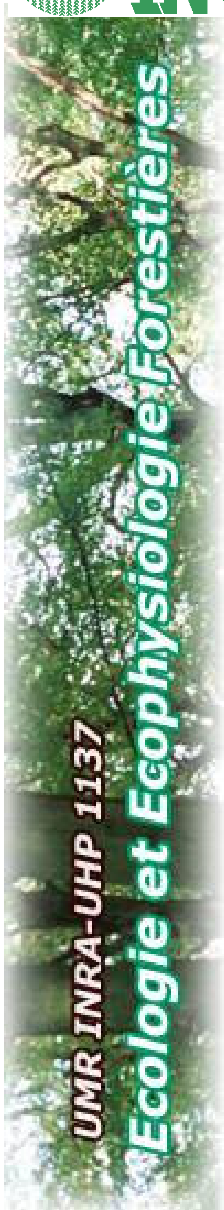
Volatile soil carbon: joint project PROCOPE

Bernard B. Longdoz, Martin Maier, Helmer Schack-Kirchner, Caroline C. Plain



VOLATILE SOIL CARBON: JOINT PROJECT PROCOPE

Bernard Longdoz, Martin Maier, Helmer Schack-Kirchner,
Caroline Plain

Bilateral project between :

Inst. Fur Bodenkunde Und Waldernahrungslehre

&

UMR Forest Ecology and Ecophysiology

+

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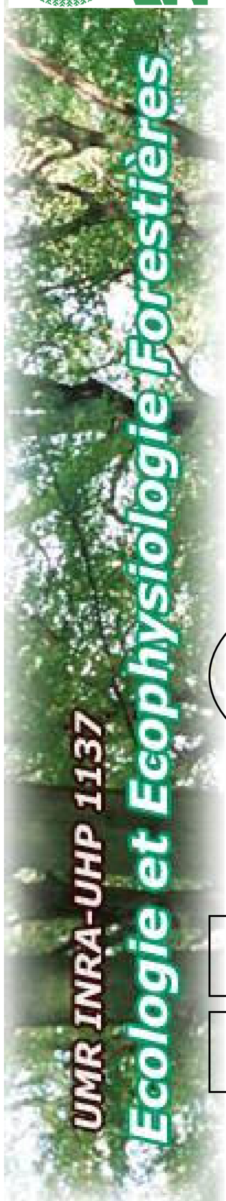


UMR FOREST ECOLOGY and ECOPHYSIOLOGY

(Director A. Granier)

Plant and ecosystem functioning under environmental changes (50 permanents, 75 people)

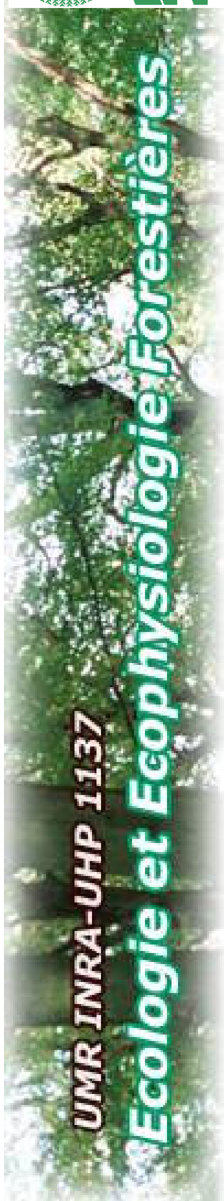
Forest Phyto-ecology
(J.-L. Dupouey)

Tree and Ecosystem Functioning
(D. Epron)

Physiology
(E. Dreyer)

Technical support (Isotope, microscope, mineral analysis (C. Brechet)

GIS (D. Maurice)



Team : Tree and Ecosystem Functioning

- ➔ Flux and budget of carbon, water and nitrogen in interaction with climate and edaphic conditions
  - ➲ Ecosystem carbon cycle :
    - ✓ Ability of the forest to store the atmospheric carbon :
      - Climatic changes
      - Forest management (harvest)
  - ➲ Tree carbon and nitrogen reserves
  - ➲ Carbon and nitrogen allocation in the tree
  - ➲ Hydraulic tree and canopy functioning

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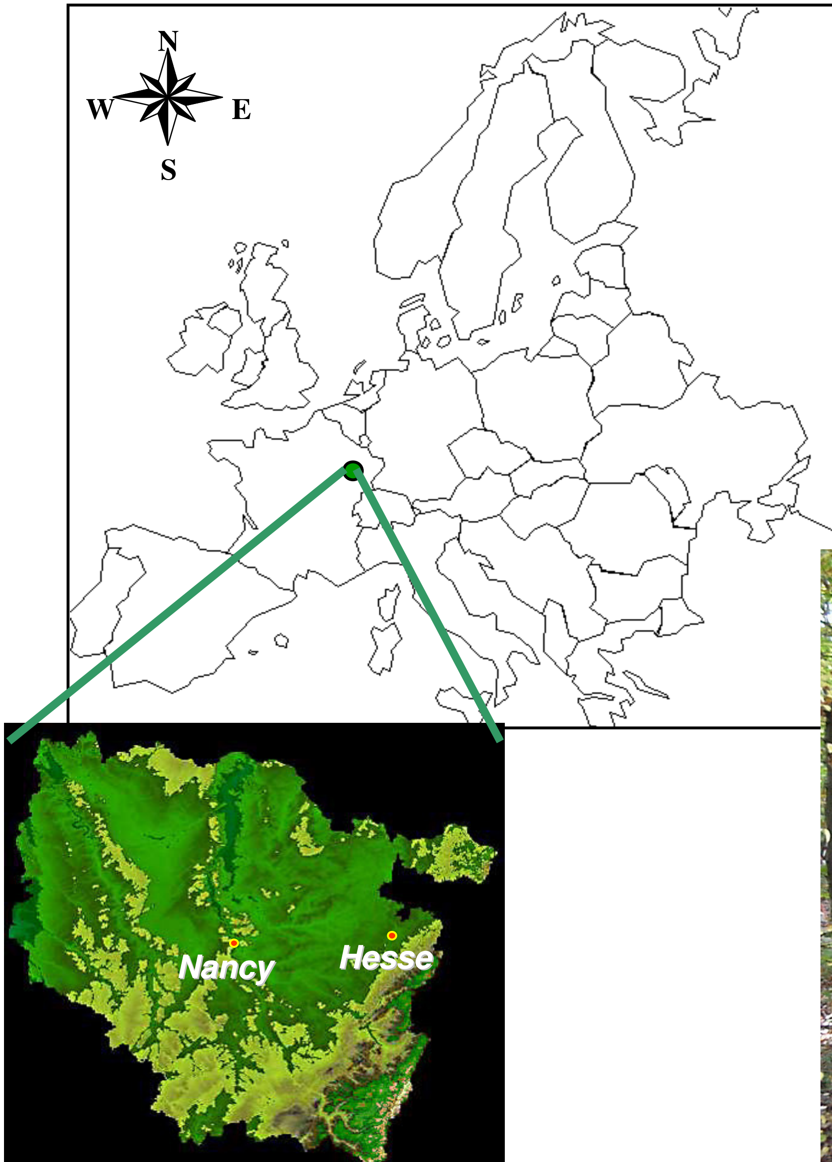
Experimental Site : Hesse



