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## **Measuring and modeling soil intra-day variability of the 13CO<sub>2</sub> & 12CO<sub>2</sub> production and transport in a scots pine forest**

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Longdoz

### ► **To cite this version:**

Stephanie Goffin, Florian Parent, C. Plain, Daniel Epron, Christophe Wylock, et al.. Measuring and modeling soil intra-day variability of the 13CO<sub>2</sub> & 12CO<sub>2</sub> production and transport in a scots pine forest. TERENO International Conference, Sep 2014, Bonn, Germany. pp.21 slides. <hal-02797813>

**HAL Id: hal-02797813**

**<https://hal.inrae.fr/hal-02797813v1>**

Submitted on 5 Jun 2020

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

Goffin Stéphanie, Parent F., Plain C., Epron D., Wylock C., Haut B.,  
Maier M., Schack-Kirchner H., Aubinet M., Longdoz Bernard

# Background & Objectives

## Soil CO<sub>2</sub> efflux (Fs)

Fs: One of the largest component of C cycle

10 times greater than fossil fuel emissions

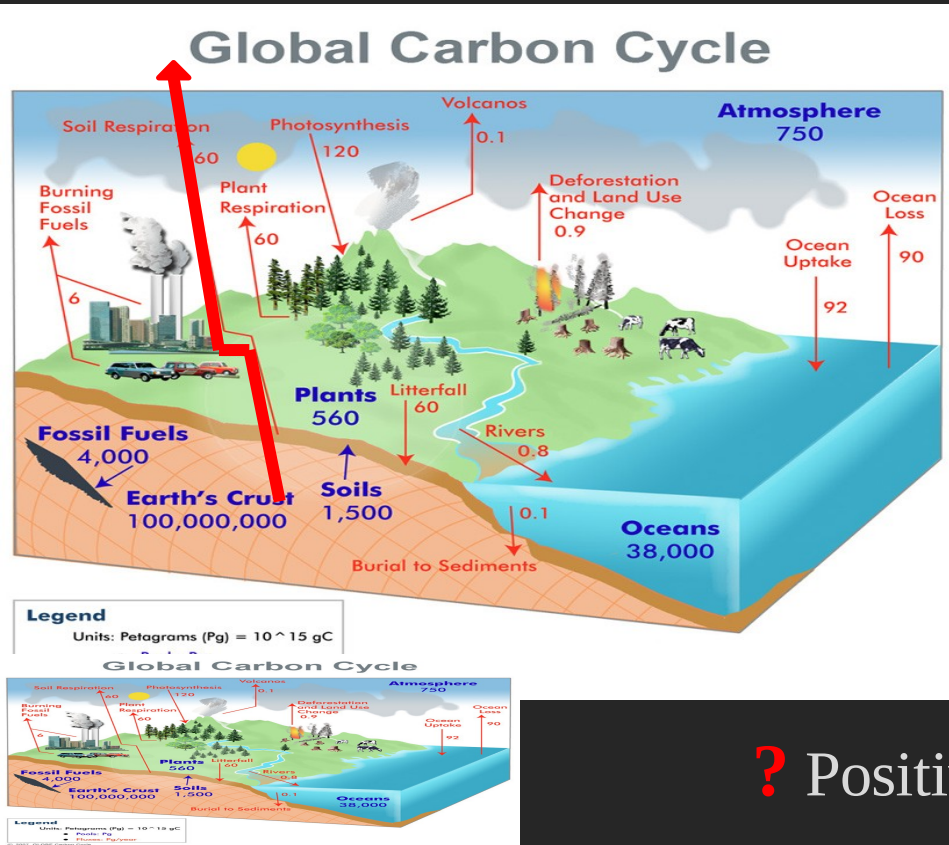
Soil: large C pool

Fs changes may rival the loading of atmosphere by fossil fuel

Uncertainties >>>

? Climate Change Impact?

? Positive feedback to the GHG effect?



