MEASURING AND MODELING SOIL INTRA-DAY VARIABILITY OF THE $^{13}CO_2$ & $^{12}CO_2$ PRODUCTION AND TRANSPORT IN A SCOTS PINE FOREST

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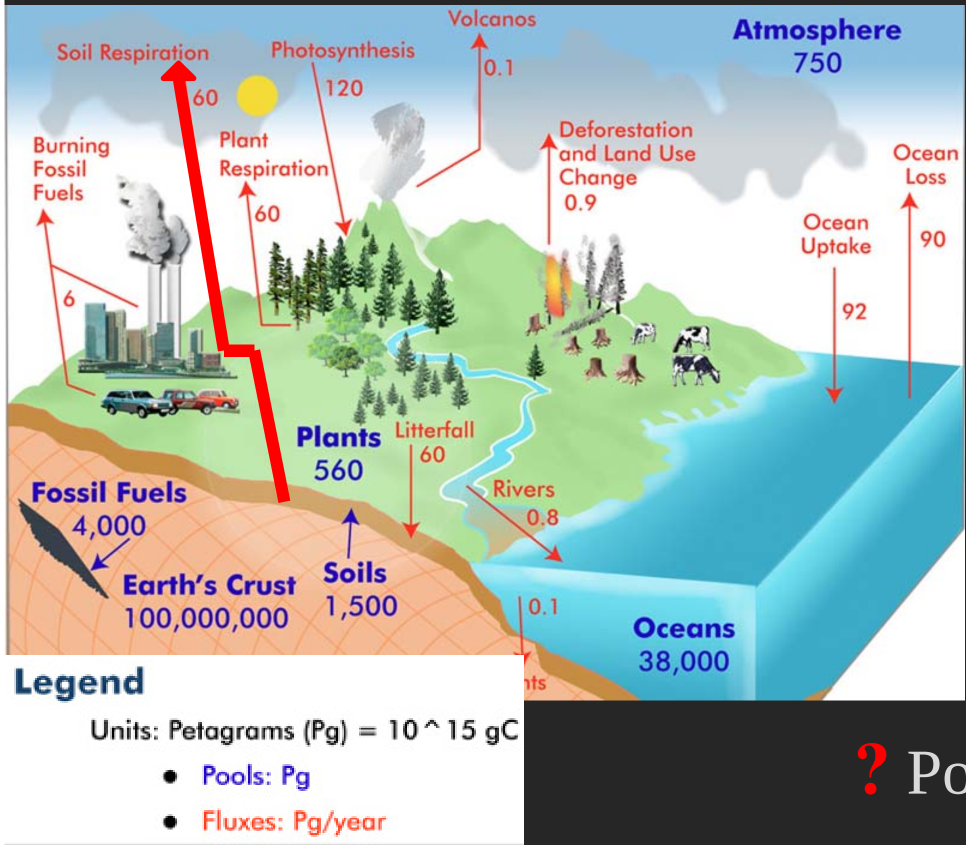
Background & Objectives

Soil CO_2 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 >>>

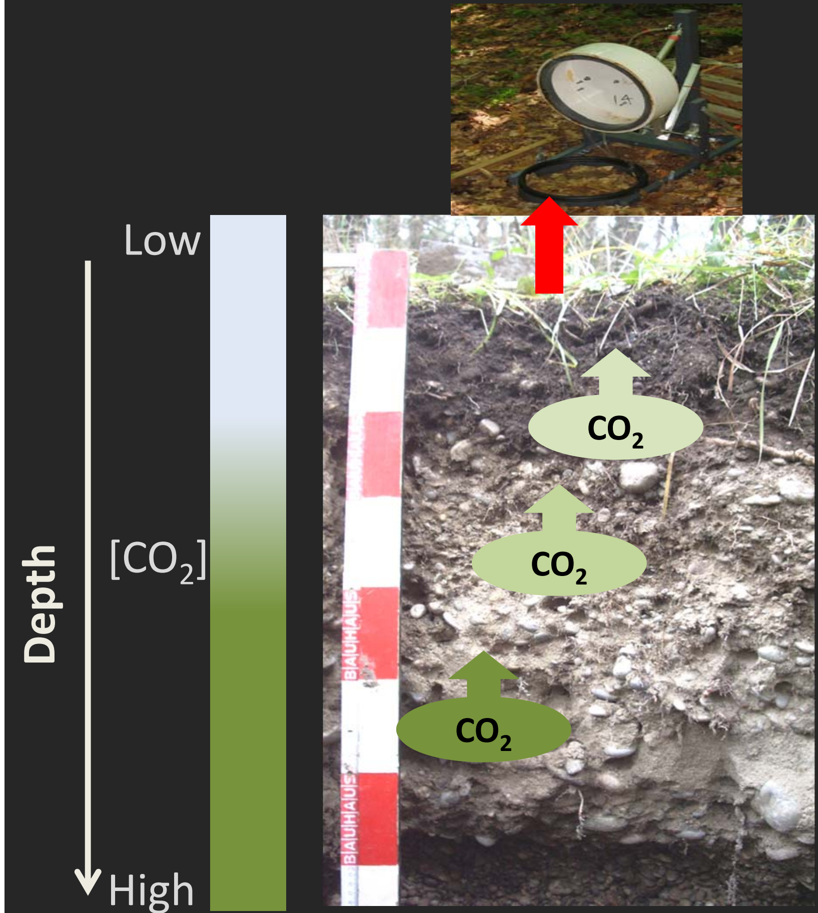
? Climate Change Impact?

? Positive feedback to the GHG effect?

Past — today — Future

Empirical description — **Mechanistic understanding**

Background & Objectives



Fs

Transport

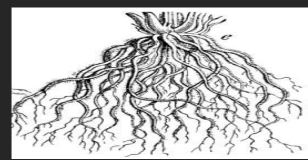
Diffusion

Avection +
Dispersion

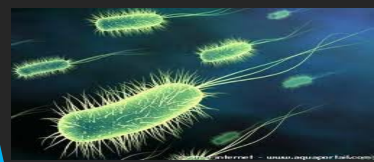
Liquid phase

Production

Autotrophic



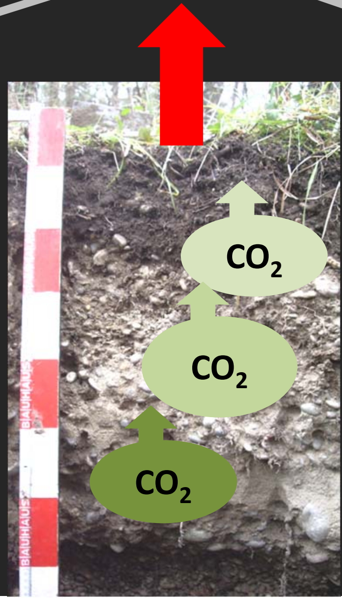
Heterotrophic



Abiotic

Background & Objectives

Fs



Transport

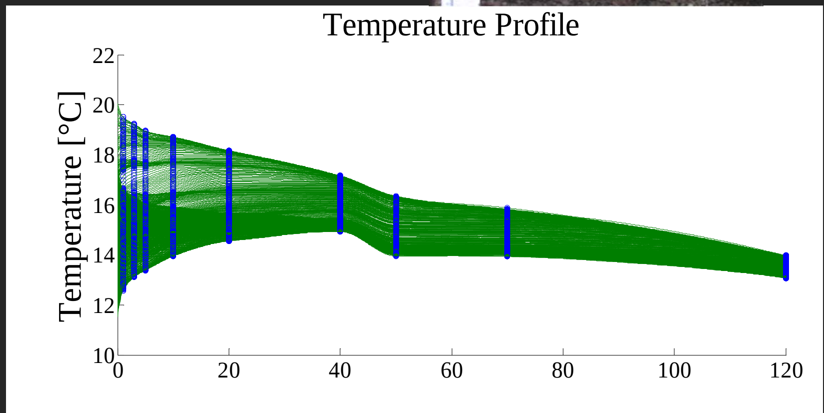
f(porosity, humidity…)