Location : 48°40'N, 7°05'E

65 km from Nancy (East)
10 km from Sarrebourg (South)

Mean annual air Temp. : 10°C

Mean annual Precip. : 950 mm

Climate : Temperate

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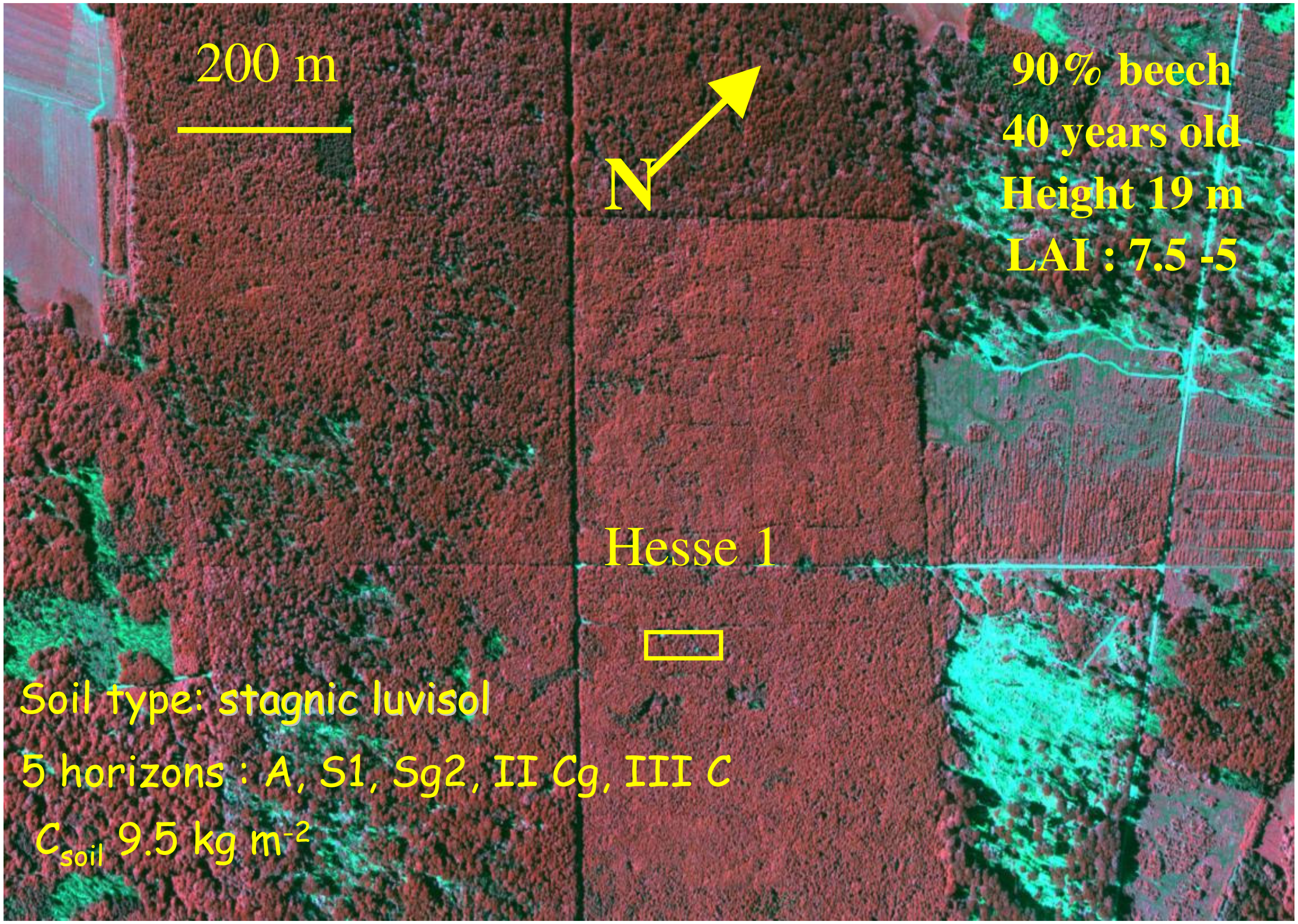
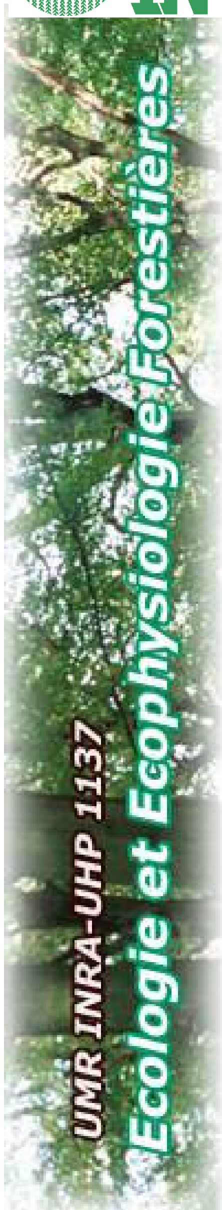