Past

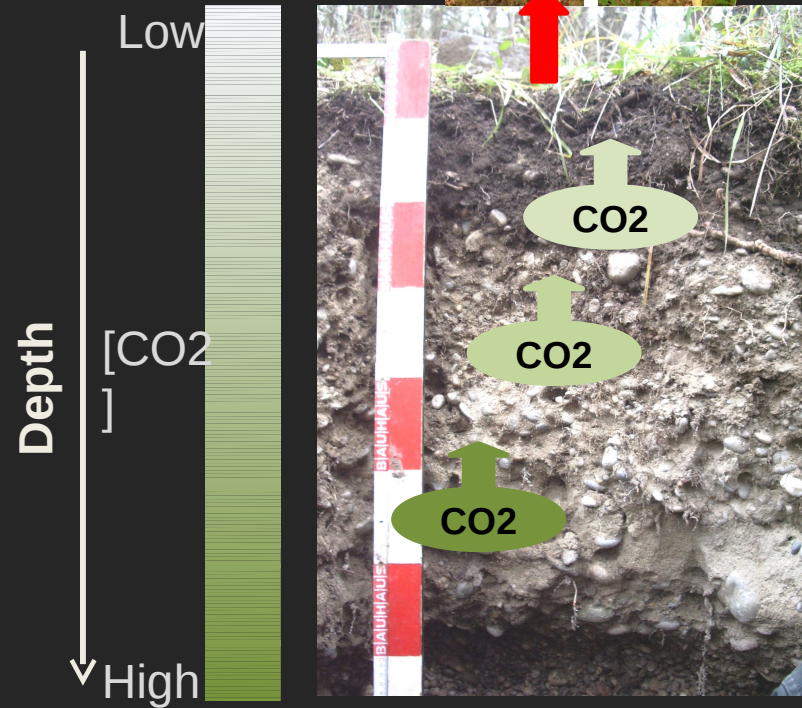
today

Future

Empirical description

Mechanistic understanding

# Background & Objectives



**Transport**

**Diffusion**

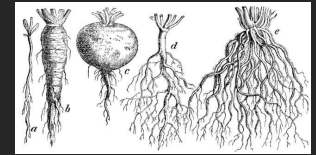
Avection +  
Dispersion

Liquid phase

**F<sub>s</sub>**

**Production**

**Autotrophic**



**Heterotrophic**



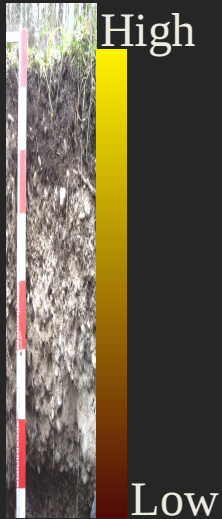
**Abiotic**

# Background & Objectives

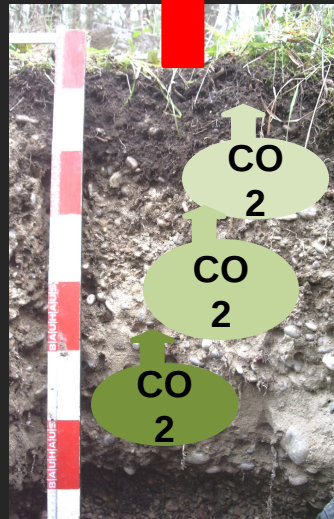
**Transport**

$f(\text{porosity, humidity...})$

Porosity



$F_s$



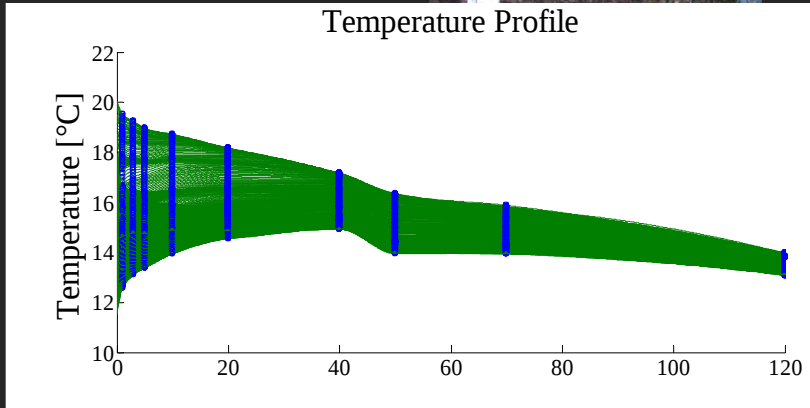
**Production  $P_s$**

**Heterotrophic**

**Autotrophic**

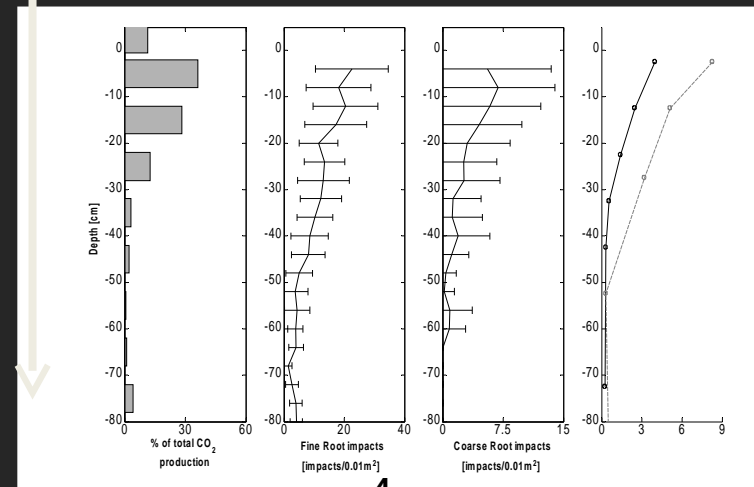
$f(\text{Temperature, humidity, substrate})$

Temperature Profile



Fine and Coarse Roots

Corg



**⇒ Multilayer Approach needed**

# Background & Objectives

□  $\delta^{13}\text{CO}_2 = -8\text{‰}$

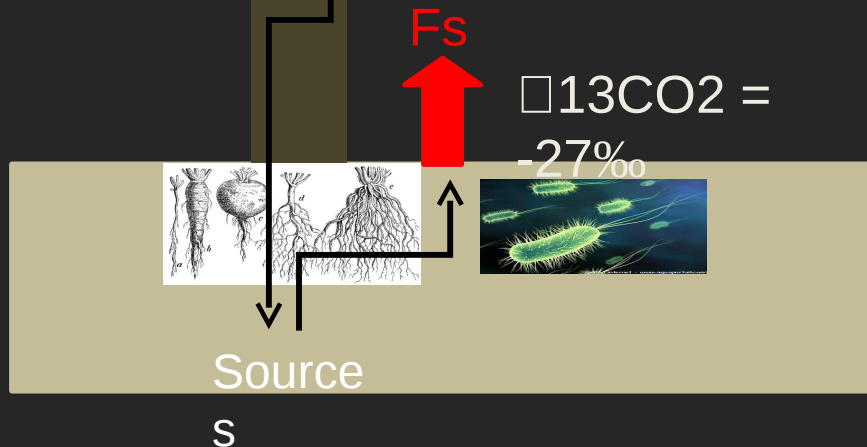
• Discrimination during  $\text{CO}_2$  assimilation

□  $\delta^{13}\text{CO}_2 = -27\text{‰}$

• Discrimination changes with climatic conditions

During drought, discrimination decrease photoassimilates more enriched in  $^{13}\text{CO}_2$  ( ex:  $-25\text{‰}$ )

Temporal variation of  $^{13}\text{CO}_2$  may give informations about transfert time of photoassimilates

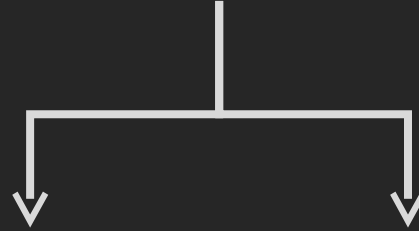


$^{13}\text{CO}_2$  may differs between  $\text{CO}_2$  sources  
 $^{13}\text{CO}_2$  may helps for partitionning  $F_s$  between sources

**⇒ Understanding of  $\delta^{13}\text{CO}_2$  fluctuations (space & time) needed**

# Background & Objectives

Improving mechanistic understanding of  $F_s$



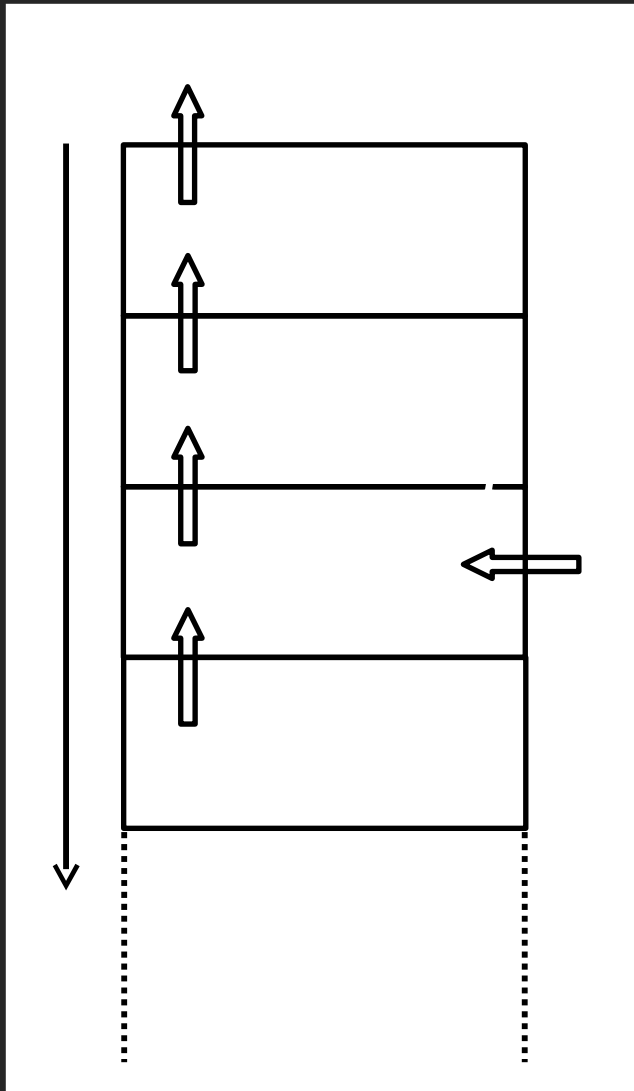
## Multilayer Approach

## Isotopic Signal Analysis

- 1) Determine the CO<sub>2</sub> production rate  $P_s$  and its isotopic signature  $^{13}P_s$  for the different soil horizons.
- 2) Find factors affecting  $P_s$  &  $^{13}P_s$  intra & inter day fluctuations
- 3) Evaluate by modeling which processes (production or transport) drive  $F_s$  temporal variability



