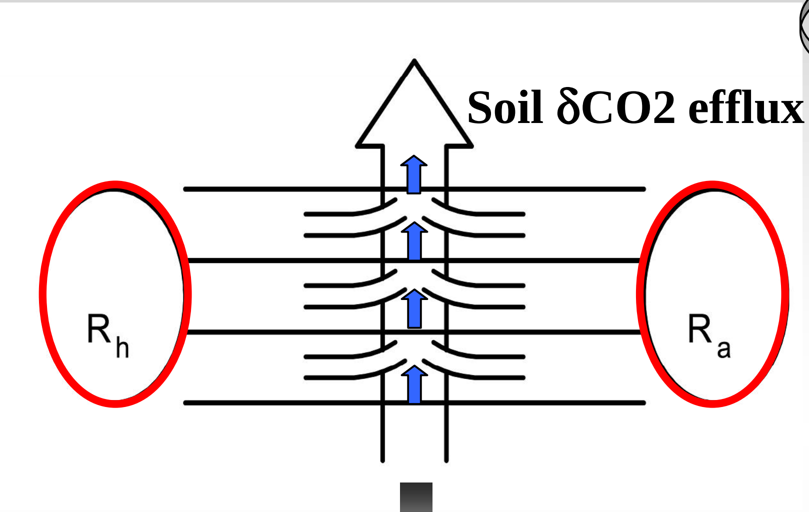
TER uncertainty of 20%

Understanding
$\delta^{13}C$ Production &
$\delta^{13}C$Transport determinism

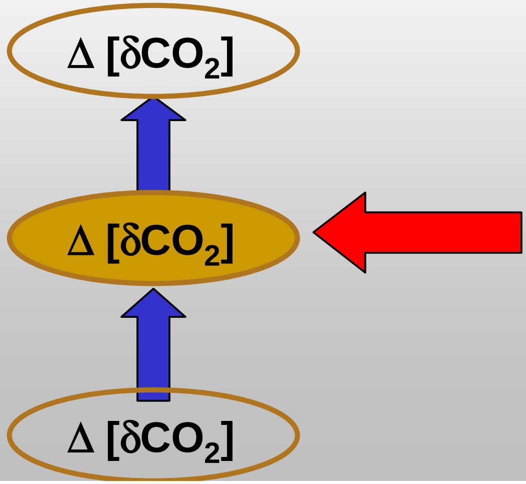
Improvement of $\delta^{13}C_{Rs}$ model

Improvement of $\delta^{13}C_{Rs}$ model

Differentiate
$\delta^{13}C$ Production & $\delta^{13}C$ Transport



Better description of the **δTransport** processes



Better description of the **$\delta^{13}C$ Production** processes

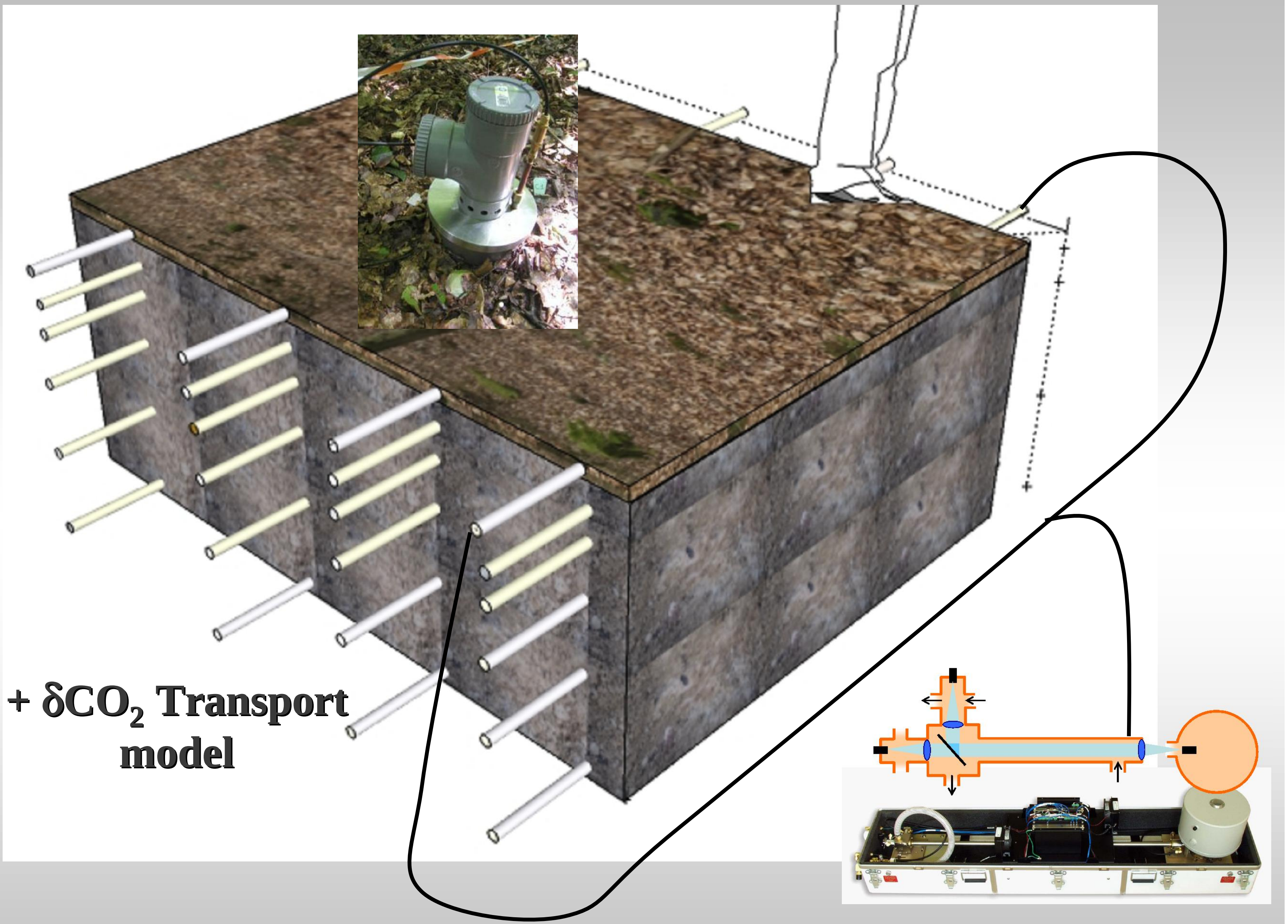
Differentiate sources and their behaviour

