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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
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
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
Experimental Site: Hesse

- 200 m from Hesse
- 90% beech
- 40 years old
- Height 19 m
- LAI: 7.5

Soil type: stagnic luvisol

- 5 horizons: A, S1, Sg2, II Cg, III C
- $C_{soil}$: 9.5 kg m$^{-2}$
Experimental Site: Hesse

Equipped since 1996

Main instrumentation: Eddy covariance system
Experimental Site: Hesse

Eddy Covariance system

Sonic anemometer

IRGA

Tower

[CO$_2$] and [H$_2$O] at high $\nu$ (>10 Hz)

3 wind speed components measurements at high $\nu$ (>10 Hz)

Air transport

Data record and storage system

Net Fluxes: CO$_2$ (NEE), Evapo-transp.
Sensible and Latent heat every 30 min
Experimental Site: Hesse

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 ($T^\circ$, radiation, humidity, precipitations)
- Edaphic conditions (soil $T^\circ$ and water content)
- Tree diameter (dendrometer) $\Rightarrow$ C biomass

Campaigns:

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

Temporal variability

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
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\textsubscript{2} stored in the canopy air and in the soil

Measurements of CO\textsubscript{2} profile in canopy air below EC system

- We need \([\text{CO}_2]_{\text{soil}}\) measurements for soil CO\textsubscript{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
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 (‰)

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

$\delta^{13}$C$_{atm} \approx -8$ ‰  
$\delta^{13}$C$_{SOM} \approx -21 \rightarrow -30$ ‰  

- Discrimination (modification of the $\delta^{13}$C value) during the biophysical processes (photosynthesis, CO$_2$ diffusion)
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

\[
NEE = GPP + \text{Réco}
\]

\[
\delta^{13}C_{NEE} \cdot NEE = \delta^{13}C_{\text{atm}} \cdot GPP + \delta^{13}C_{\text{Réco}} \cdot \text{Réco}
\]

\[
( -8\%\circ) \quad ( -26\%\circ)
\]

- Input for inverse carbon cycle model

Determination of terrestrial & oceanic fluxes from $[\text{CO}_2]_{\text{atm}}$ and $\delta_{\text{atm}}$

\[
\delta = -26\%\circ \quad \delta = -12\%\circ
\]
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
Tunable Diode Laser Spectrophotometer

Sample detector

Reference detector

Pump

Reference gas (10% CO₂)

Sample cell

Dewar

Laser

Sample
Chamber description

[CO₂] and ¹³C of gas coming into the chamber

[CO₂] and ¹³C of gas leaving the chamber

To TDLS
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:
- CO2 diffusion through the soil (from production point to the surface)

To separate the impact of physical from biological processes

We need measurements of [CO2]_{soil} and its δ^{13}CO2
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