Production Ps

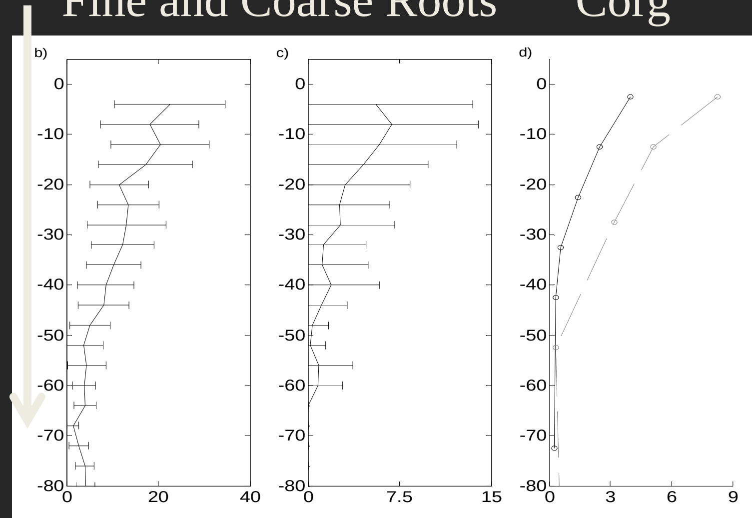
Heterotrophic **Autotrophic**

f(Temperature, humidity, substrate)

Porosity

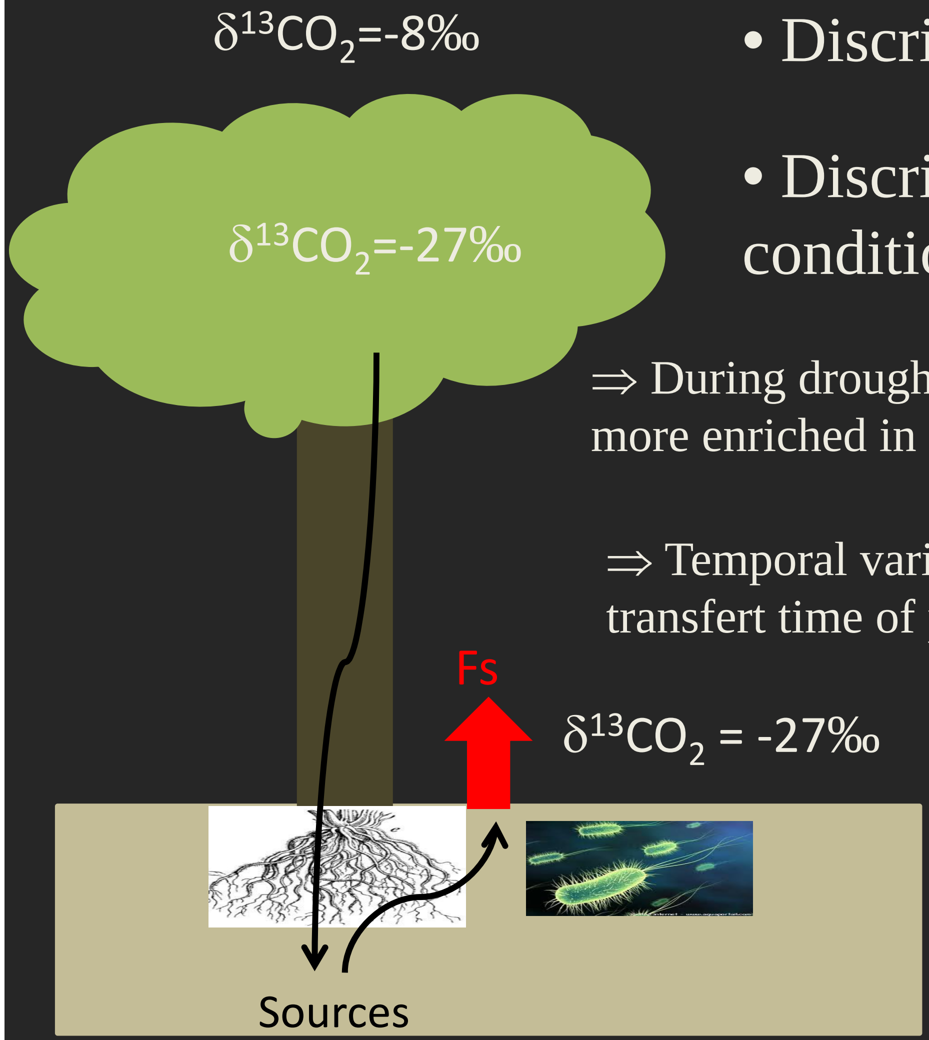


Fine and Coarse Roots Corg



⇒ Multilayer Approach needed

Background & Objectives



- Discrimination during CO_2 assimilation

- Discrimination changes with climatic conditions

⇒ During drought, discrimination decrease ⇒ photoassimilats more enriched in $^{13}CO_2$ (ex: -25‰)

⇒ Temporal variation of $\delta^{13}CO_2$ may give informations about transfert time of photoassimilates

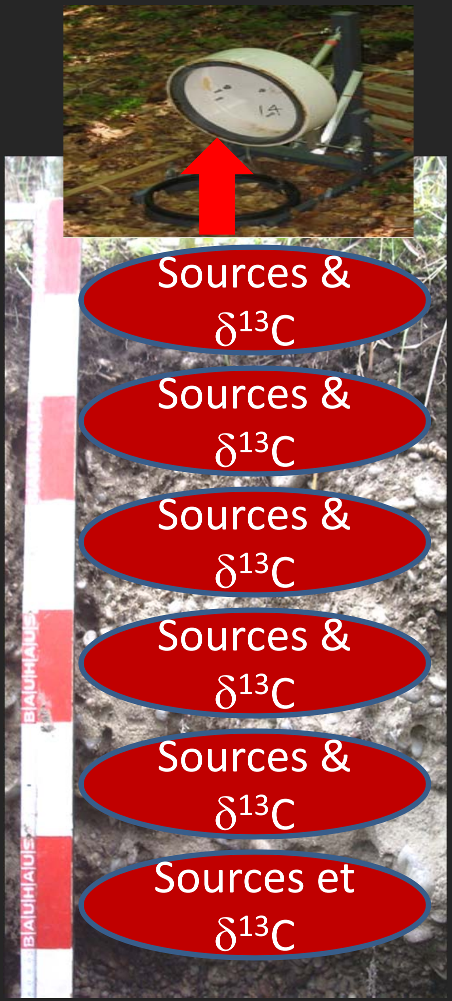
$\delta^{13}CO_2$ may differs between CO_2 sources