Important vertical profile

response to environmental conditions

Not enough information

Need for δCO2 concentration measurements in the different layers



+ δCO_2 Transport model

To be continued in the Caroline Plain Talk

Improvement of $\delta^{13}C_{Rs}$ model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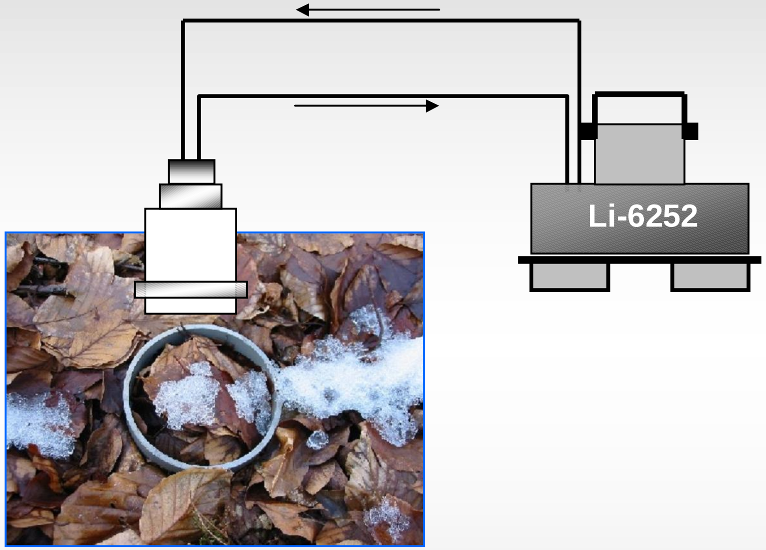
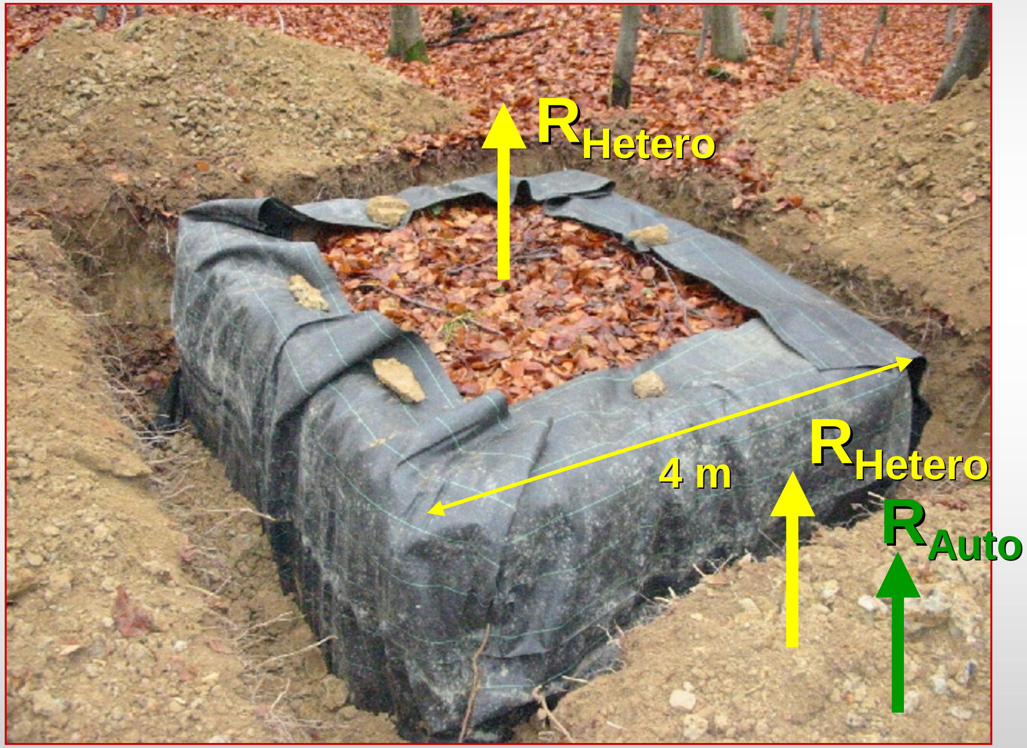
NPP from Eddy covariance (NPPec)