Experimental Site : Hesse

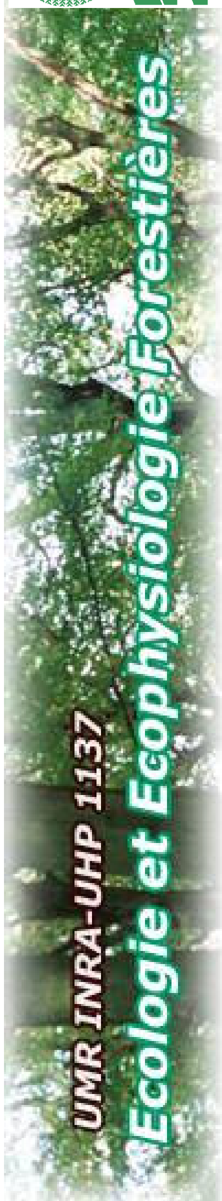
Equipped since 1996

Institut National de la Recherche Agronomique

Office National des Forêts

GIP ECOFOR

Main instrumentation : Eddy covariance system



Experimental Site : Hesse

Eddy Covariance system

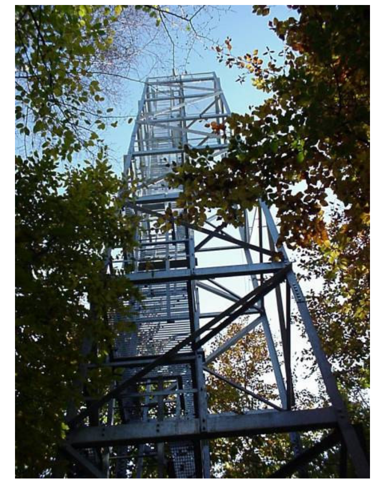
Sonic anemometer

3 wind speed components measurements at high ν (>10 Hz)

IRGA

[CO_2] and [H_2O] at high ν (>10 Hz)

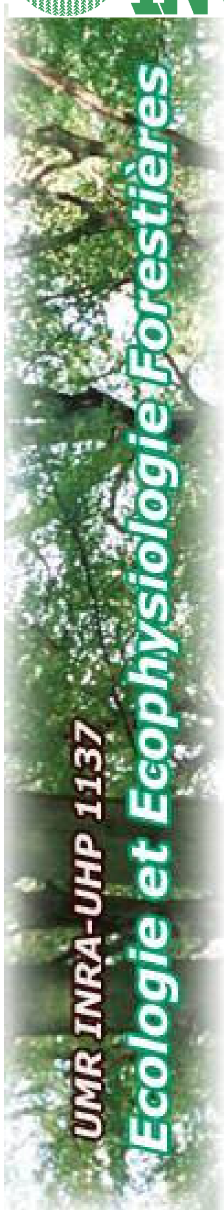
Tower



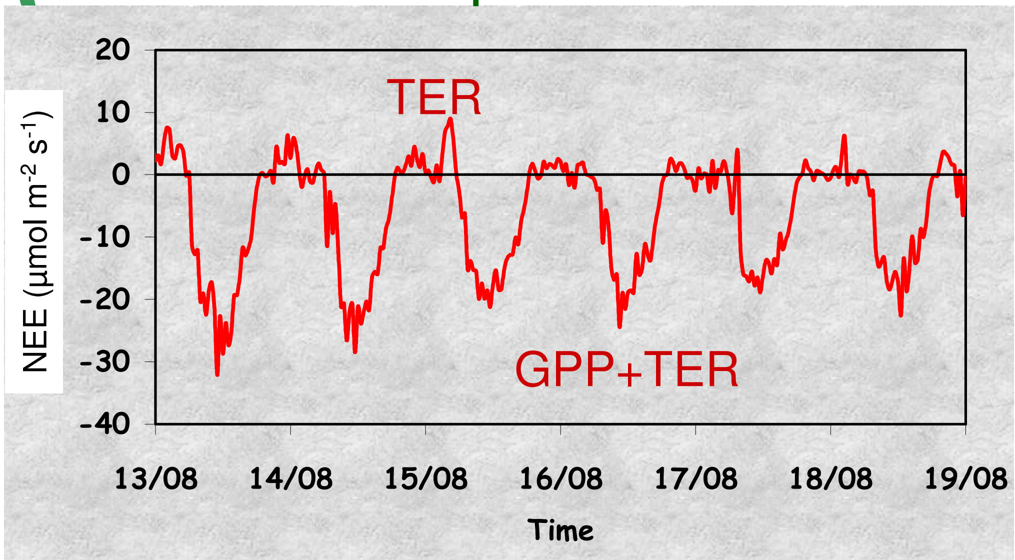
Air transport

Data record and storage system

Net Fluxes : CO_2 (NEE), Evapo-transp.
Sensible and Latent heat
every 30 min



Experimental Site : Hesse



NEE

GPP (Photosynthesis)

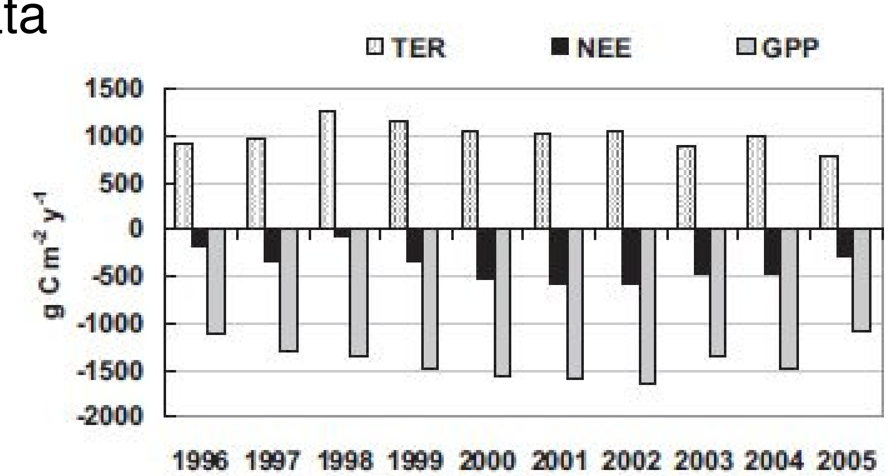
TER (Total ecosystem respiration)