⇒ $\delta^{13}CO_2$ may helps for partitionning Fs between sources

⇒ Understanding of $\delta^{13}CO_2$ fluctuations (space & time) needed

Background & Objectives

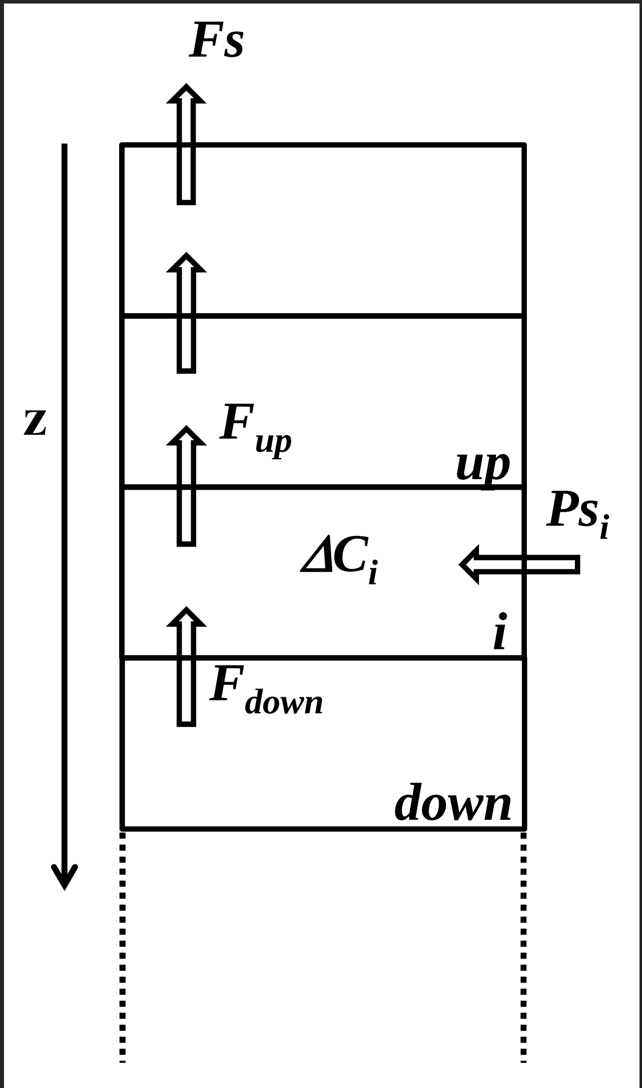
Improving mechanistic understanding of F_s



Multilayer Approach **Isotopic Signal Analysis**

1) Determine the CO_2 production rate ***Ps*** and its isotopic signature δ^{13}***Ps*** for the different soil horizons.
2) Find factors affecting ***Ps*** & δ^{13}***Ps*** intra & inter day fluctuations
3) Evaluate by modeling which processes (production or transport) drive ***Fs*** temporal variability

1. Determine Ps and δ^{13}Ps for ≠ layers



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

$$\frac{\Delta(\varepsilon_i * C_i)}{\Delta t} = \frac{F_{down} - F_{up}}{thick_i} + Ps_i$$ for $^{12}CO_2$ & $^{13}CO_2$

- Diffusive Flux-Gradient approach

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

$$\Rightarrow Ps_i = \varepsilon_i * \frac{\Delta C_i}{\Delta t} + \frac{\left(D * \frac{\Delta C}{\Delta z}\right)_{down\_i} - \left(D * \frac{\Delta C}{\Delta z}\right)_{up\_i}}{thick_i}$$

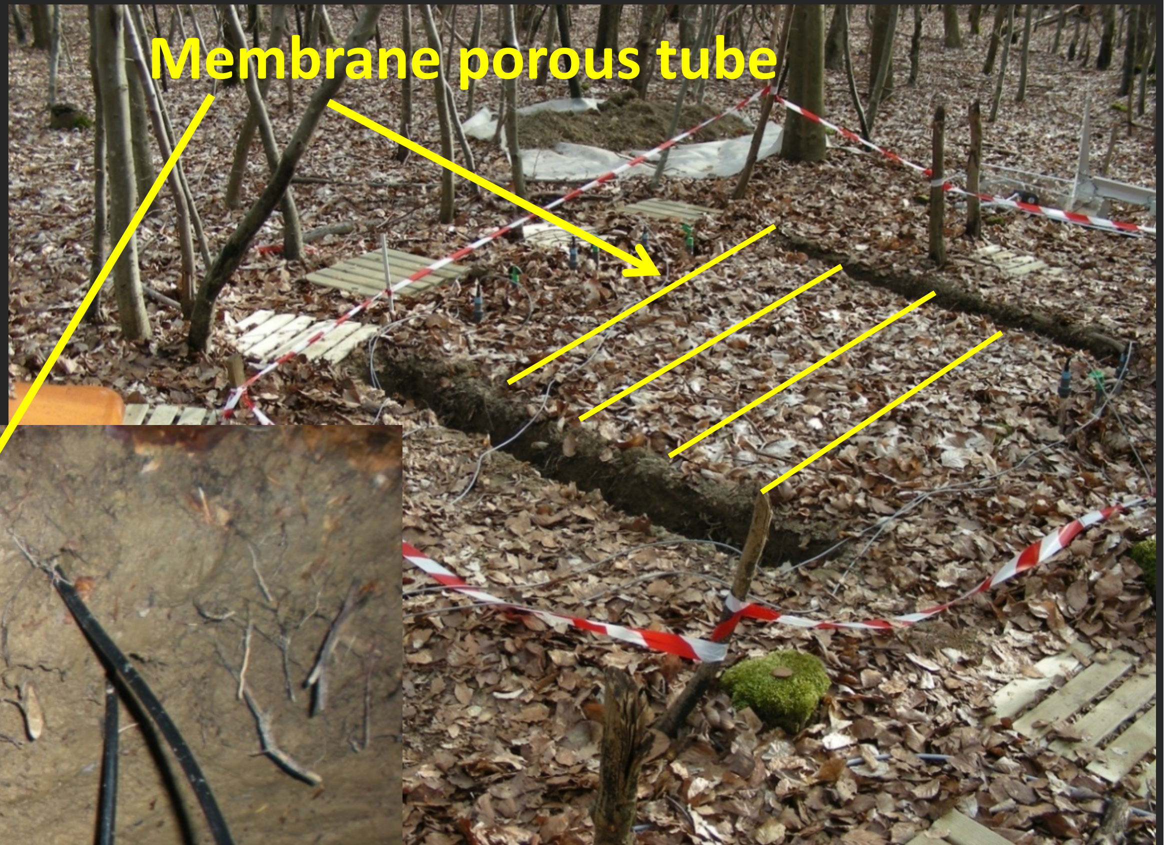
Vertical profile of their dependence on SWC measured on samples at ALBERT-LUDWIGS-UNIVERSITÄT FREIBURG

