APBI403/SOIL503

Soil Physics-

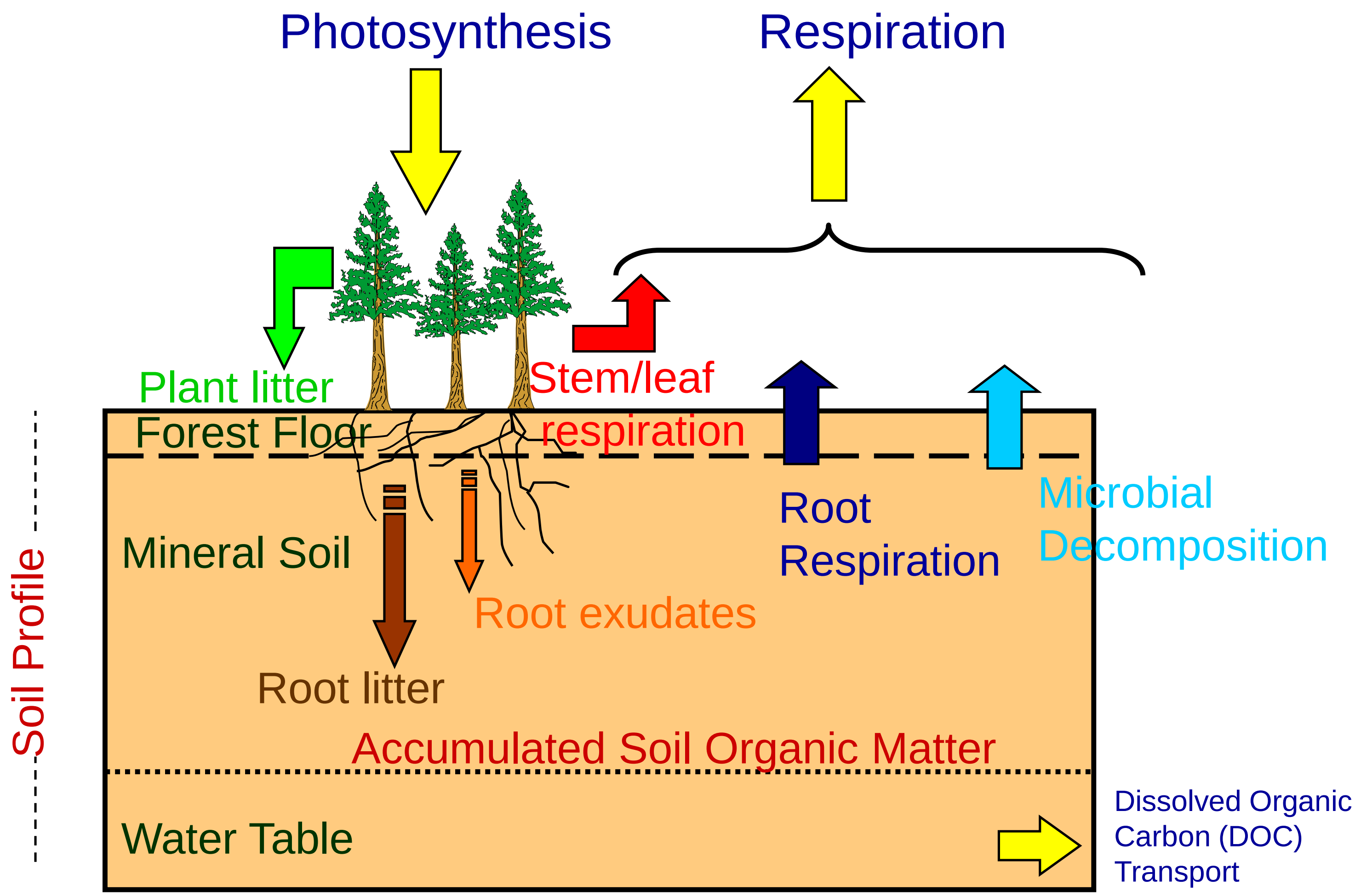
Lecture 8

Outline

- Ecosystem Carbon balance (overview)
- Soil respiration
  - Chamber methods
  - Soil gradient method


Soil respiration

Ecosystem C-balance



Carbon Sequestration = Photosynthesis - Respiration - DOC Transport

(carbon gain) (carbon loss)

Net ecosystem productivity (NEP)

Source: UBC Biometeorology

Ecosystem respiration

$= R_{a\ foliage}$
$+ R_{a\ stem\ +\ branches}$ } Autotrophic (R_a)
$+ R_{a\ roots}$