# 1. Determine $P_s$ and $\delta^{13}P_s$ for $\neq$ layers



- $^{12}CO_2$  &  $^{13}CO_2$  balances for each  $i$

$$\frac{d(C_i * thick_i)}{dt} = \frac{F_{down} - F_{up}}{thick_i} + P_{S_i} \text{ for } ^{12}CO_2 \text{ \& } ^{13}CO_2$$

- Diffusive Flux-Gradient approach

$$F_x = D_{x-i} * \frac{C_x - C_i}{z_x - z_i} = \left( D * \frac{\Delta C}{\Delta z} \right)_{x-i} \text{ for } ^{12}CO_2 \text{ \& } ^{13}CO_2$$

$$\Rightarrow P_{S_i} = \epsilon_i * \frac{\Delta C_i}{\Delta t} + \frac{\left( D * \frac{\Delta C}{\Delta z} \right)_{down-i} - \left( D * \frac{\Delta C}{\Delta z} \right)_{up-i}}{thick_i}$$

Vertical profile of their dependence on SWC measured on samples at



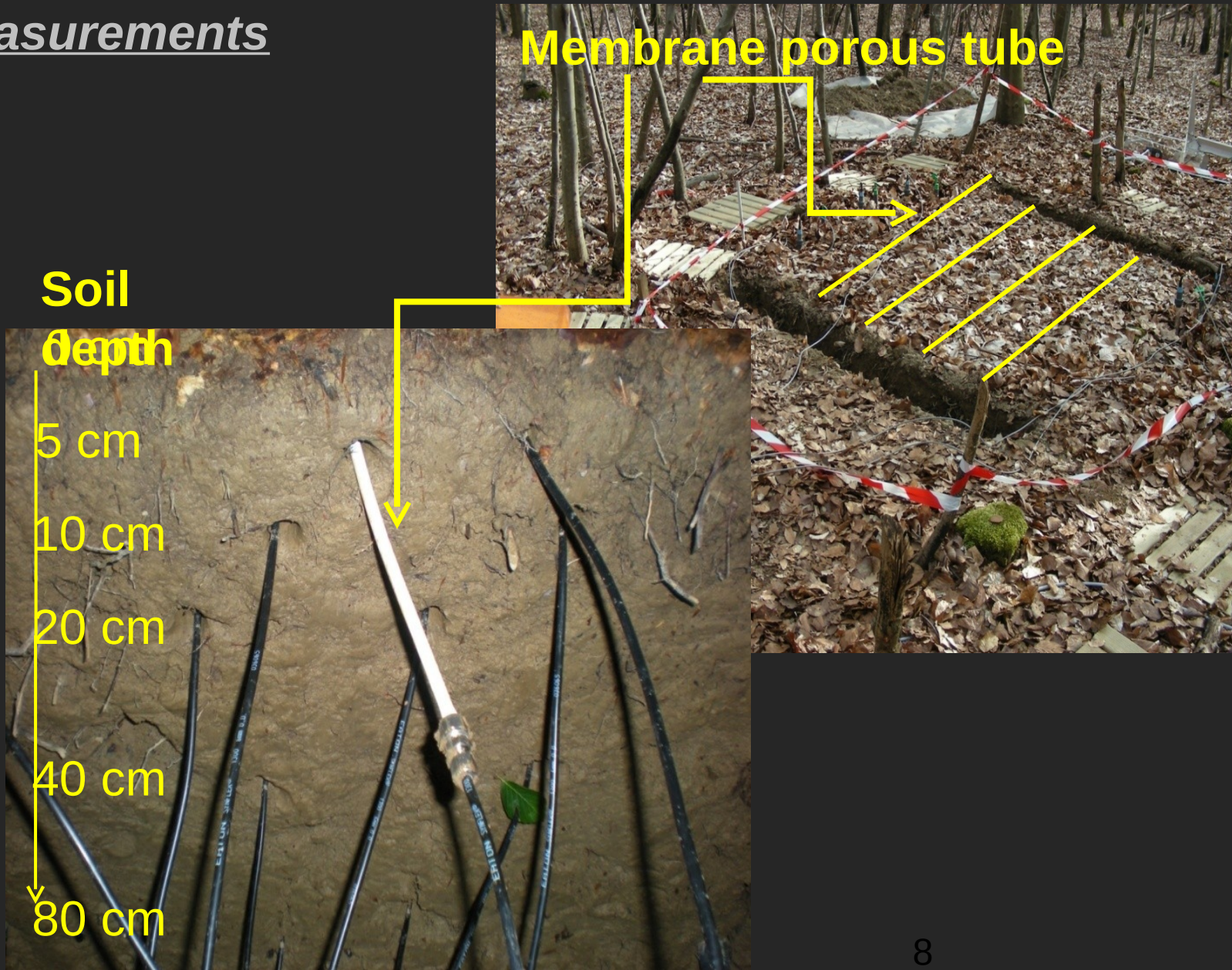
$^{12}CO_2$  &  $^{13}CO_2$  vertical profile measured by