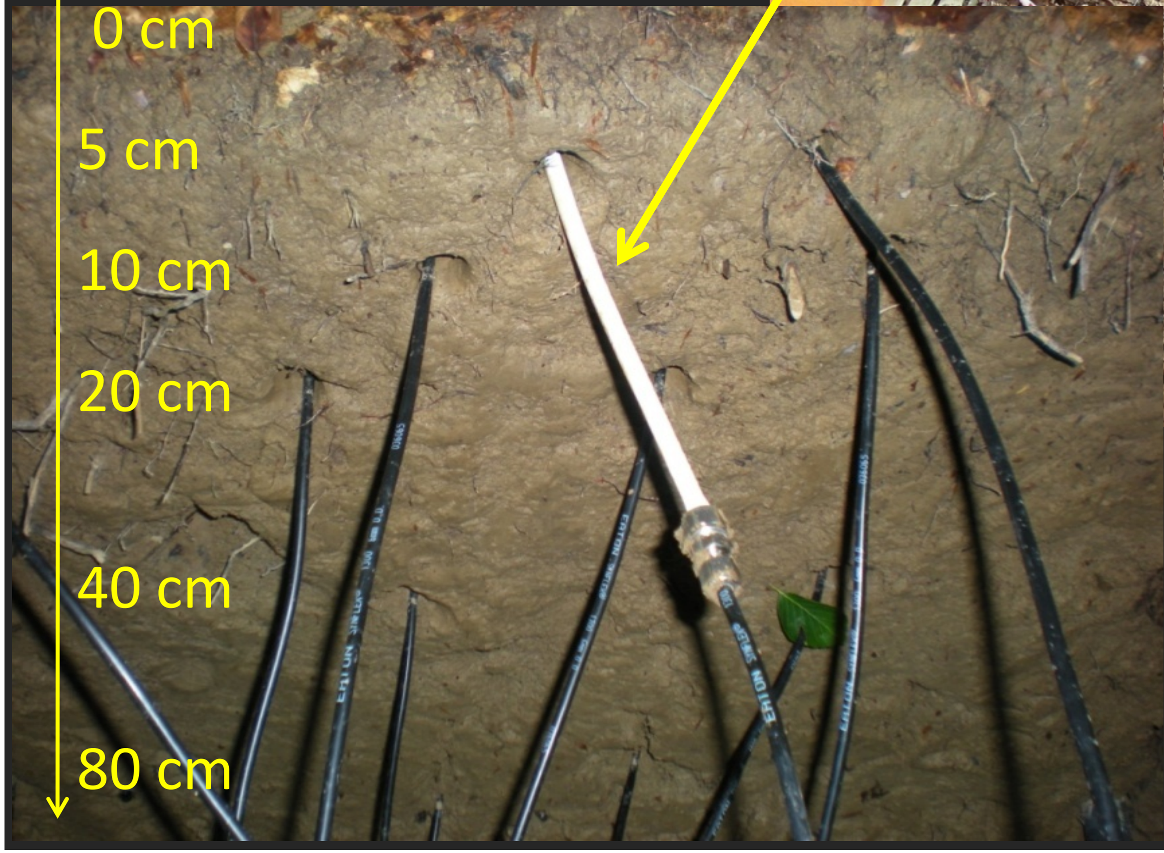
$^{12}CO_2$ & $^{13}CO_2$ vertical profile measured by INRA SCIENCE & IMPACT, UNIVERSITÉ DE LORRAINE

➡ Ps and δPs for each layer

1. Determine Ps and δ^{13}Ps for ≠ layers (Parent et al. 2013)

Field Measurements

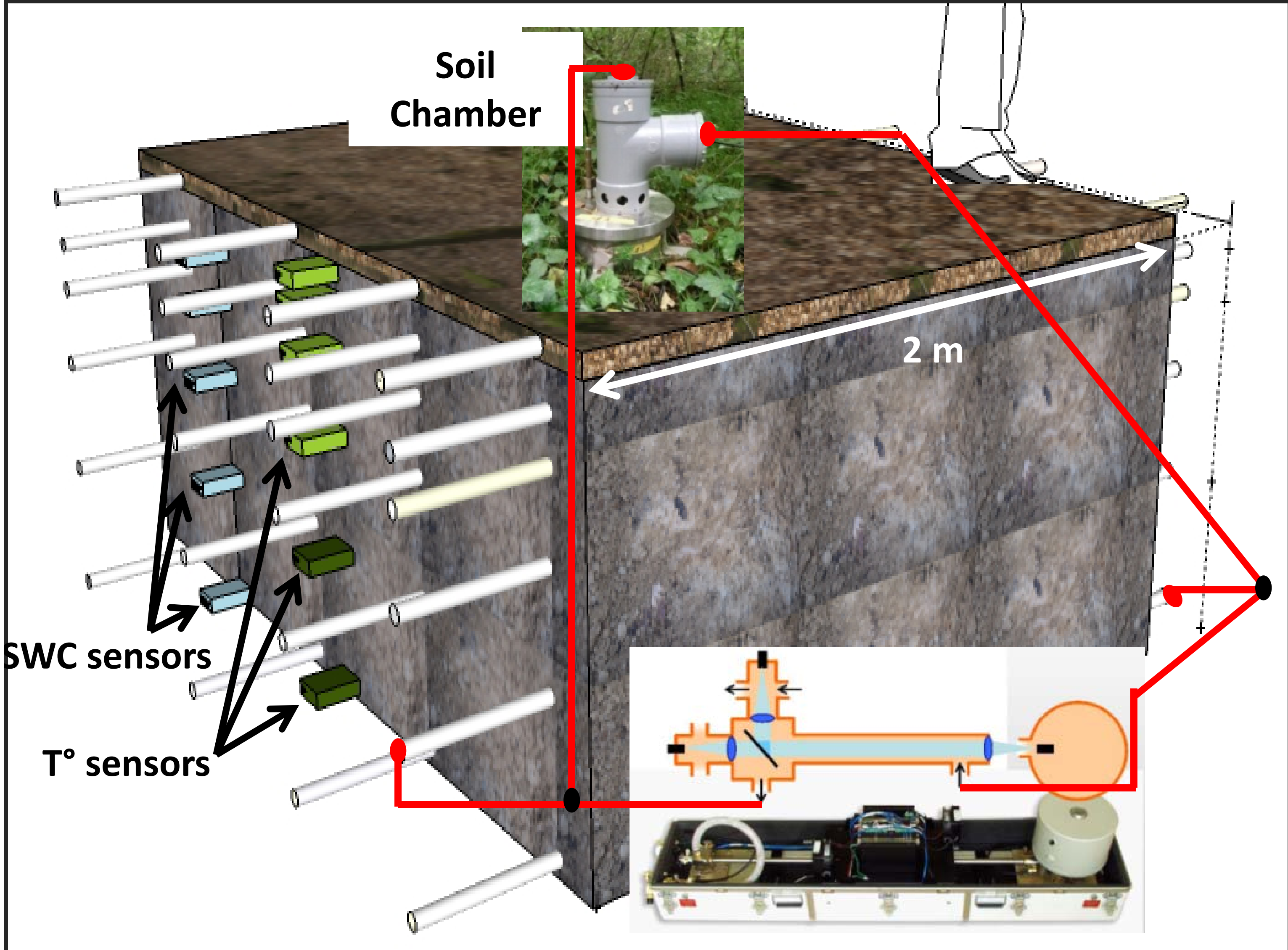




1. Determine Ps and δ^{13}Ps for ≠ layers (Parent et al. 2013)

Field Measurements

Half-hourly In situ measurements during 21 days



TDLS:

$^{12}[CO_2]$ & $^{13}[CO_2]$

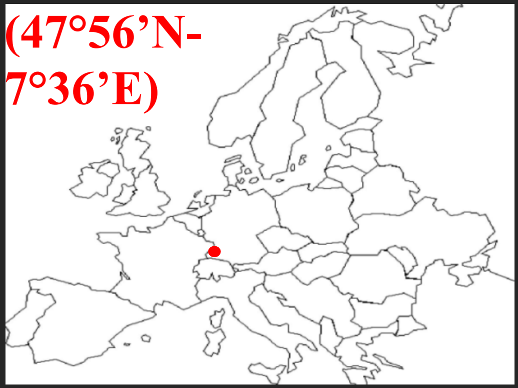
1) membrane tube ≡ $[CO_2]$ & $\delta^{13}CO_2$ in soil layers

2) from chamber ≡ *EFs* & δ^{13}*EFs*

1. Determine Ps and δ^{13}Ps for ≠ layers

Site Description

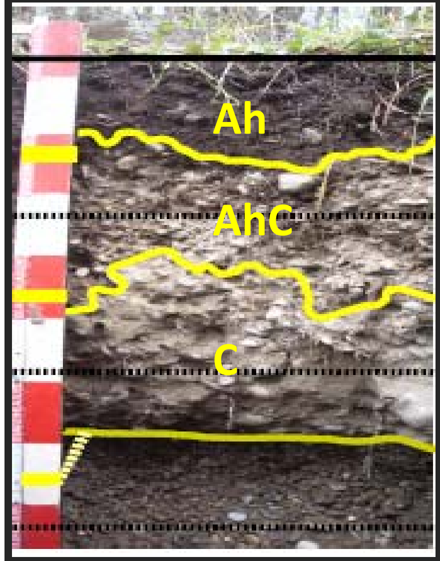
Hartheim experimental site



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)