$+ R_{h\ coarse\ woody\ debris}$
$+ R_{h\ soil\ organic\ matter}$ } Heterotrophic (R_h)

R_{soil} is a large fraction of ecosystem respiration

(includes $R_{a\ roots}$, $R_{h\ soil\ organic\ matter}$ and may include some of $R_{h\ coarse\ woody\ debris}$)

Significance

More C stored in world's soils than is present in the atmosphere

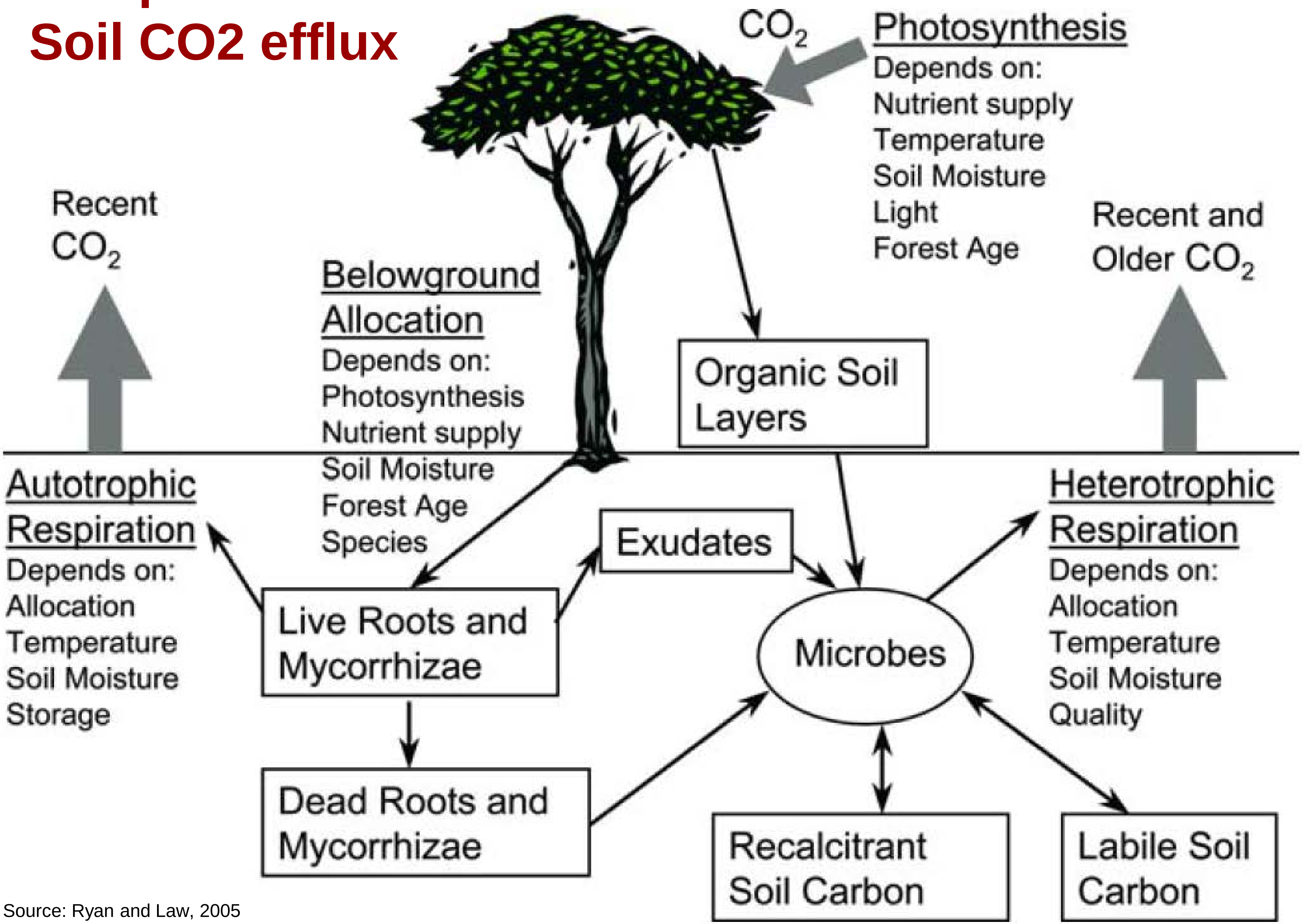
What will be the effects of CC on global C stocks?

1) Warming induced acceleration of decomposition (positive feedback)
2) Increase plant derived C inputs > increased decomposition (negative feedback)

How do environmental constraints e.g. moisture content effect decomposition?