Estimation of TER during daytime by extrapolation of night EC data

GPP = NEE –TER

Annual

- carbon sequestration (NEE)
- GPP
- TER



Experimental Site : Hesse

Automatic :

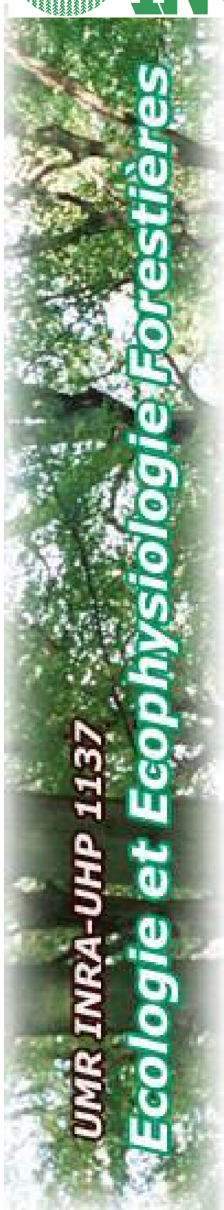
- Eddy covariance (Net CO_2 Ecosystem Exchange)
- Climate (T°, radiation, humidity, precipitations)
- Edaphic conditions (soil T° and water content)
- Tree diameter (dendrometer) ⇨ C biomass

Temporal variability

Campaigns :

- LAI
- Soil respiration (Rs)
- Aerial biomass (trunks, leaves,…)
- Below ground biomass (roots)
- Soil composition,…

Partitioning



Why Soil Respiration ?

- Partitioning NEE between components fluxes

  (Rs second flux, Rs = 60-70% of TER)
- Explain temporal variability of TER
- Explain spatial variability of TER

Why Volatile Carbon Soil ?

- Solve eddy covariance measurement problems
- Improve soil carbon modelling
- Explain stable isotope fluctuations of soil CO_2 efflux

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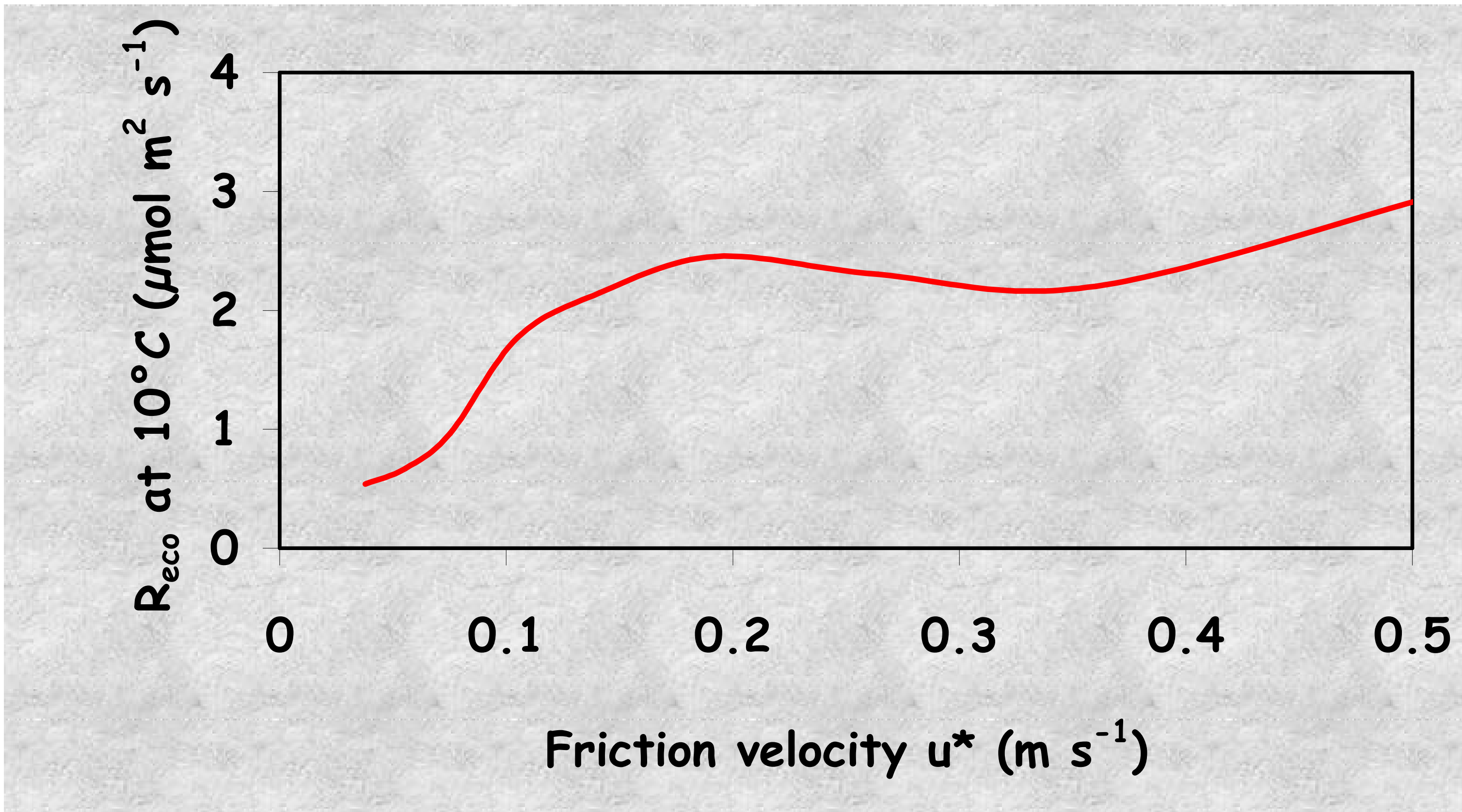
Eddy Covariance Problems

When low turbulence = quite nights

➔ EC fluxes ≠ Total ecosystem respiration (30% of the nighttimes)

(Longdoz et al. 2008)