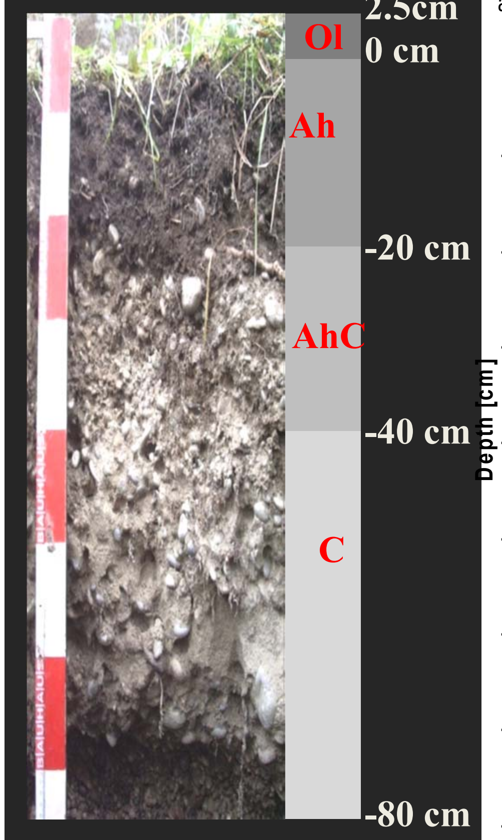
Humus type is mull (1-3 cm thick)

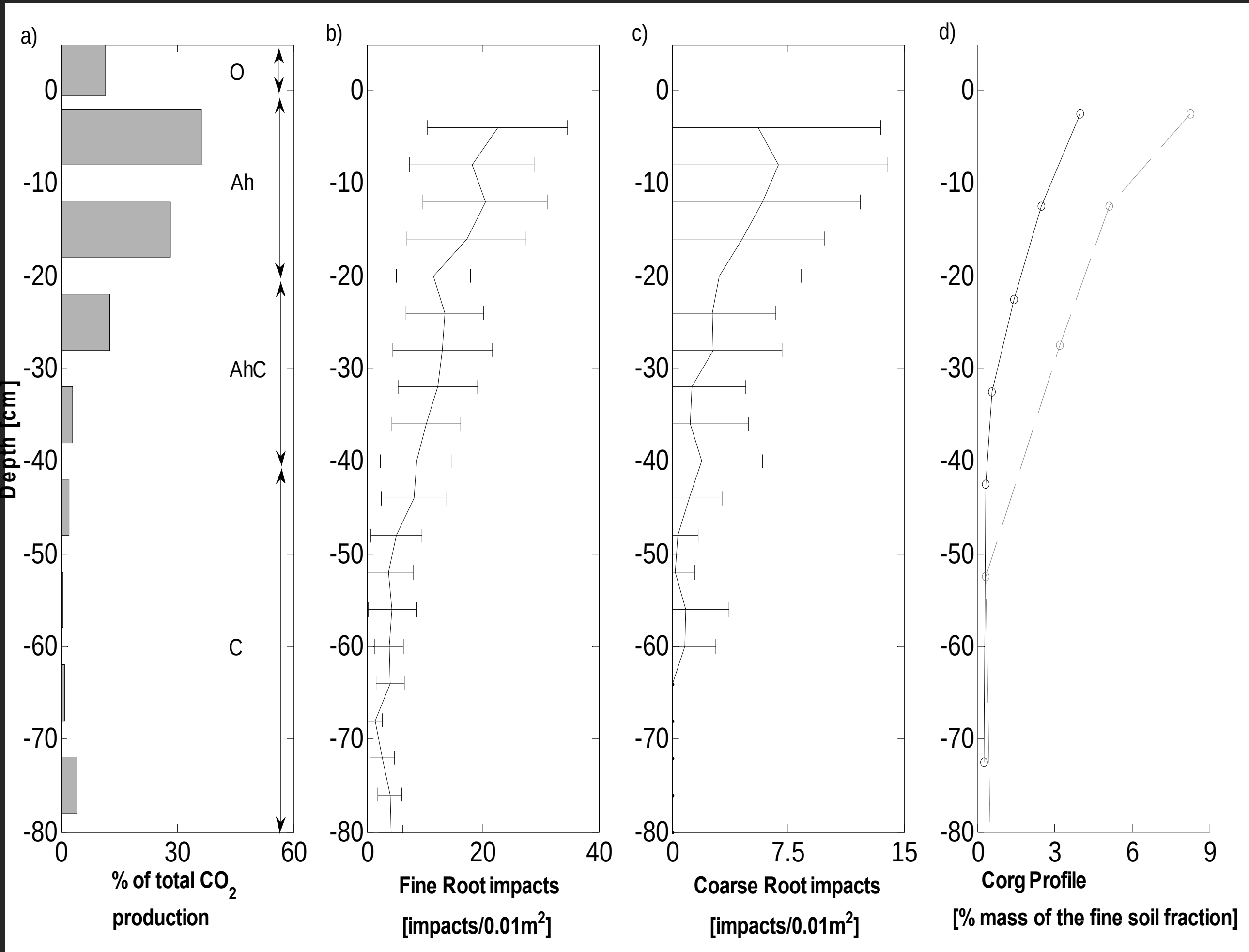
Eddy Covariance tower Meteorological station

1. Determine Ps and δ^{13}Ps for ≠ layers

Vertical Profile of Ps

Horizon	% CO_2 Prod
Ol	11.5
Ah	64.7
AhC	15.8
C	8

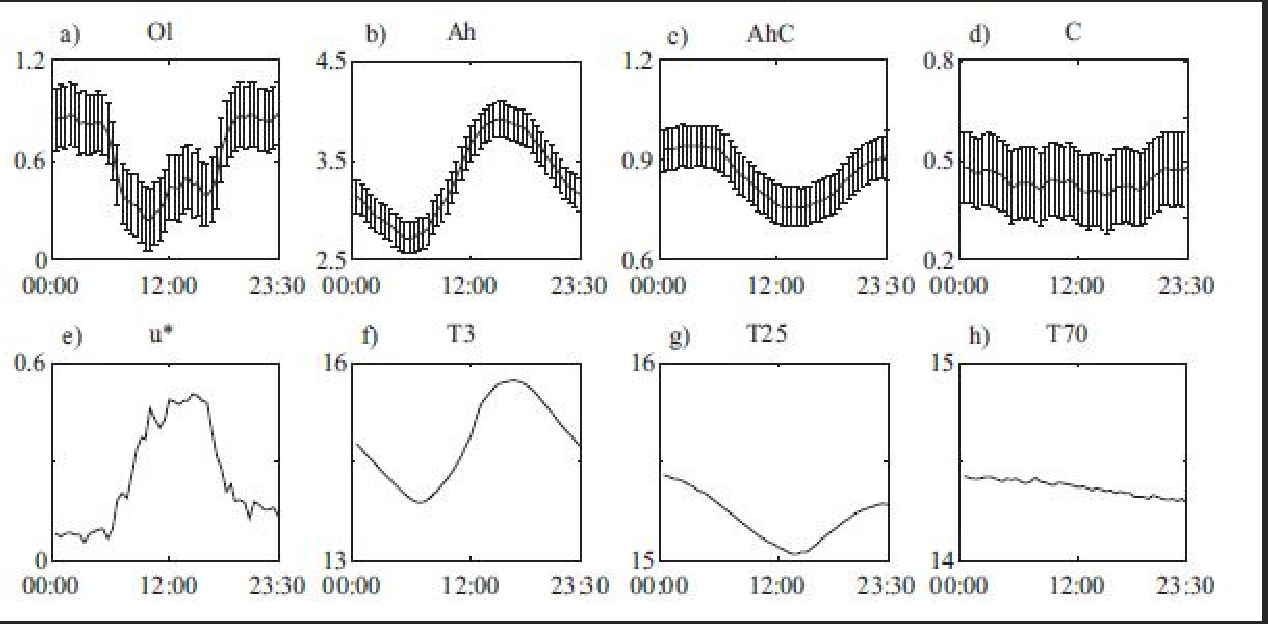




2. Factors affecting Ps and δ^{13}Ps

(Goffin et al. 2014)