→  $P_s$  and  $\delta P_s$  for each layer

# 1. Determine $P_s$ and $\delta^{13}P_s$ for $\neq$ layers (Parent et al. 2013)

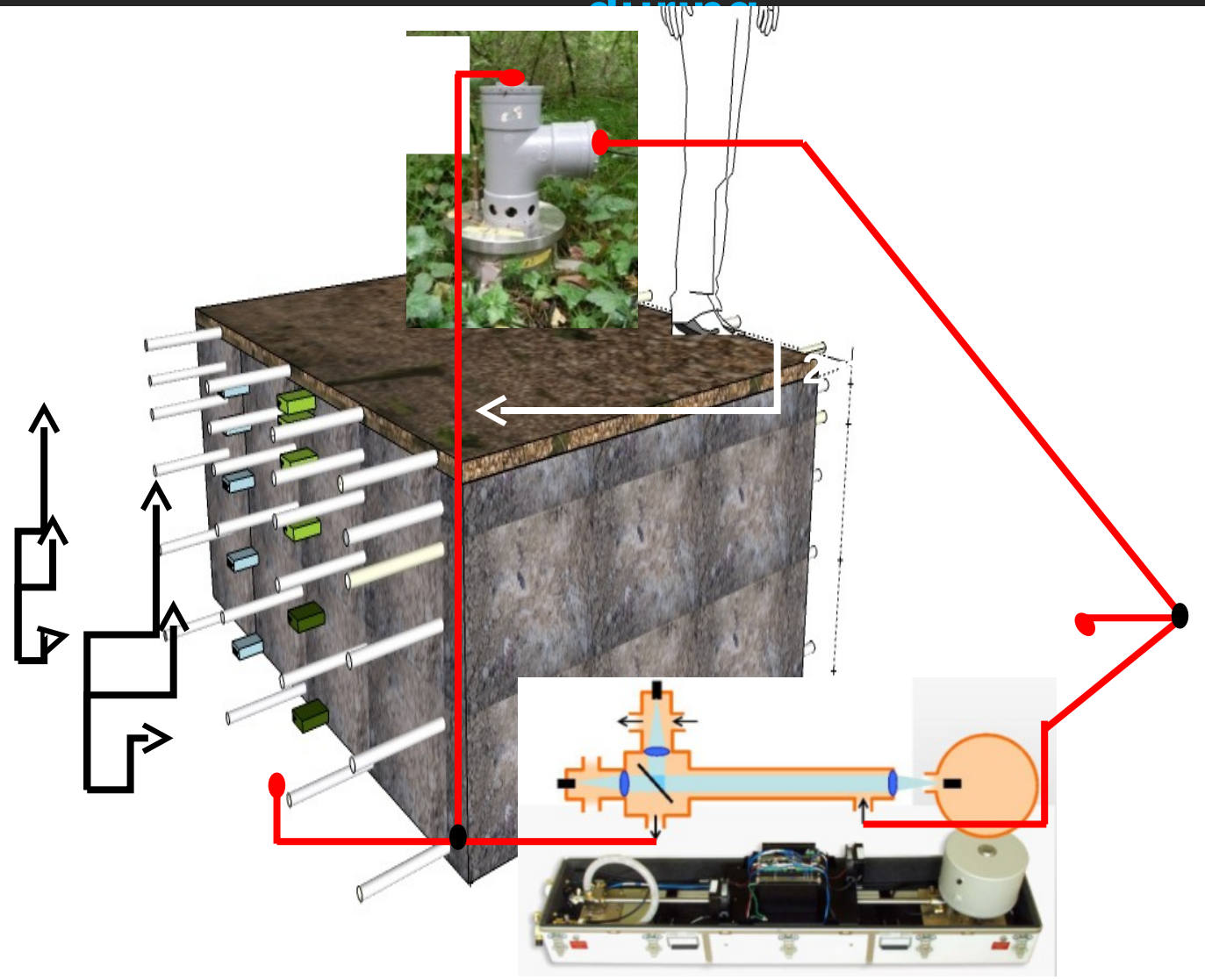
## Field Measurements



# 1. Determine $P_s$ and $\delta^{13}P_s$ for $\neq$ layers (Parent et al. 2013)

## Field Measurements

Half-hourly In situ measurements  
during  
21 days



**TDLS:**  
**12[CO<sub>2</sub>] &**  
**13[CO<sub>2</sub>]**  
1) **membrane**  
**tube ≡**  
**[CO<sub>2</sub>] &**  
**δ<sup>13</sup>CO<sub>2</sub> in**  
**soil layers**  
2) **from**  
**chamber ≡**  
**EFs &**  
**δ<sup>13</sup>EFs**

# 1. Determine $P_s$ and $\delta^{13}P_s$ for $\neq$ layers

## Site

### Description

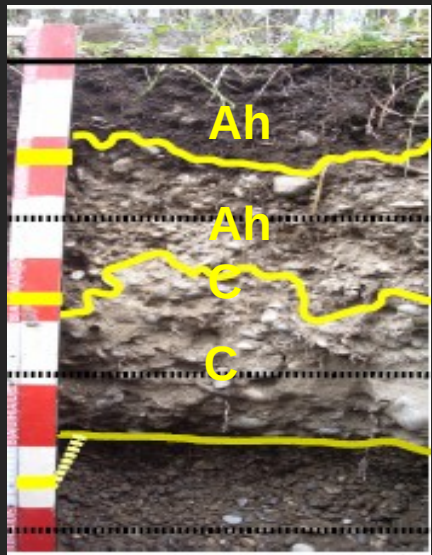
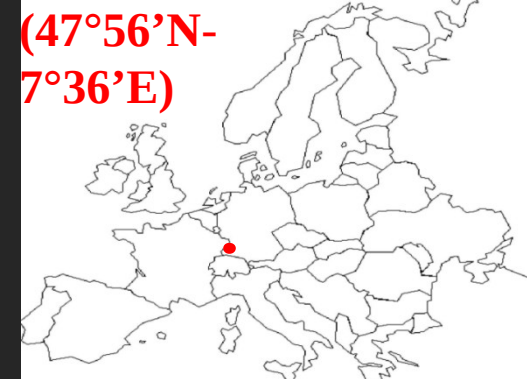


## Hartheim experimental site

Slow growing 46 year old Scots Pine Forest (*Pinus sylvestris* L.)

Mean annual air Temp: 10.3°C

Mean annual precip: 642 mm



Haplic Regosol (calcaric, humic) (FAO, 2006)

Humus type is mull (1-3 cm thick)