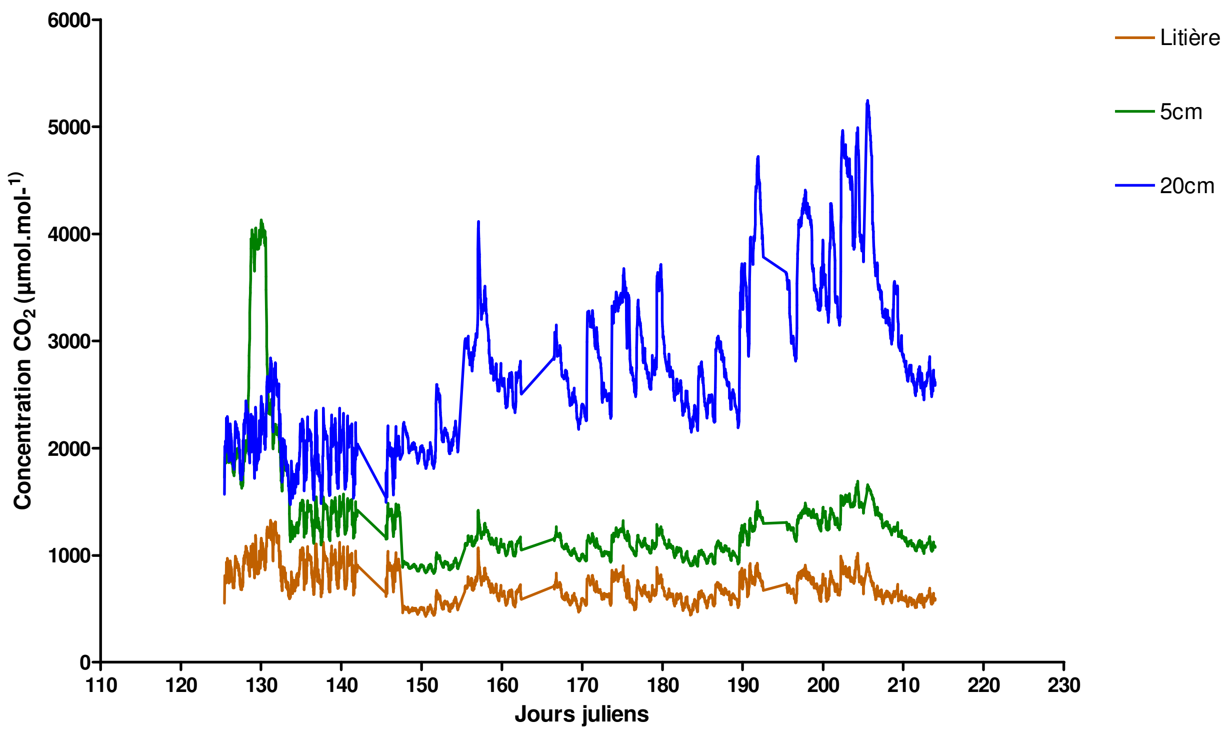


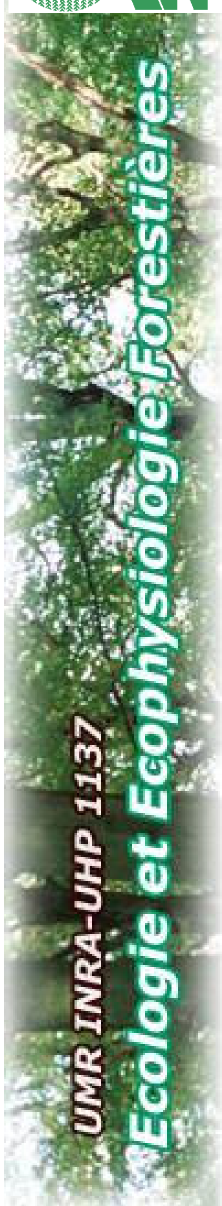
Eddy Covariance Problems

Correction CO_2 stored in the canopy air and in the soil

Measurements of CO2 profile in canopy air below EC system

➔ **We need $[CO_2]_{soil}$ measurements for soil CO_2 storage estimation**





Modelling (carbon, water, energy)

(Longdoz et al. 2004)

Simulate impact of
- Climate changes (extreme events)
- Management
- Differences between species behaviour

on carbon sequestration

Two « black boxes » : Soil carbon budget & photosyntates allocation

Soil carbon model :
- "Century" soil carbon pools
- Site specific soil CO_2 efflux function Fc (t°, SWC)

➔Multi-layers model :
- CO_2 production profile depending on layer features

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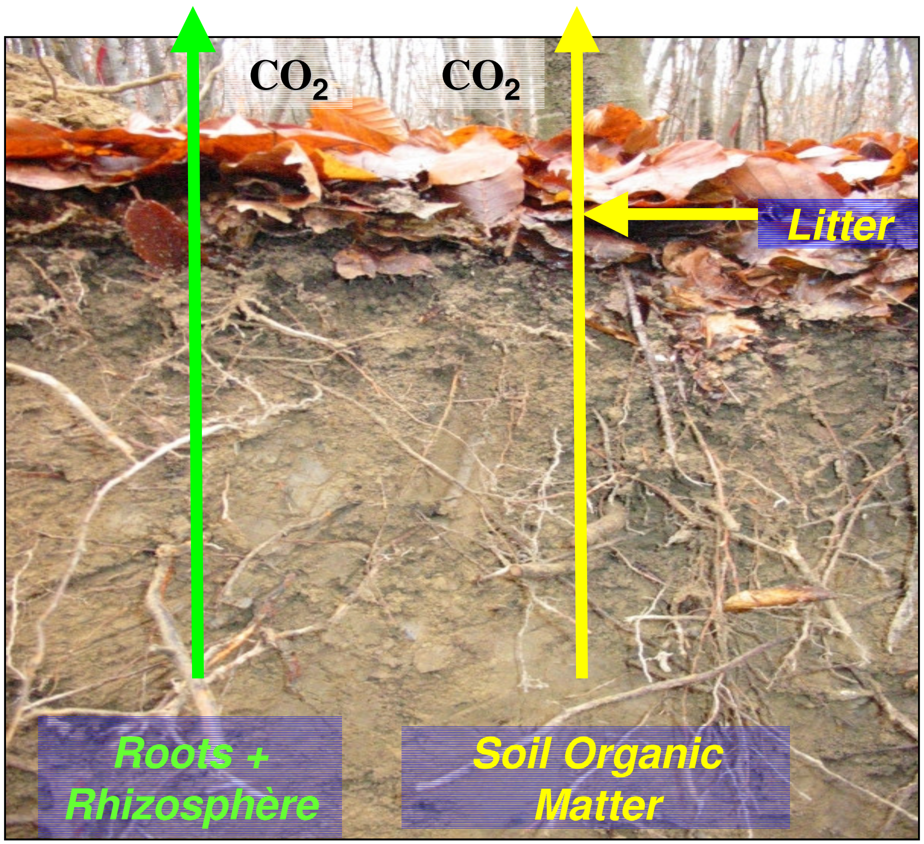
Modelling