Intra-day Ps variability



Mean diel variation

- Mean diel varation 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

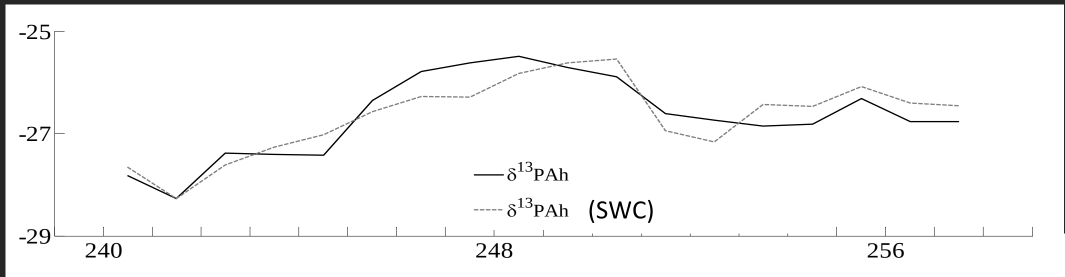
$$Ps + Adv = \frac{d(\varepsilon * C)}{dt} + \frac{d}{dz}\left(D\frac{dC}{dz}\right)$$

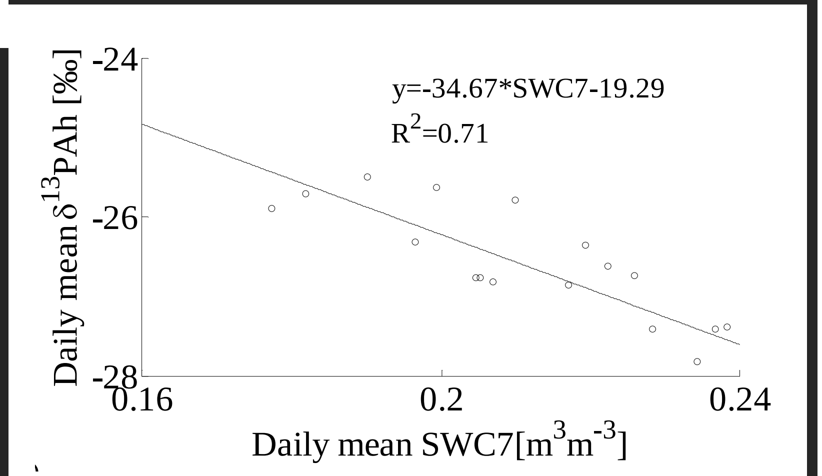
2. Factors affecting Ps and δ13Ps

(Goffin et al. 2014)

Inter-day δ13Ps variability

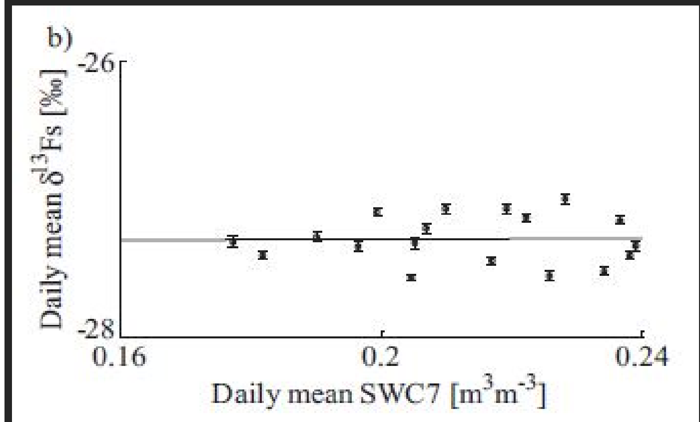
- **Significant day to day variations of δ13Ps (> 2.5‰) in Ah**





- **Best explained by soil moisture**

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



- **Not observed with chamber efflux measurements**

o Mixing of ≠ layers contributions
o Perturbation of local soil climate by chamber ?

3. Who (transport or production) is responsible for Ps and δ^{13}Ps temporal variability ?

(Goffin et al. undre review)

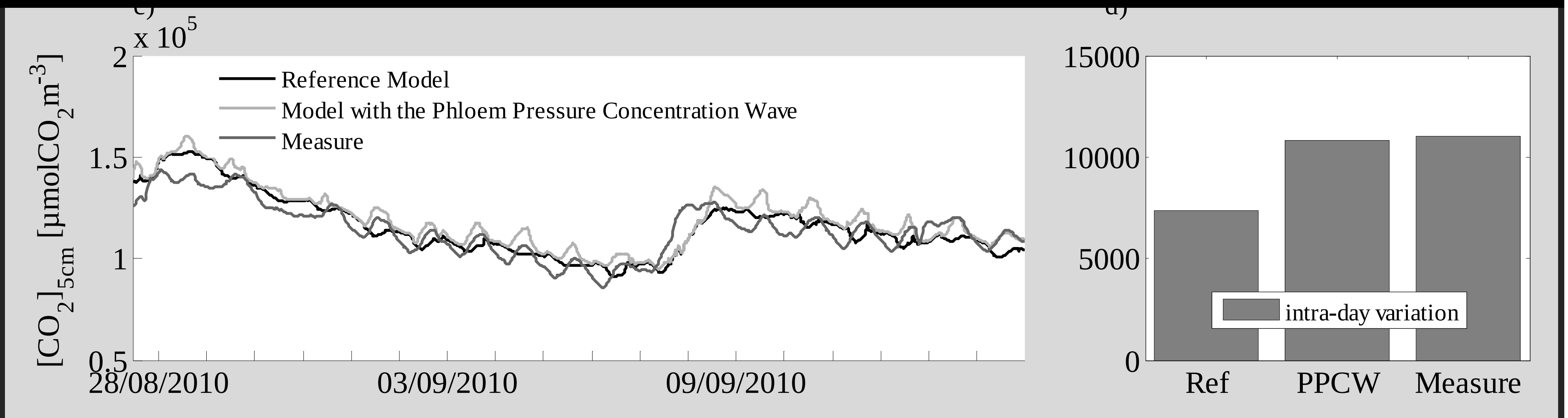
- **3 model versions simulating CO_2 production and transport**
- **Comparison of their outputs with [CO_2] and Fs measurements**

  - Reference model (RM):
    each layer produce CO_2 following Q10 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 Ps and δ^{13}Ps temporal variability ?