NPP = NEE – Rs hetero

Rs : soil chambers



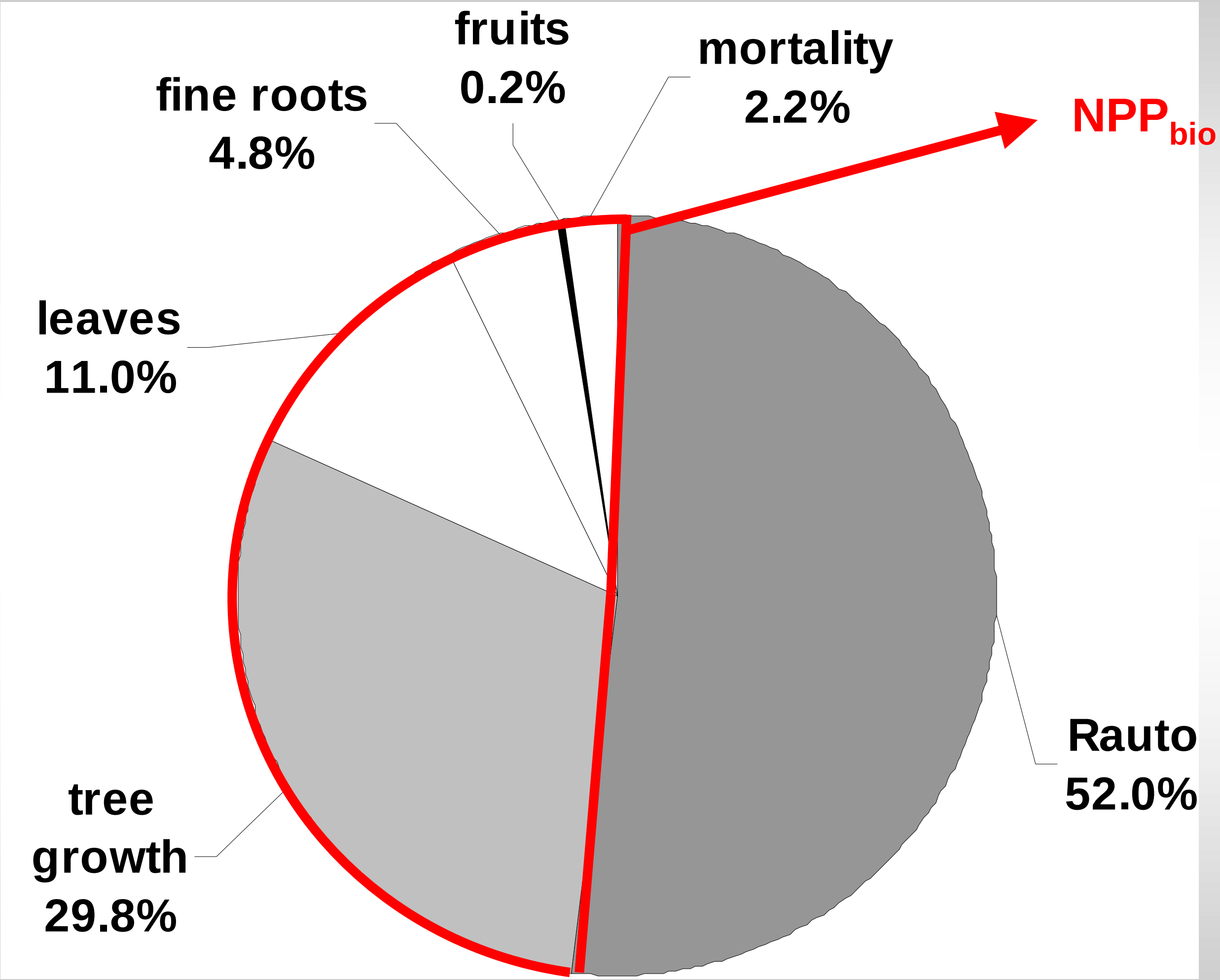
Rs autotrophic-heterotrophic partitioning: Trenched plots