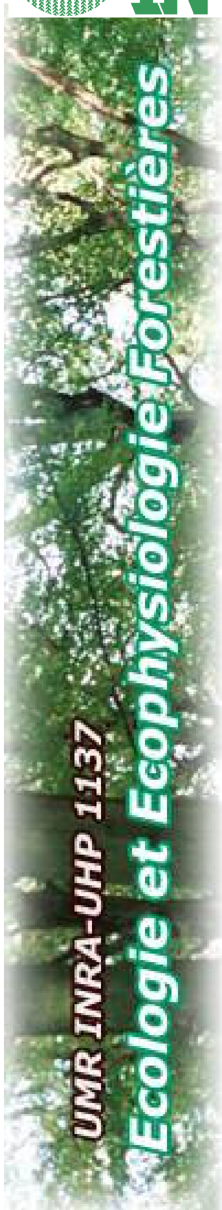
➔Multi-layers model :

CO_2 production profile depending on layer features

➔ Heterotrophic – Autotrophic partitioning



➔ **We need $[CO_2]_{soil}$ measurements in addition to efflux**



Temporal variability of isotopic signature of soil efflux

➔ Carbon has two main isotopes (^{12}C and ^{13}C)

➔ Isotopic composition $\delta^{13}C$ (‰)

$$\delta^{13}C = \frac{R_{13/12}^{mes}}{R_{13/12}^{st}} - 1$$

$\delta^{13}C_{atm} \simeq -8$ ‰

$\delta^{13}C_{SOM} \simeq -21 \rightarrow -30$ ‰

➔ Discrimination (modification of the $\delta^{13}C$ value) during the biophysical processes (photosynthesis, CO_2 diffusion)

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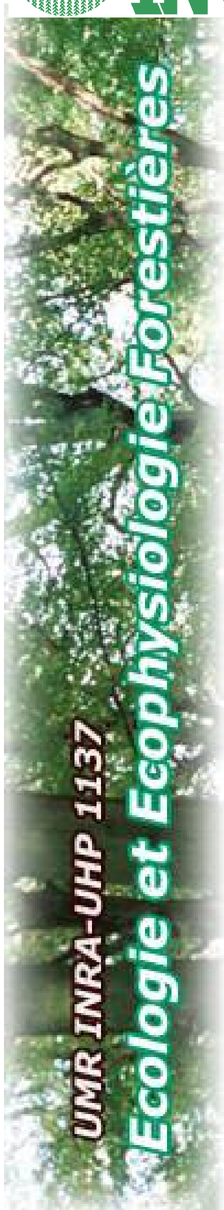


Measurements of $\delta^{13}C$ soil respiration

➔ Contribution of the heterotrophic respiration sources (litter/old SOM)

➔ Contribution of the plant organs (soluble sugar and amino acids, storage carbohydrate and proteins) in autotrophic soil respiration

➔ Separation of NEE between GPP-Reco

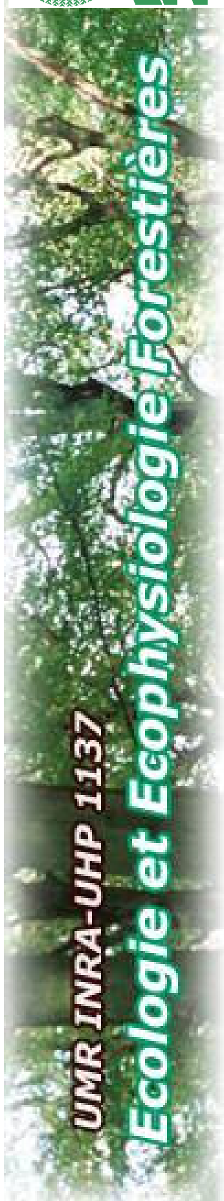
$$NEE = GPP + Réco$$

$$\delta^{13}C_{NEE} \cdot NEE = \underset{(-8‰)}{\delta^{13}C_{atm}} \cdot GPP + \underset{(-26‰)}{\delta^{13}C_{Réco}} \cdot Réco$$

➔ Input for inverse carbon cycle model

Determination of terrestrial & oceanic fluxes from $[CO_2]_{atm}$ and δ_{atm}

$\delta = -26‰$ $\delta = -12‰$



Up to now low frequency measurements (Keeling plots)

but temporal variability of $\delta^{13}C_{Rs}$!!!!

➔ Daily and seasonal $\delta^{13}C_{Rs}$ variations ?

➔ Which factors control these variations ?

High frequency measurements of fluxes of $^{13}CO_2$ and $^{12}CO_2$ with a Tunable Diode Laser Spectrophotometers (TDLS) as a promising tool for these purposes