(Goffin et al. undre 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_2 model

Key points

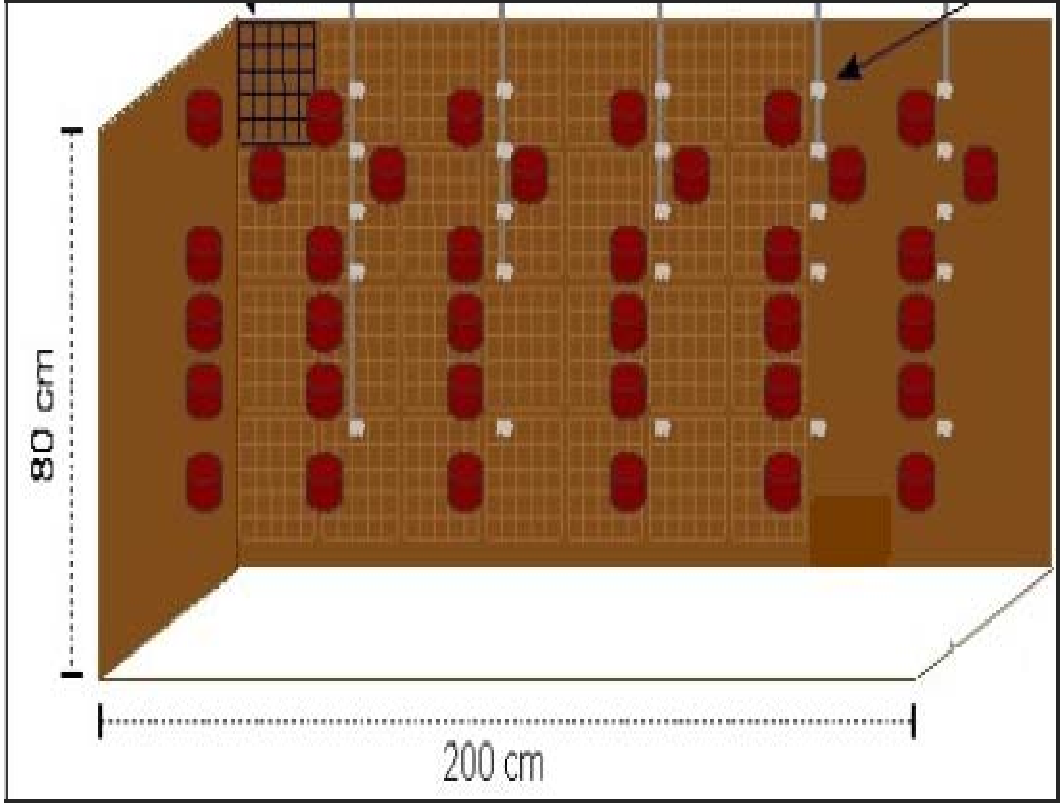
- Set up of an experimental *in-situ* device to obtain vertical profile of Ps and δPs
- Identify a dependence of one layer to local temperature
- Indentify enrichment of Ps with soil drought in Ah horizon
- Soil CO_2 model should develop production description more than transport one to simulate hourly/daily variability

Thank you for your attention

Meet me on poster #21

Materials & Method

4. Laboratory Measurements



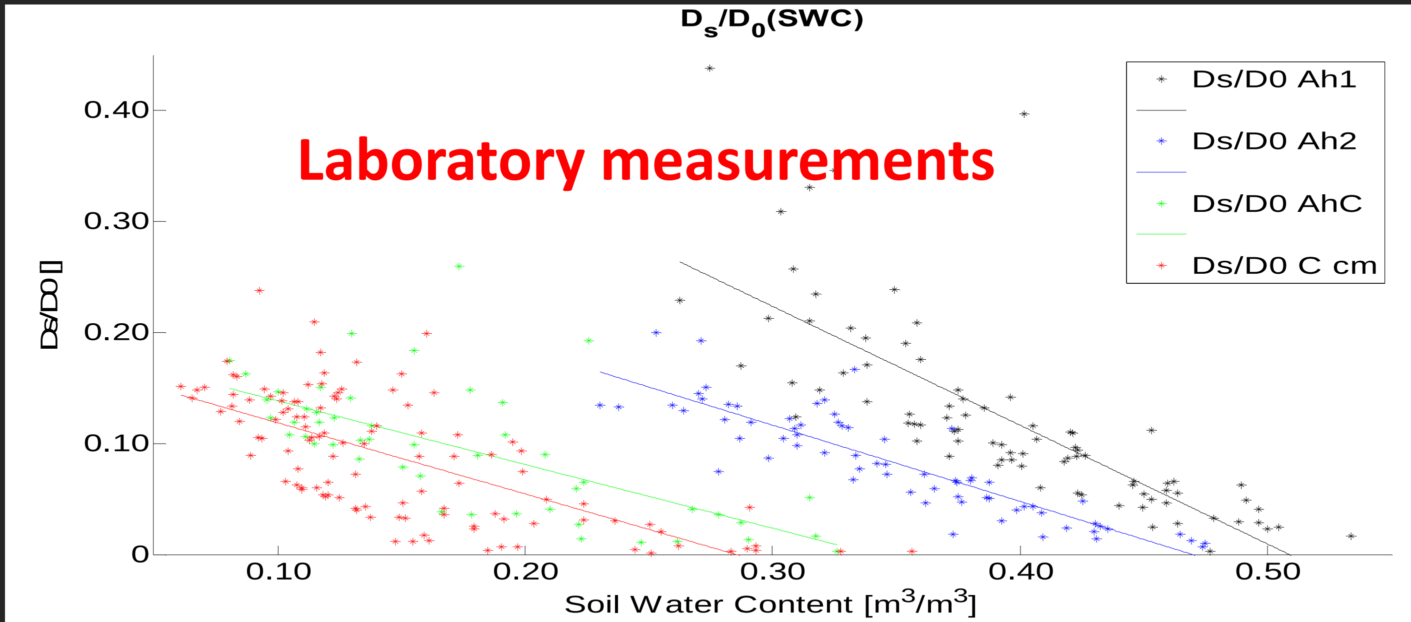
➢ Undisturbed soil cores of 200 cm^3 collected in each horizon

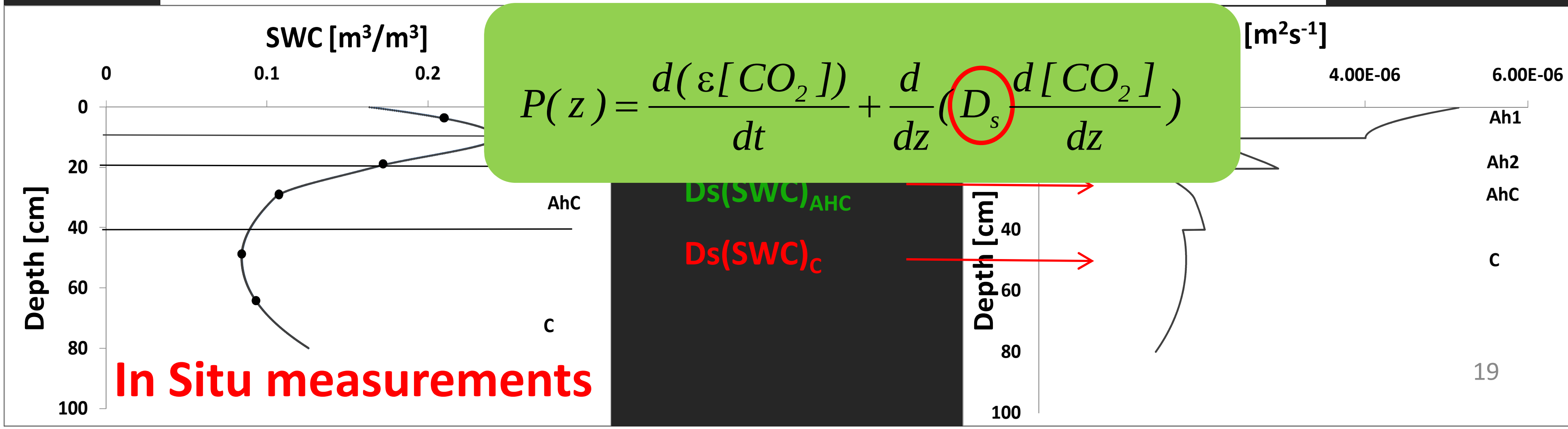
➢ Soil horizon specific physical parameters :