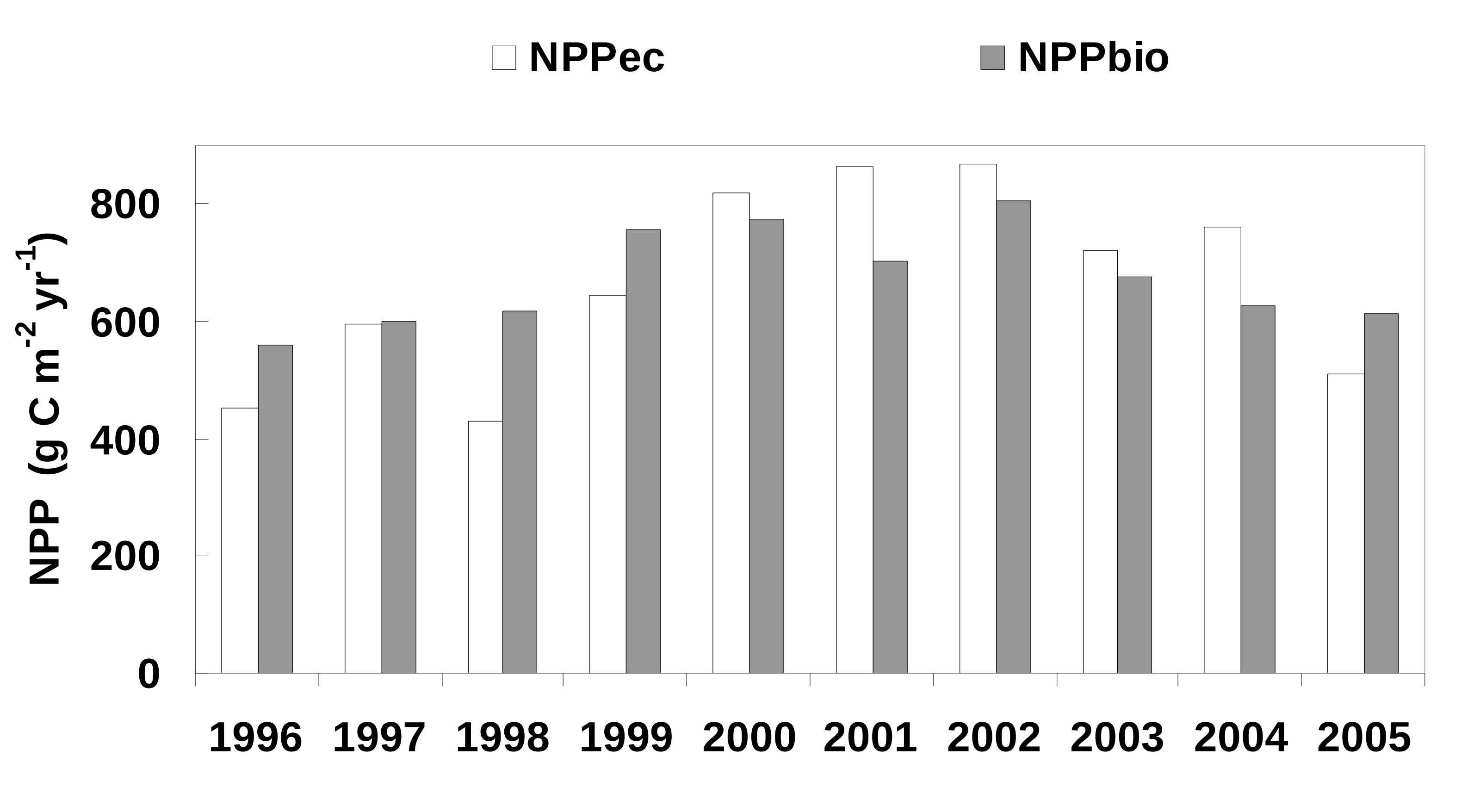
Corrections: - trenched roots decomposition
- higher SWC in trenched plot

Rauto = 69% de Rs

NPP from biomass measurements (NPPbio)



Pourcentage from GPP = 1404 gC m^{-2}



On 10 years : difference of 1%

General good reproduction of inter-annual variability but large divergences unexplained (1998 & 2001)

Work in progress on allocation (CATS) et modelling (soil)