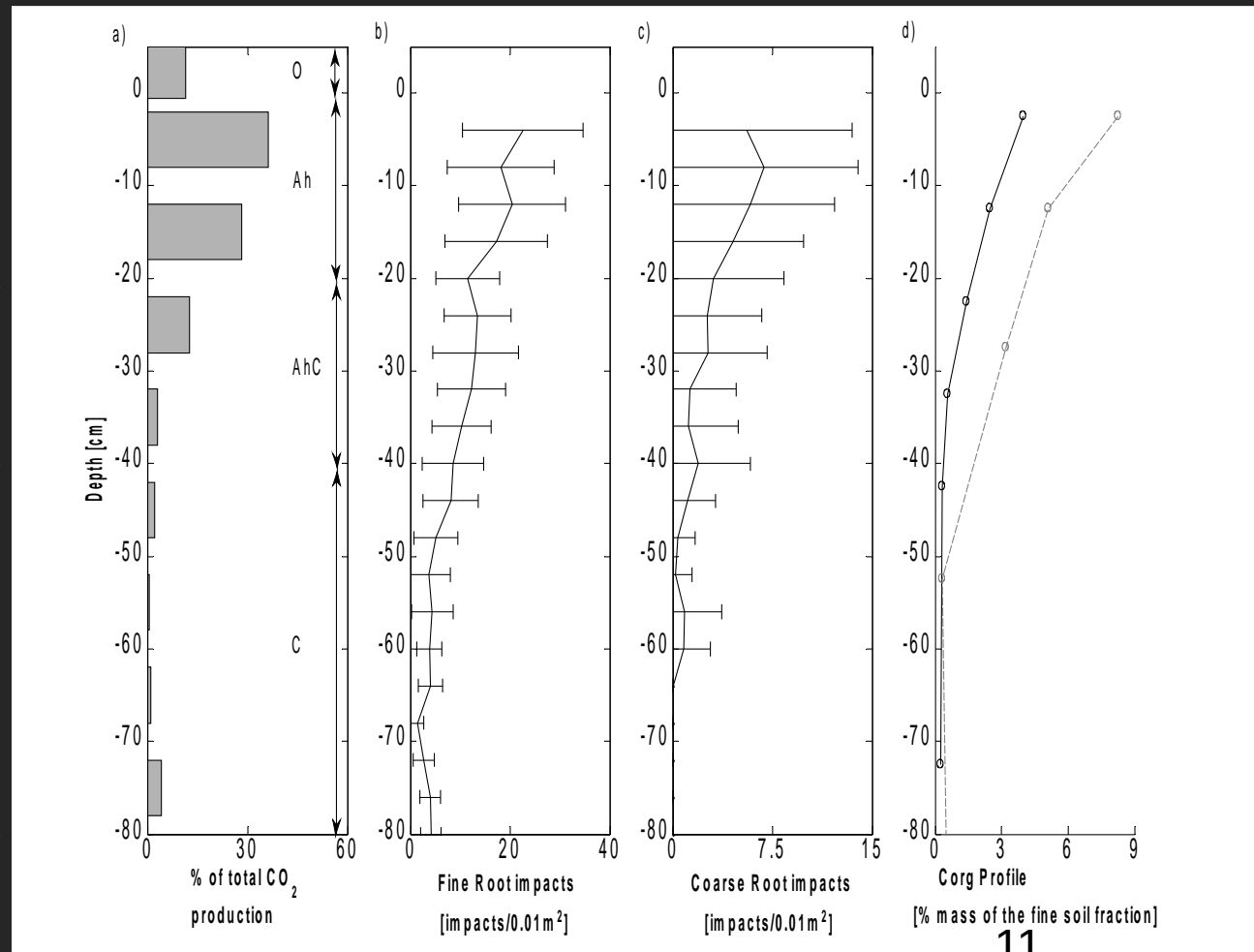
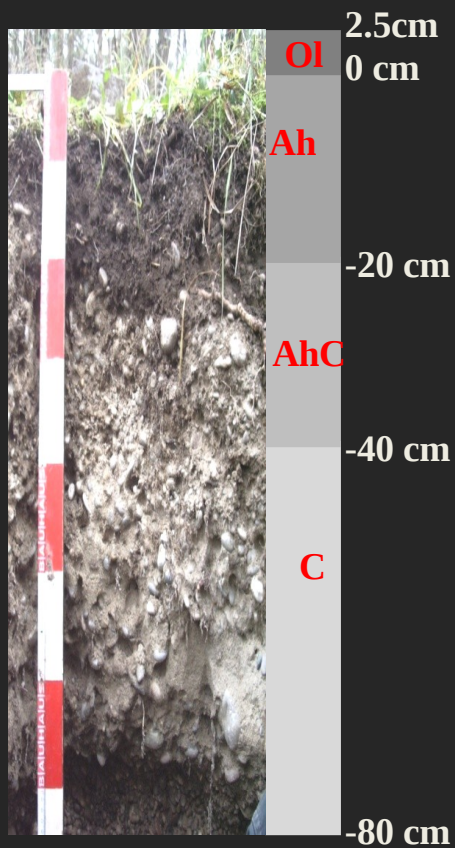


**Eddy  
Covariance  
tower  
Meteorological  
station**

# 1. Determine $P_s$ and $\delta^{13}P_s$ for $\neq$ layers

## Vertical Profile of $P_s$

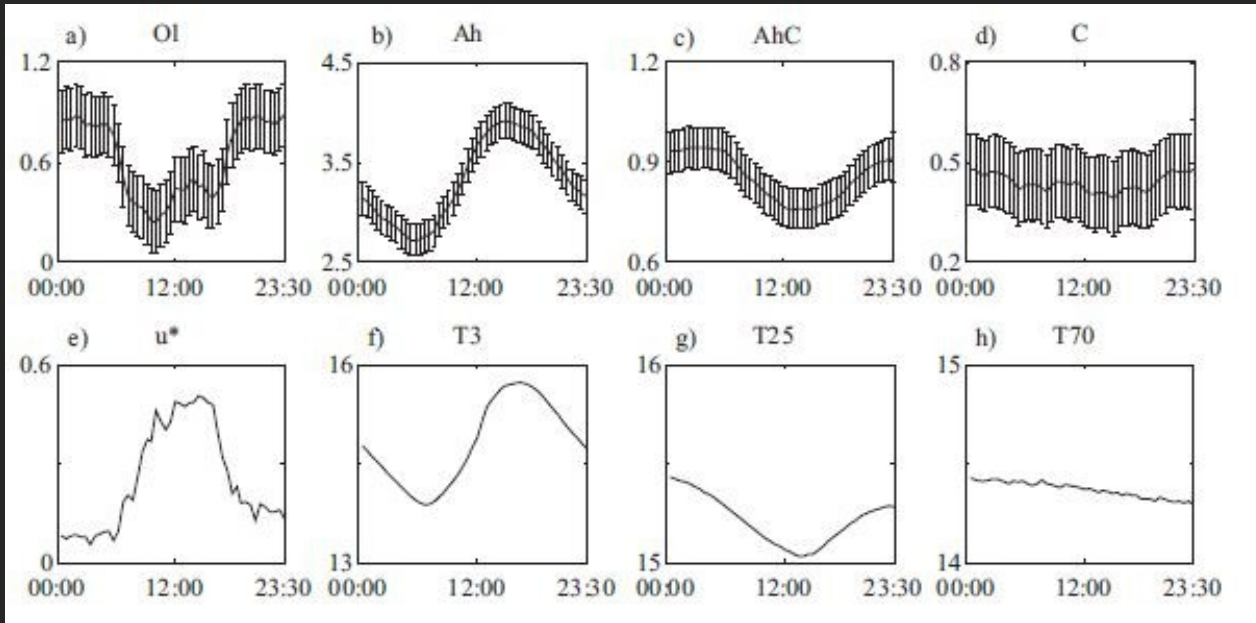
Horizon	%CO <sub>2</sub> Prod
OI	11.5
Ah	64.7
AhC	15.8
C	8



## 2. Factors affecting $P_s$ and $\delta^{13}P_s$

(Goffin et al. 2014)

### Intra-day $P_s$ variability



Mean diel  
variation

- Mean diel variation explained by **LOCAL T°** in Ah & AhC
- No significant diel variation in C
- In the litter relationship with  $u^*$  because of advection not taken into account