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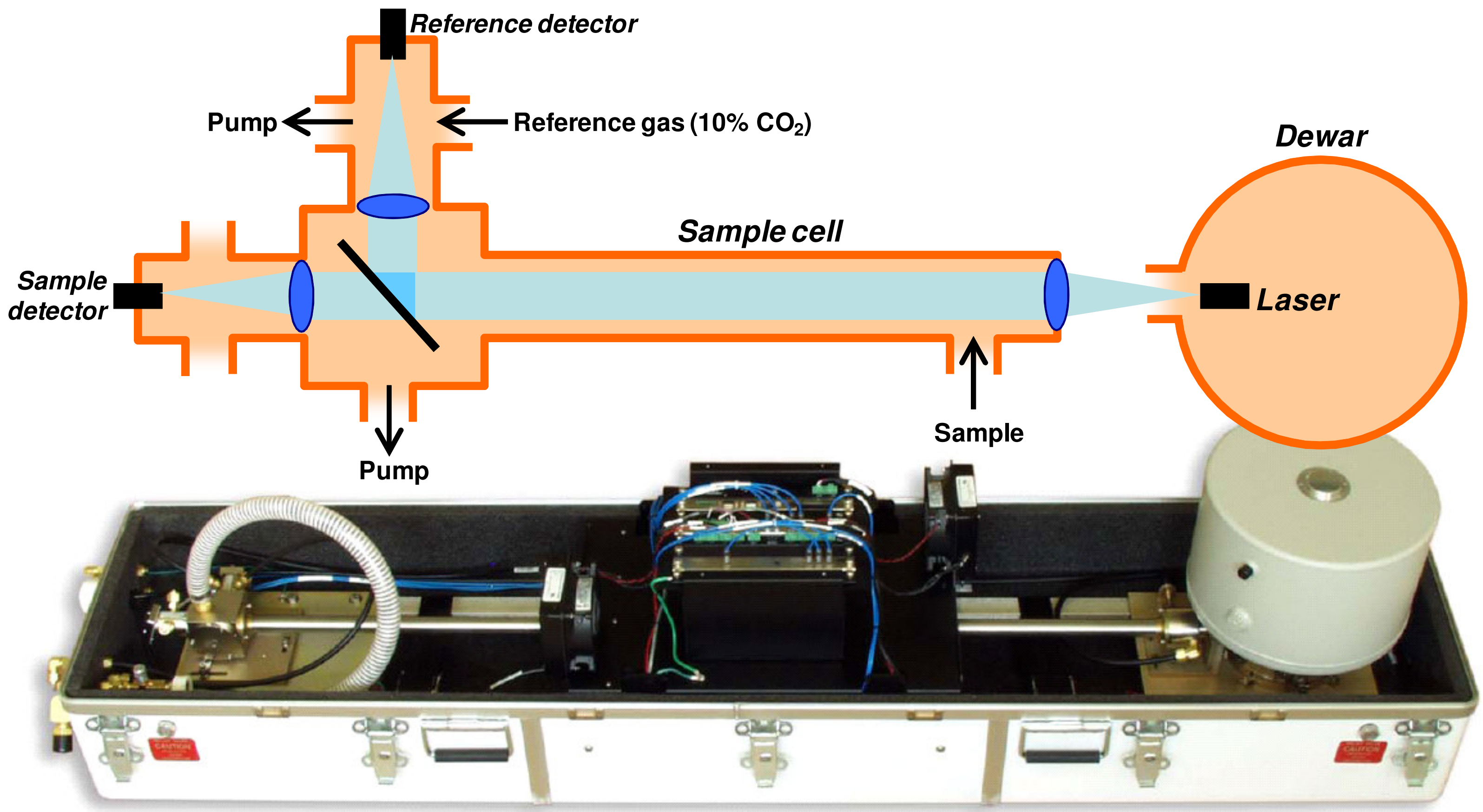
Tunable Diode Laser Spectrophotometer



