



HAL
open science

Measuring and modeling soil intra-day variability of the $^{13}\text{CO}_2$ & $^{12}\text{CO}_2$ production and transport in a scots pine forest

Stephanie Goffin, Florian Parent, Caroline Plain, Daniel Epron, Christophe Wylock, Benoit Haut, Martin Maier, Helmer Schack-Kirchner, Bernard Longdoz

► To cite this version:

Stephanie Goffin, Florian Parent, Caroline Plain, Daniel Epron, Christophe Wylock, et al.. Measuring and modeling soil intra-day variability of the $^{13}\text{CO}_2$ & $^{12}\text{CO}_2$ production and transport in a scots pine forest. 1st ICOS International Conference on Greenhouse Gases and Biogeochemical Cycles, Sep 2014, Bruxelles, Belgium. hal-01269271

HAL Id: hal-01269271

<https://hal.science/hal-01269271>

Submitted on 5 Jun 2020

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

MEASURING AND MODELING SOIL INTRA-DAY VARIABILITY OF THE $^{13}\text{CO}_2$ & $^{12}\text{CO}_2$ PRODUCTION AND TRANSPORT IN A SCOTS PINE FOREST

Goffin Stéphanie ⁽¹⁾, Parent F. ⁽²⁾, Plain C. ⁽²⁾, Epron D. ⁽²⁾, Wylock C. ⁽³⁾, Haut B. ⁽³⁾, Maier M. ⁽⁴⁾, Schack-Kirchner H. ⁽⁴⁾, Aubinet M. ⁽¹⁾, Longdoz Bernard ⁽²⁾ (bernard.longdoz@nancy.inra.fr)

(1) University of Liège - GxABT, Unit of Biosystem Physics, Gembloux, Belgium; (2) INRA Centre de Nancy - Henri Poincaré University, UMR 1137, Forest Ecology and Ecophysiology, France; (3) University of Bruxelles, Transfers, Interfaces and Processes, Belgium; (4) Institute of Soil Science and Forest Nutrition University of Freiburg, Germany

CONTEXT

- > Future dynamics of soil CO_2 efflux (F_s) = key question in climate change research.
- > Two processes lead to F_s : CO_2 production P (heterotrophic + autotrophic) + transport F to surface
- > Factors affecting P & F (t° , moisture, substrate...) vary vertically and temporally.
- > Better understanding of the mechanisms controlling F_s needs - soil **multilayer approach**
 - fine temporal resolution (intra-day) study
- > Use of ^{13}C & ^{12}C improve F_s origin (partitioning) and pathway (spatiotemporal tracer) knowledge

OBJECTIVE 1: Determine soil horizons P_s and $\delta^{13}P_s$

Based on $^{12}\text{CO}_2$ & $^{13}\text{CO}_2$ balances for layer i & Diffusive Flux-Gradient approach

$$\varepsilon_i * \frac{\Delta C_{i-1}}{\Delta t} = \frac{F_{down} - F_{up}}{thick_i} + P_i \quad (\text{Eq. 1})$$

$$F_x = D_{x-i} * \frac{C_x - C_{i-1}}{z_x - z_{i-1}} = \left(D * \frac{\Delta C}{\Delta z} \right)_{x-i} \quad (\text{Eq. 2})$$

where $C_i = [^{12}\text{CO}_2]$ or $[^{13}\text{CO}_2]$; ε_i & $thick_i$ = layer i soil porosity & thickness;

D_{x-i} = soil diffusivity at the $x-i$ boundary

$$P_i = \varepsilon_i * \frac{\Delta C_i}{\Delta t} + \left(D * \frac{\Delta C}{\Delta z} \right)_{down,i} - \left(D * \frac{\Delta C}{\Delta z} \right)_{up,i} \quad (\text{Eq. 3})$$

P_i and $\delta^{13}P_i$ can be obtain by measuring the temporal evolution of the $[^{12}\text{CO}_2]$ & $[^{13}\text{CO}_2]$ vertical profiles + Lab. measurement (on soil samples) of ε and dependence of D on soil water content (vertical profiles)

Boundary conditions : $F_{bottom} = 0$; $F_{top} = F_s$

Experimental device (Parent et al. 2013)



Results

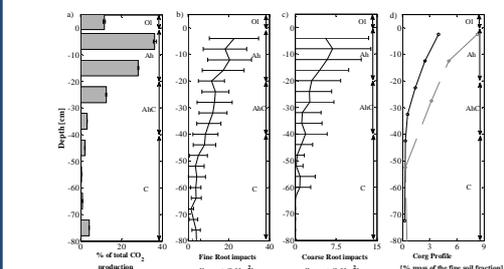


Fig. 1: Mean P_s (over the campaign) of soil horizons (Ol, Ah, AhC, C) in parallel with fine roots and carbon content vertical profiles