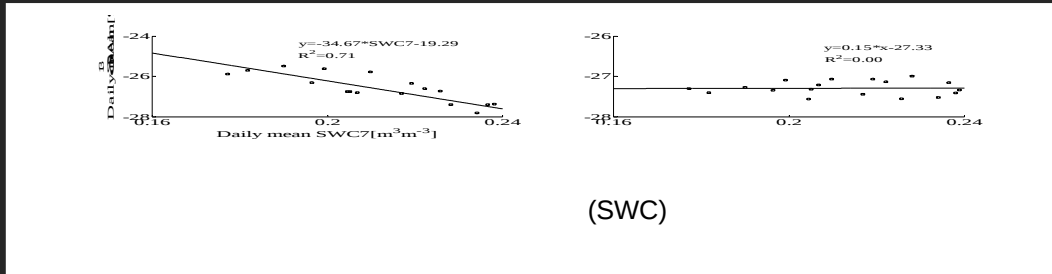
$$P_s + Adv = \frac{d(\varepsilon * C)}{dt} + \frac{d}{dz} \left( D \frac{dC}{dz} \right)$$

## 2. Factors affecting Ps and $\delta^{13}P$ s

(Goffin et al. 2014)

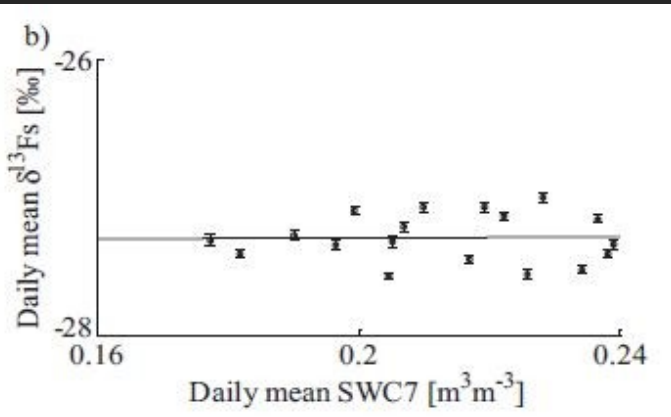
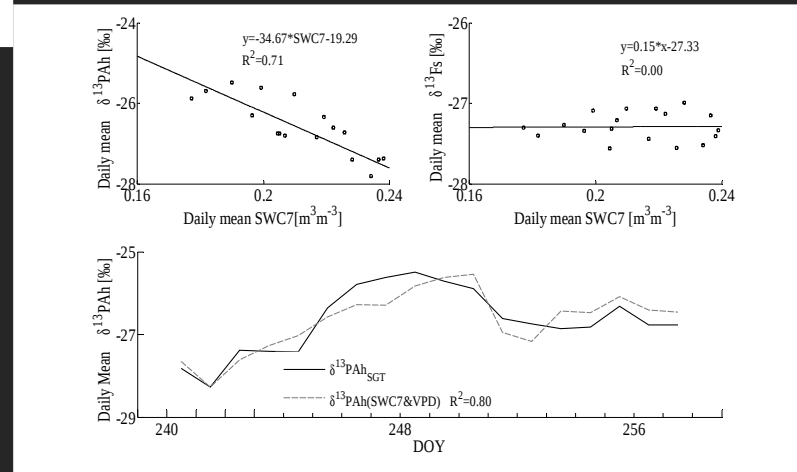
### Inter-day $\delta^{13}P$ s variability

- Significant day to day variations of  $\delta^{13}P$ s ( $> 2.5\text{‰}$ ) in Ah



- Best explained by soil moisture

Soil drought impact = enrichment  
Same impact as for photosynthesis  
discrimination !!!



- Not observed with chamber efflux measurements

- Mixing of  $\neq$  layers contributions
- Perturbation of local soil climate by chamber

?

### 3. **Who (transport or production) is responsible for $P_s$ and $\delta^{13}P_s$ temporal variability ?**

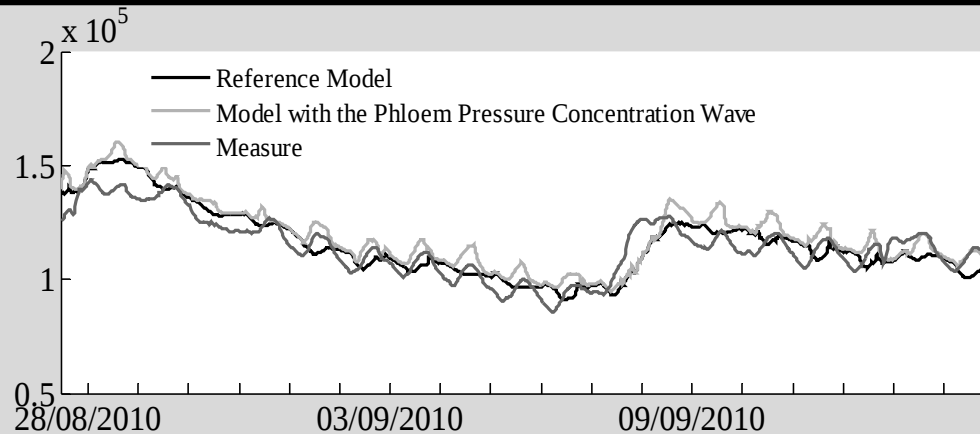
(Goffin et al. undre review)

- **3 model versions simulating CO<sub>2</sub> production and transport**
- **Comparison of their outputs with [CO<sub>2</sub>] and F<sub>s</sub> measurements**
  - Reference model (RM):
    - each layer produce CO<sub>2</sub> following Q<sub>10</sub> relationship with the local t° & diffusion is the only transport process
  - Transport Version (TV):
    - Advection and dispersion are ss
  - Production Version :
    - Production is also driven by Photosynthesis Pressure Concentration Wave (PPCW) by adding a dependence on VPD

### 3. Who (transport or production) is responsible for $P_s$ and $\delta^{13}P_s$ temporal variability ?

(Goffin et al. under review)

- RM: Relatively good reproduction of inter-day variability but intra-day variability too low and not in phase



- No significant improvement with TV
  - PPCW : Not perfect but diurnal fluctuations are better reproduced and difference in phase is reduced
- ➔ **Working on production description instead on transport one is a better option to improve soil CO<sub>2</sub> model**