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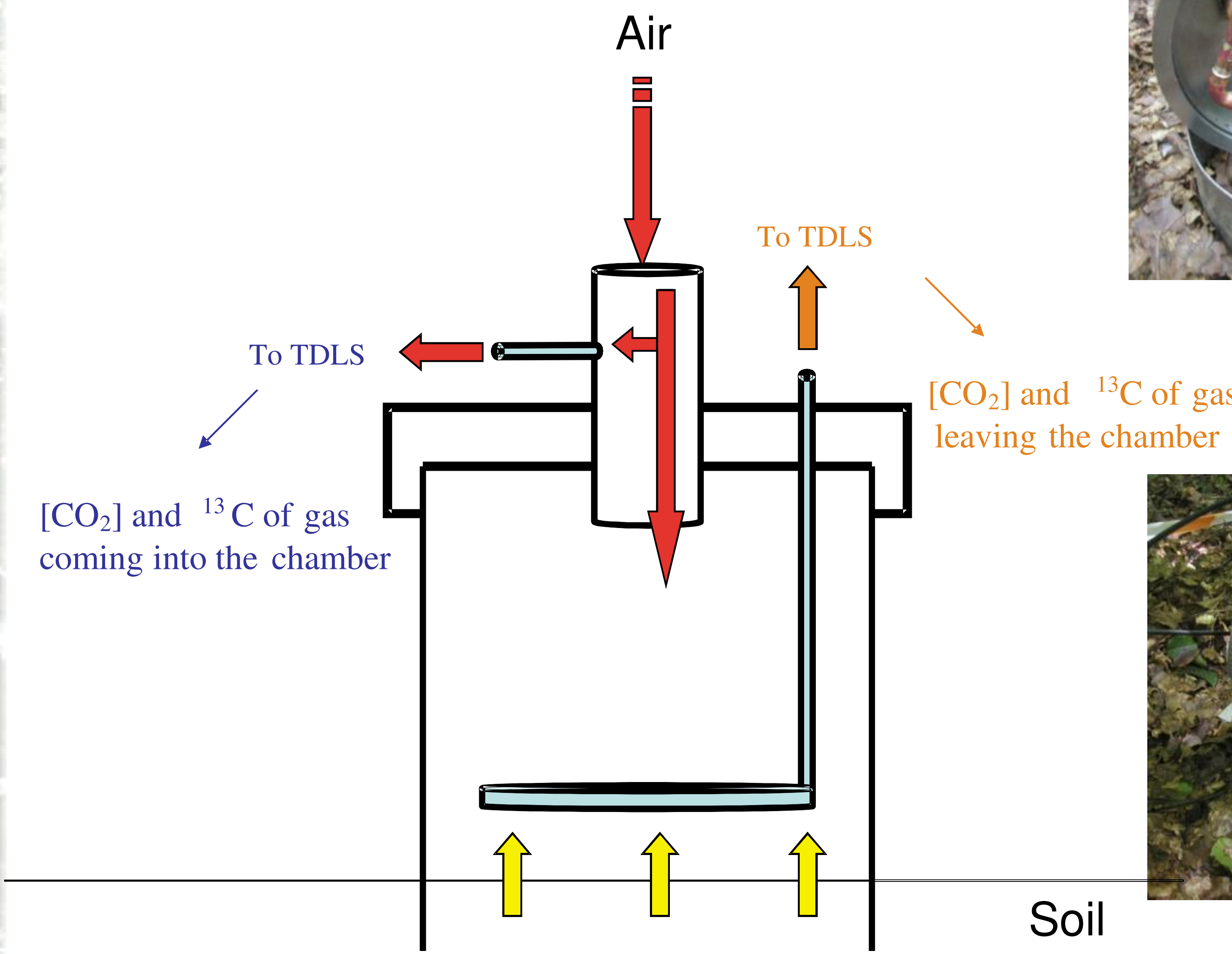
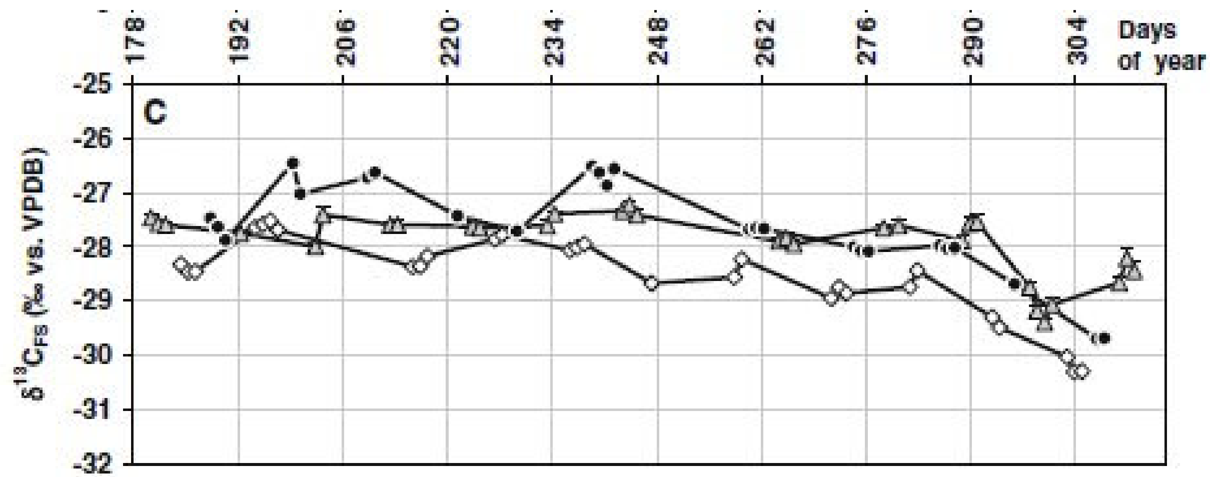
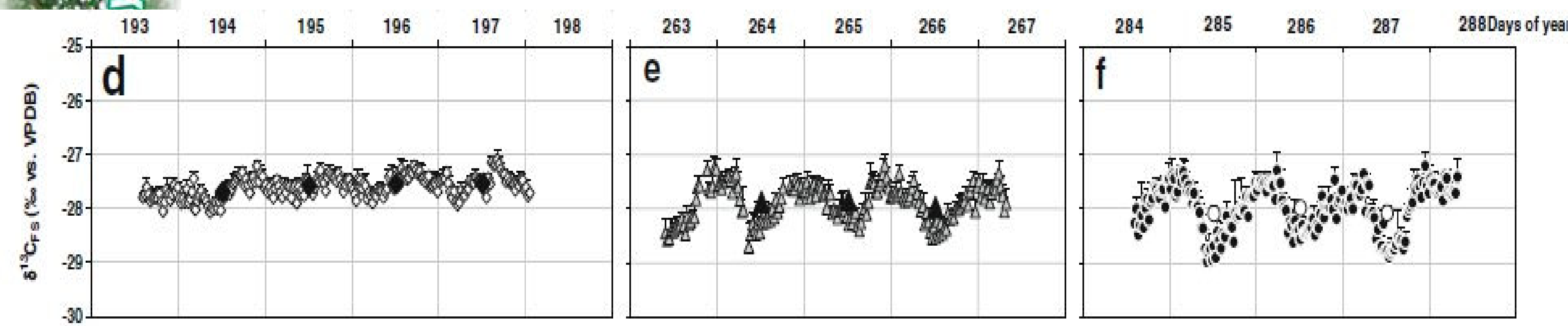
Chamber description



Seasonal $\delta^{13}C_{Rs}$ variations



Daily $\delta^{13}C_{Rs}$ variations



!!! Same range of fluctuation (up to 2‰) !!!

➔ Too large variations to avoid them

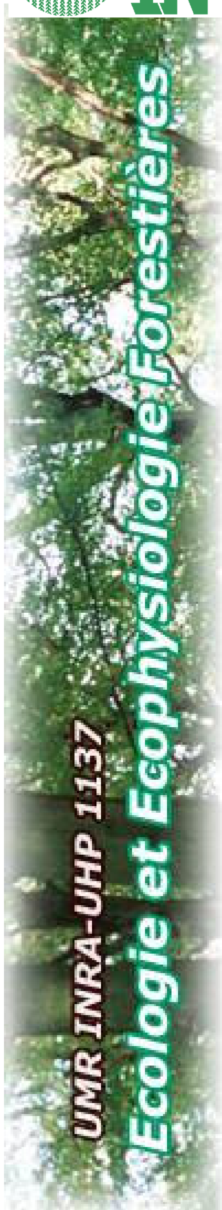
➔ What causes these variations ? (toward prediction of them)

Biological process during:
- ✓ Photosynthesis
- ✓ Carbon Transport
- ✓ CO2 respiration (Production)

Physical process during:
- ✓ CO_2 diffusion through the soil (from production point to the surface)

To separate the impact of physical from biological processes

➔ **We need measurements of $[CO_2]_{soil}$ and its $\delta^{13}CO_2$**



Isotope workpackage of the project

Two/one time(s) per month

➞ air sampling (≠ depths) ➡ IRMS analyses for $^{13}CO_2$ in soil

➞ Keeling plot ➡ $^{13}CO_2$ of soil CO2 efflux