- CO₂ production decrease with depth as fine roots & carbon contents
- Clear intraday variability in Ol, Ah & AhC horizons
- Not plausible negative CO₂ production (consumption) in Ol! (see explanation in Objective 2 section)

Fig. 3: Temporal evolution of $\delta^{13}P_s$ for Ah (a & b) and Ahc (c & d). Hourly variability (a & c) and daily means (b & d) are presented

- Significant day to day variation of $\delta^{13}P_s$ in Ah

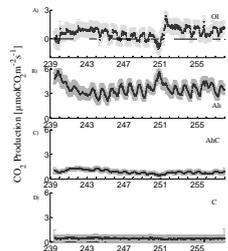
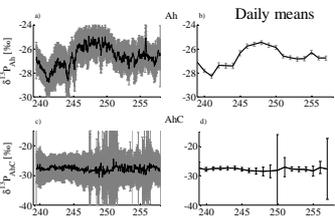


Fig. 2: Temporal evolution of the CO₂ production for the different horizons

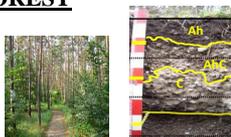


OBJECTIVES

- Determine P_s and its isotopic signature $\delta^{13}P_s$ for the different soil horizons.
- Find factors affecting P_s & $\delta^{13}P_s$ intra & inter day fluctuations
- Evaluate by modeling which processes (those linked to production or transport) drive F_s temporal variability

EXPERIMENTAL SITE: HARTHEIM FOREST

- > 46 year old Scots Pine Forest (*Pinus sylvestris* L.)
- > Mean annual Air Temp/Prec: 10.3°C/642 mm
- > Haplic Regosol (calcaric, humic)
- > Humus type is mull (1-3 cm thick)



OBJECTIVE 2: Factors affecting P_s and $\delta^{13}P_s$ (Goffin et al. 2014)

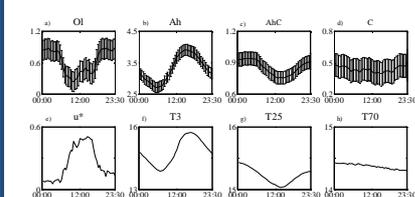
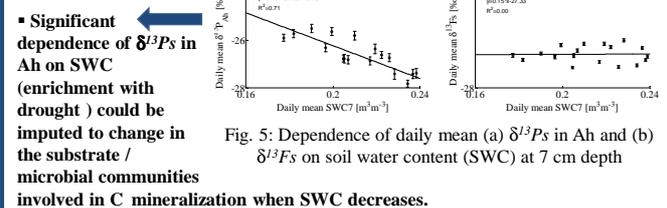


Fig. 4: Mean diurnal evolution of the P_s , soil temperature (3, 25, 70 cm depth) and friction velocity (u^*)

- P_s in Ah and AhC are correlated to their local temperature
- No diurnal evolution of P_s in C ($t^\circ \approx$ constant over the campaign)
- P_s in Ol (litter) is correlated to u^* . The CO₂ transport processes due to turbulence are not represented in Eq. 1 & 3 when they are actually present in the litter layer. Consequently their influences are reflected back in the P_s term (\equiv Eq. 3 output). This point explains also negative value of P_s in Ol met in Fig. 2



- Significant dependence of $\delta^{13}P_s$ in Ah on SWC (enrichment with drought) could be imputed to change in the substrate / microbial communities involved in C mineralization when SWC decreases.

OBJECTIVE 3: Model applications to evaluate the part of production and transport processes in the $[\text{CO}_2]_{\text{soil}}$ & F_s temporal variability (Goffin et al. under review).

- Model run with a reference version simulating production in the \neq layers (rate depending on local t°) and diffusion as the only CO₂ transport process
- Model runs with testing versions where (a) advection, (b) dispersion and (c) production regulated by phloem pressure concentration waves (PPCW) are successively added
- Comparison of the reference and testing versions outputs with $[\text{CO}_2]_{\text{soil}}$ & F_s

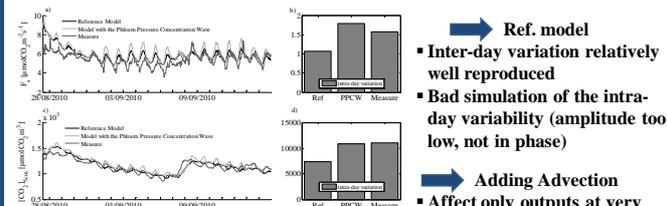


Fig. 6 a & c: Time evolutions of F_s and $[\text{CO}_2]_{\text{soil}}$ obtained with reference model, model including the phloem pressure concentration wave (PPCW) and measurements

Fig. 6 b & d: Corresponding averaged intra-day variability

- Adding PPCW
 - Improve significantly the simulation of F_s & $[\text{CO}_2]_{\text{soil}}$ amplitude and phase
 - Best way to reproduce the intra-day F_s & $[\text{CO}_2]_{\text{soil}}$ variations