# Key points

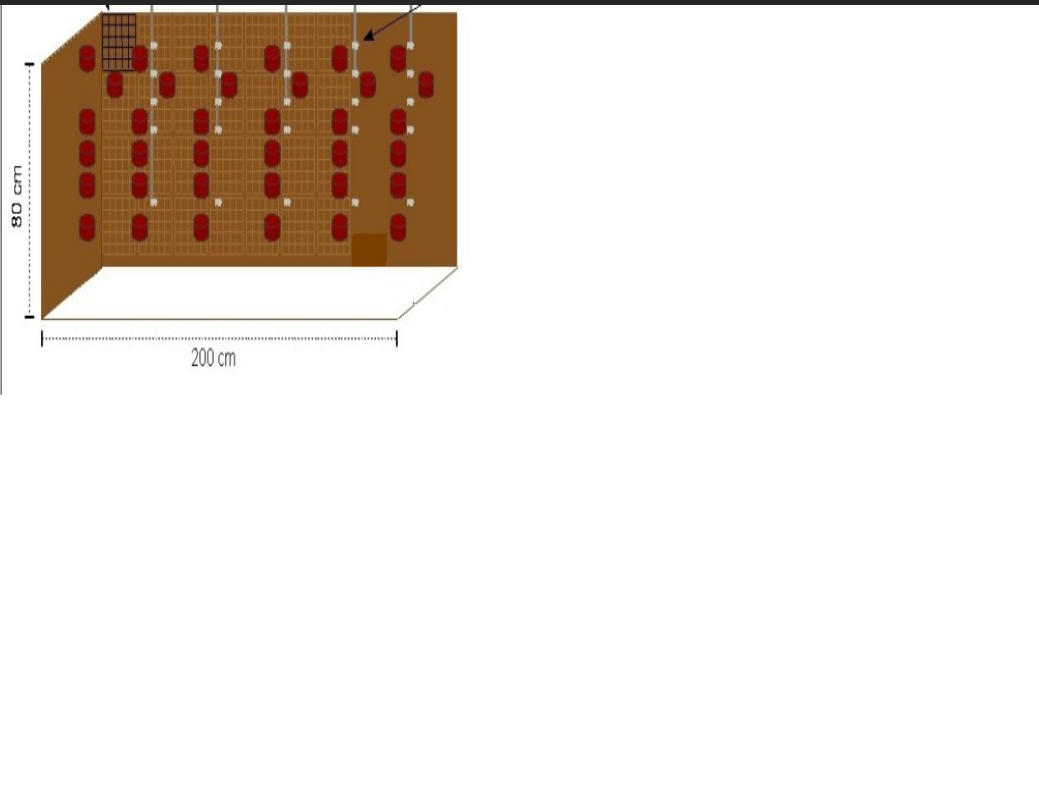
- Set up of an experimental *in-situ* device to obtain vertical profile of  $P_s$  and  $\delta P_s$
- Identify a dependence of one layer to local temperature
- Identify enrichment of  $P_s$  with soil drought in Ah horizon
- Soil CO<sub>2</sub> model should develop production description more than transport one to simulate hourly/daily variability

Thank you for your  
attention

Meet me on poster #21

# Materials & Method

## 4. Laboratory Measurements



➤ Undisturbed soil cores of 200 cm<sup>3</sup> collected in each horizon

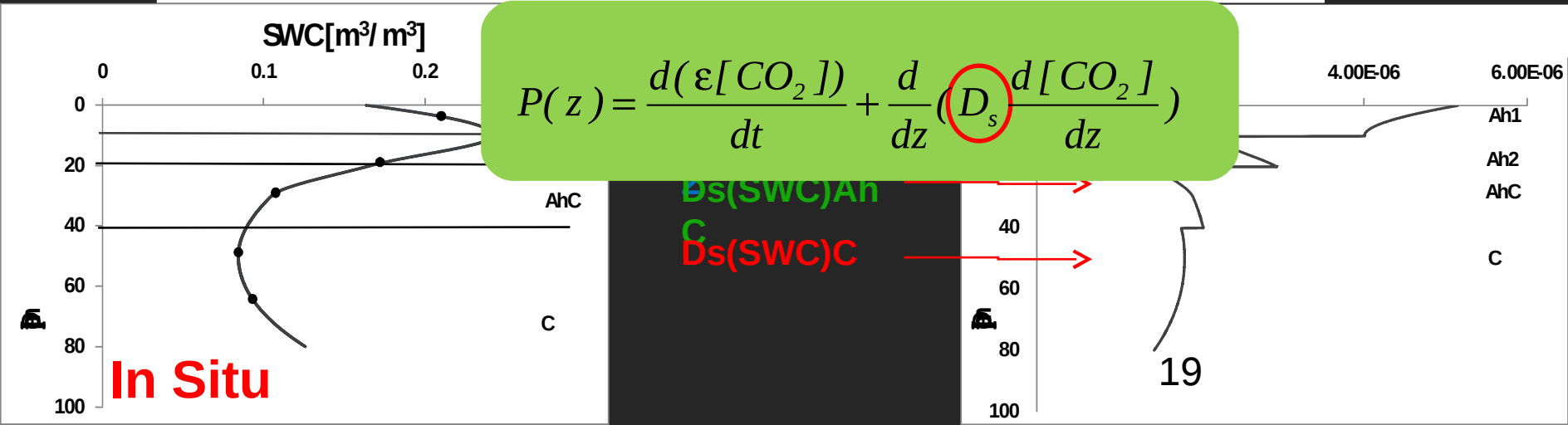
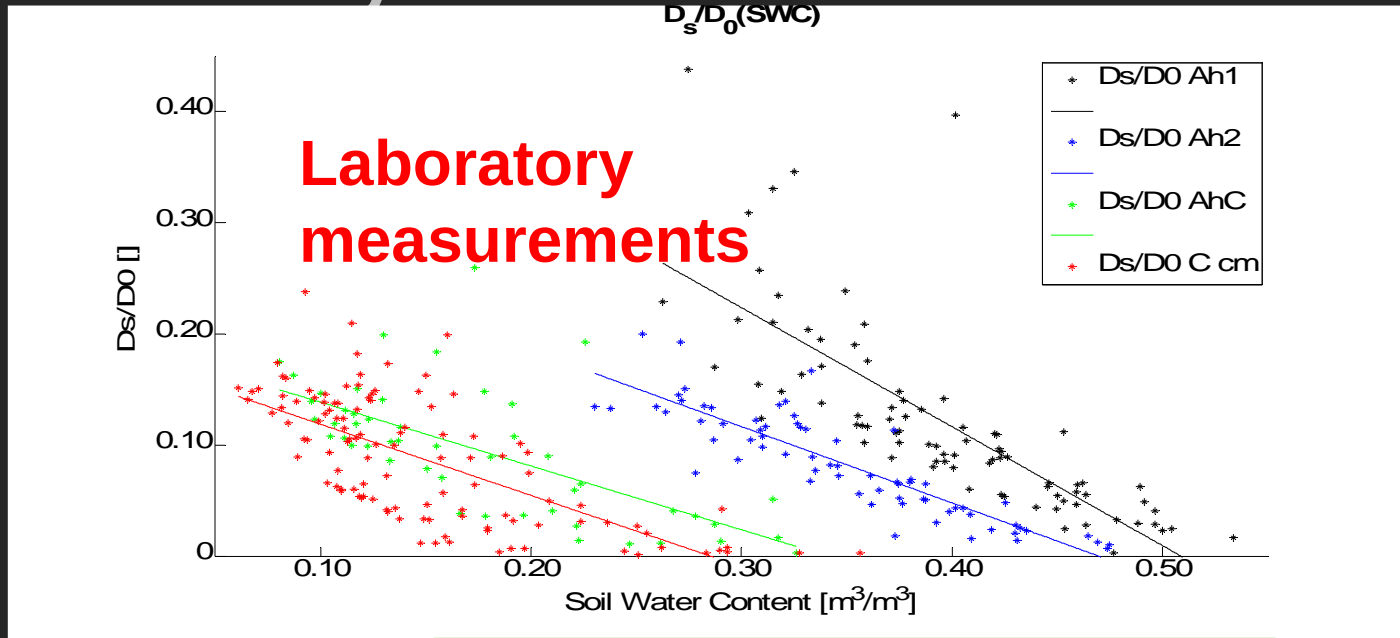