- Porosity, pF curves
- Relationships between Ds(SWC)

Material & Method

4. Laboratory measurements – Ds determination

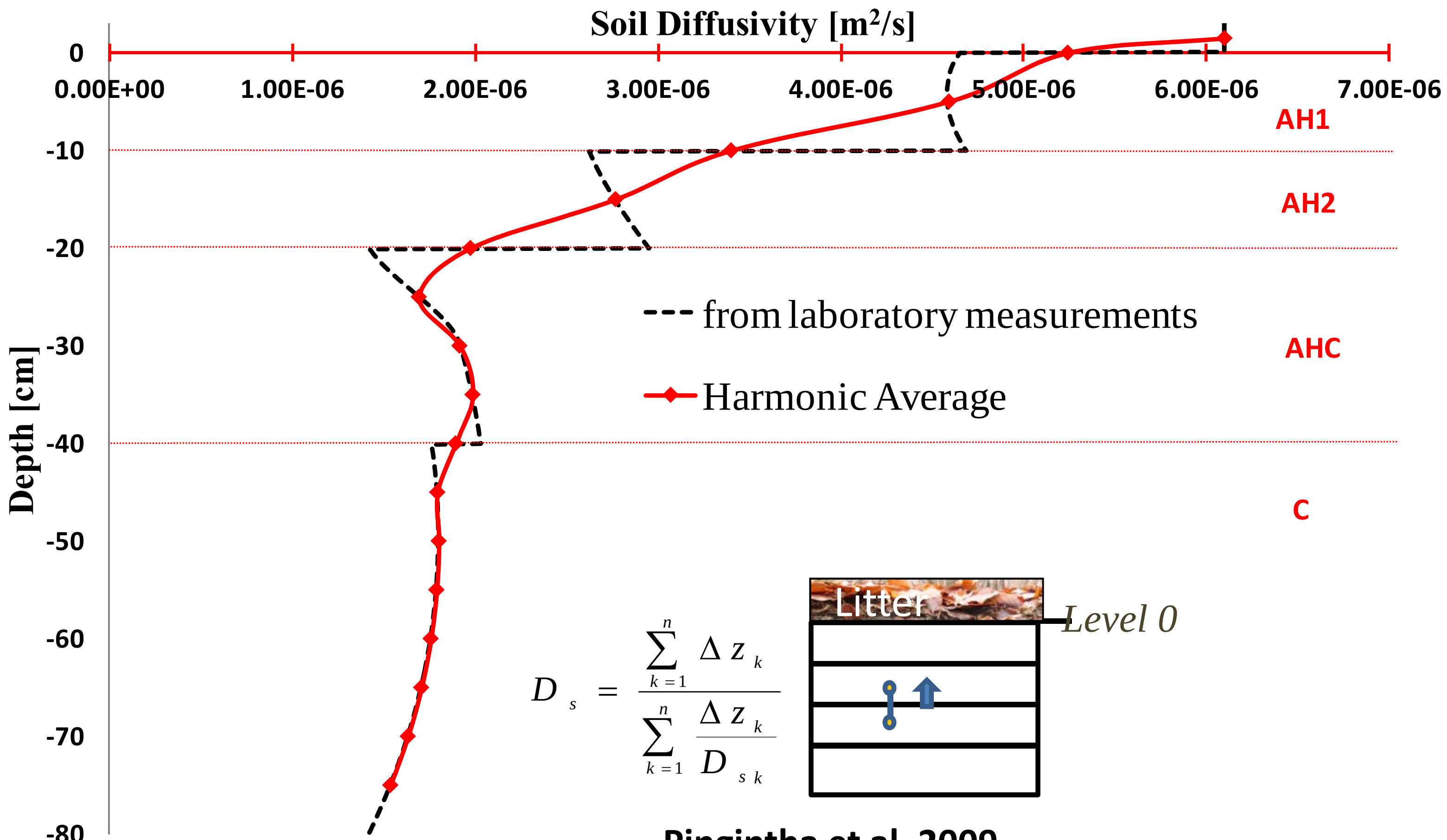




$$P(z) = \frac{d(\varepsilon[CO_2])}{dt} + \frac{d}{dz}\left(D_s \frac{d[CO_2]}{dz}\right)$$

Materials & Method

4. Laboratory Measurements– Parametization



$$D_s = \frac{\sum_{k=1}^{n} \Delta z_k}{\sum_{k=1}^{n} \frac{\Delta z_k}{D_{sk}}}$$

Pingintha et al, 2009

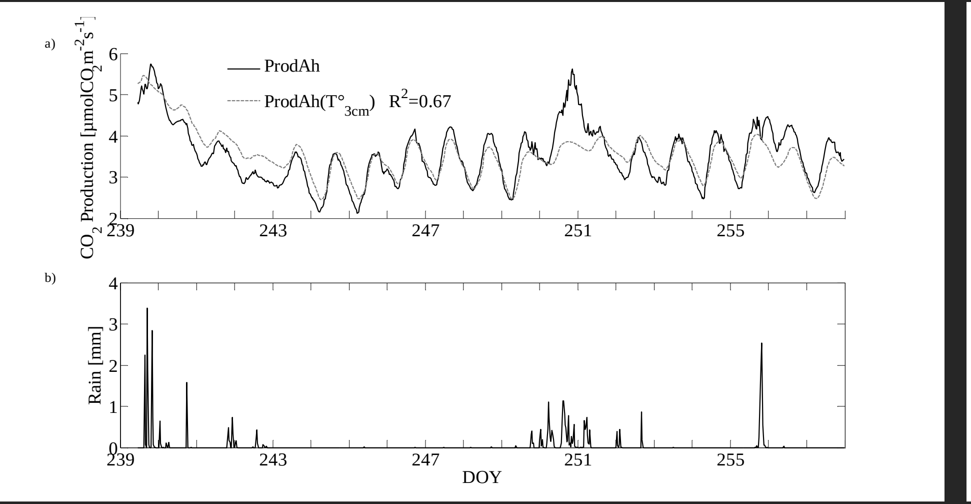
1. Determine Ps and δ^{13}Ps for ≠ layers

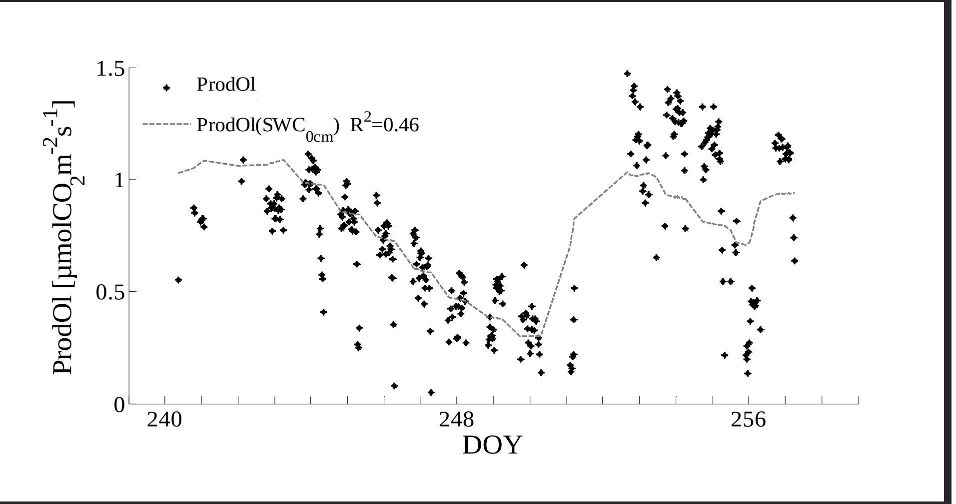
Day to day variation

Vertical Profile of CO_2 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_2 production

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