➤ Soil horizon specific physical parameters :

- Porosity, pF curves
- Relationships between  $D_s(\text{SWC})$

# Material & Method

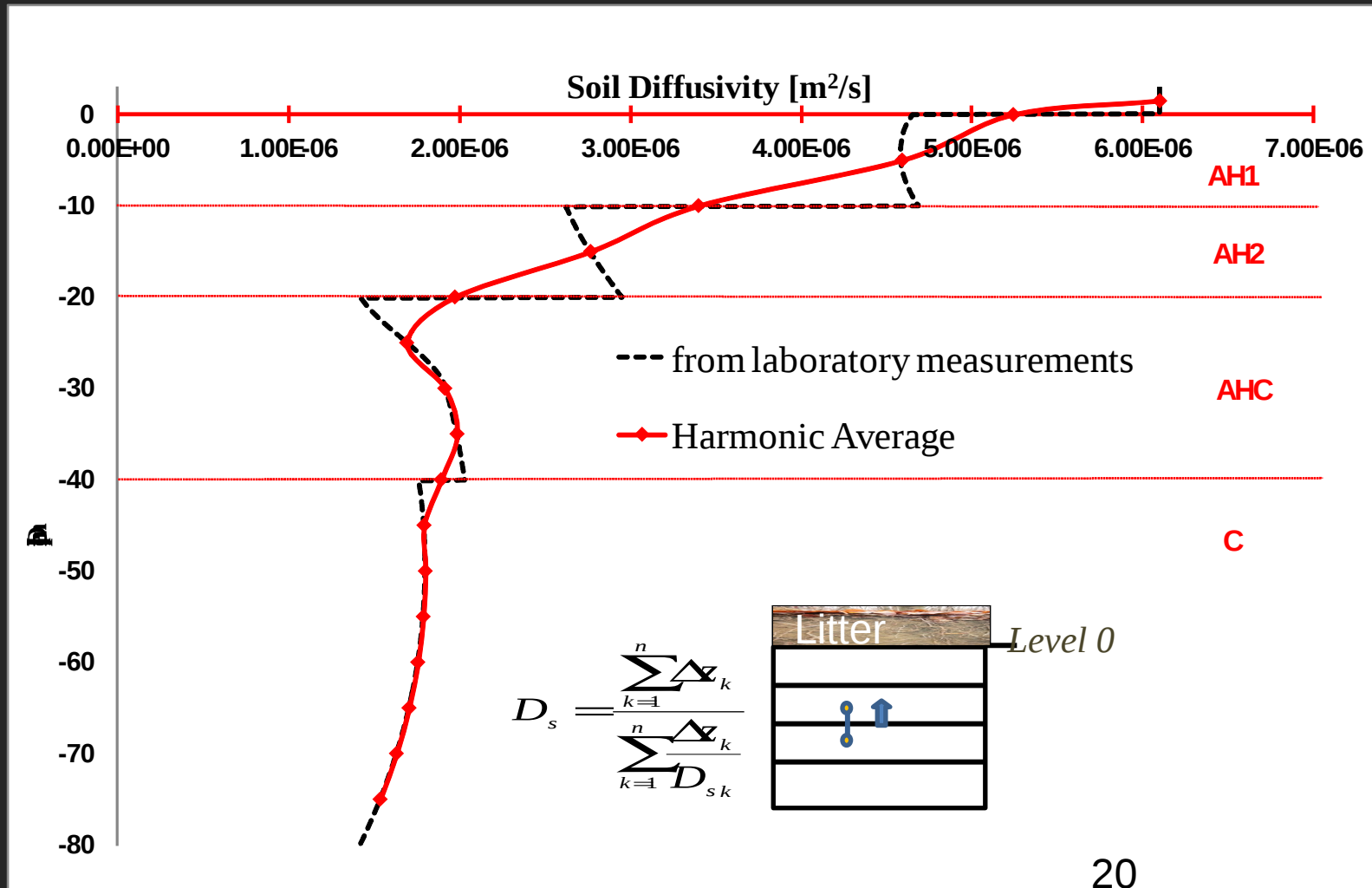
## 4. Laboratory measurements – Ds



# Materials & Method

Background & Objectives  
Materials & Method  
Results & Discussion  
Conclusions

## 4. Laboratory Measurements– Parametization



# 1. Determine Ps and $\delta^{13}P_s$ for $\neq$ layers

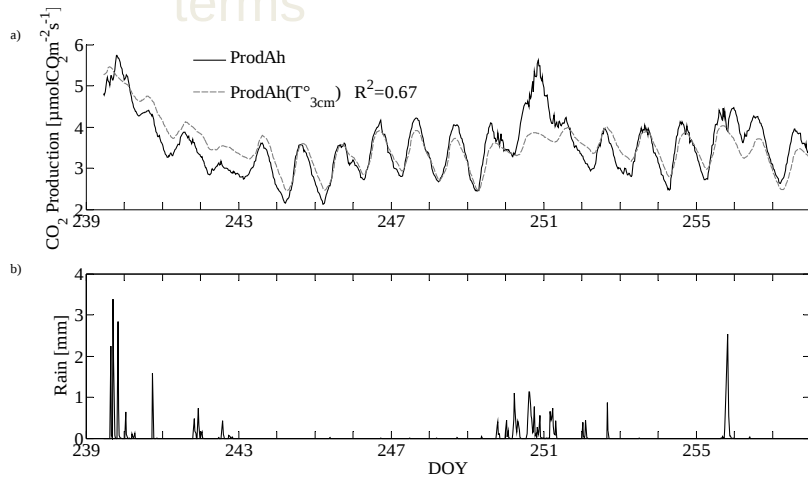
Day to day variation

## Vertical Profile of CO<sub>2</sub>

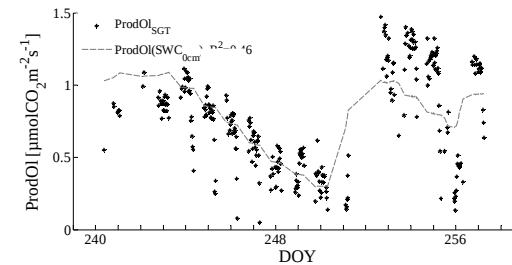
### sources

Ah Production

terms



Litter Production terms



- Soil production shows clear diel and daily fluctuations in **Ah**
- The diel and daily fluctuations are best explained by the T measured in the topsoil  
temperature is the most important driver of soil CO<sub>2</sub> production

- Unlike other horizons, Ol production was best explained by surface soil water content (SWC) ( $R^2=0.46$ )