Source: Davidson & Janssens, Nature 2006

Components of Soil CO2 efflux



Source: Ryan and Law, 2005

Soil respiration

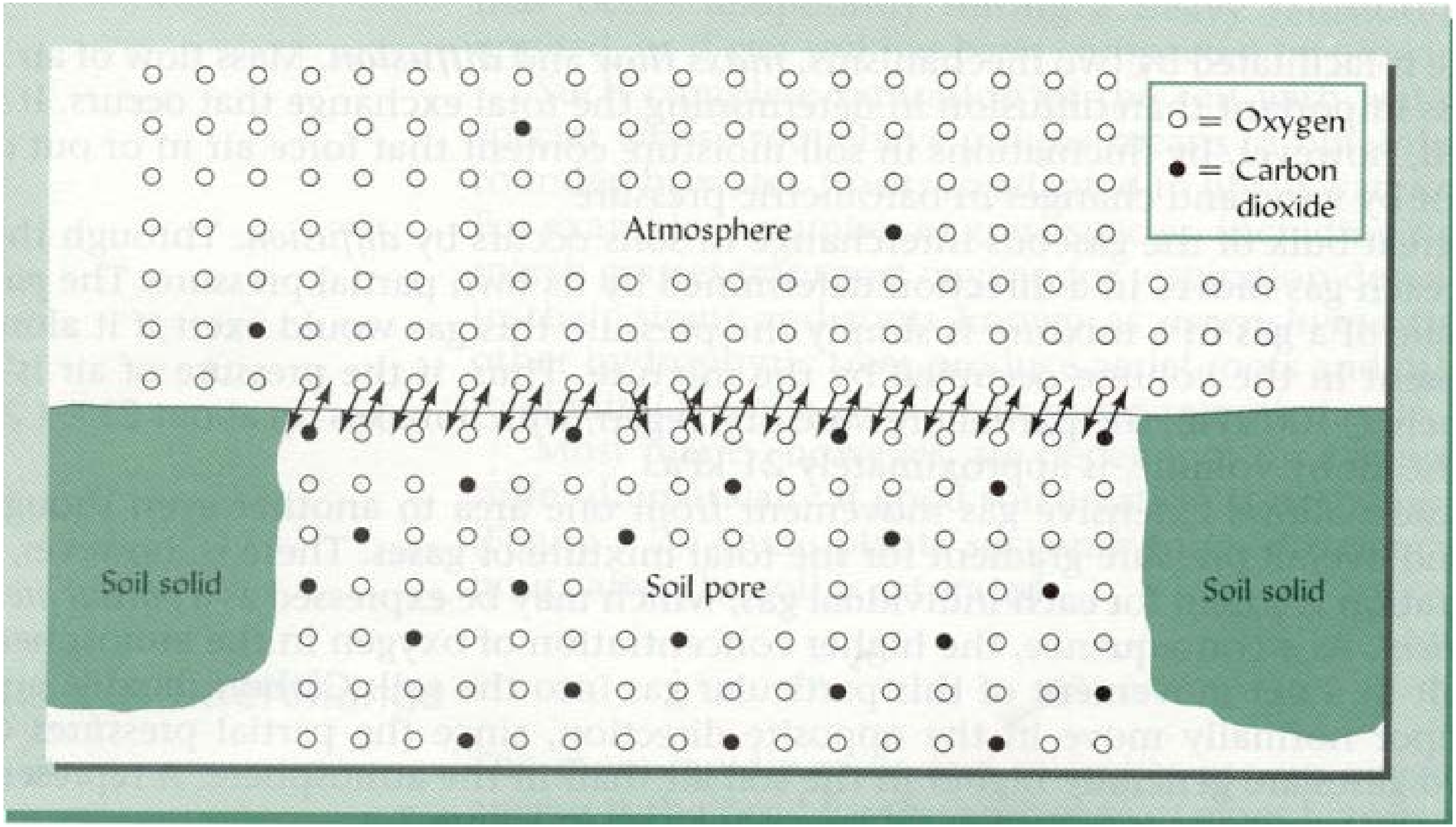
In soil there are 2 main sources of respired CO_2:

- decomposition of organic matter by soil microbes (heterotrophic respiration, or Rh)
- respiration of roots including the respiration of microbes in the rhizosphere, of micorrhizae and of symbiotic microbes, which are all fed by root exudates (rhizosphere respiration, or R_{rhiz})

$$R_s = R_h + R_{rhiz} = \text{soil } CO_2 \text{ efflux}$$

Review
- diffusivity

CO_2 and O_2 diffusion between atmosphere and soil air



Source: SoilWeb

Fick's Law of Diffusion

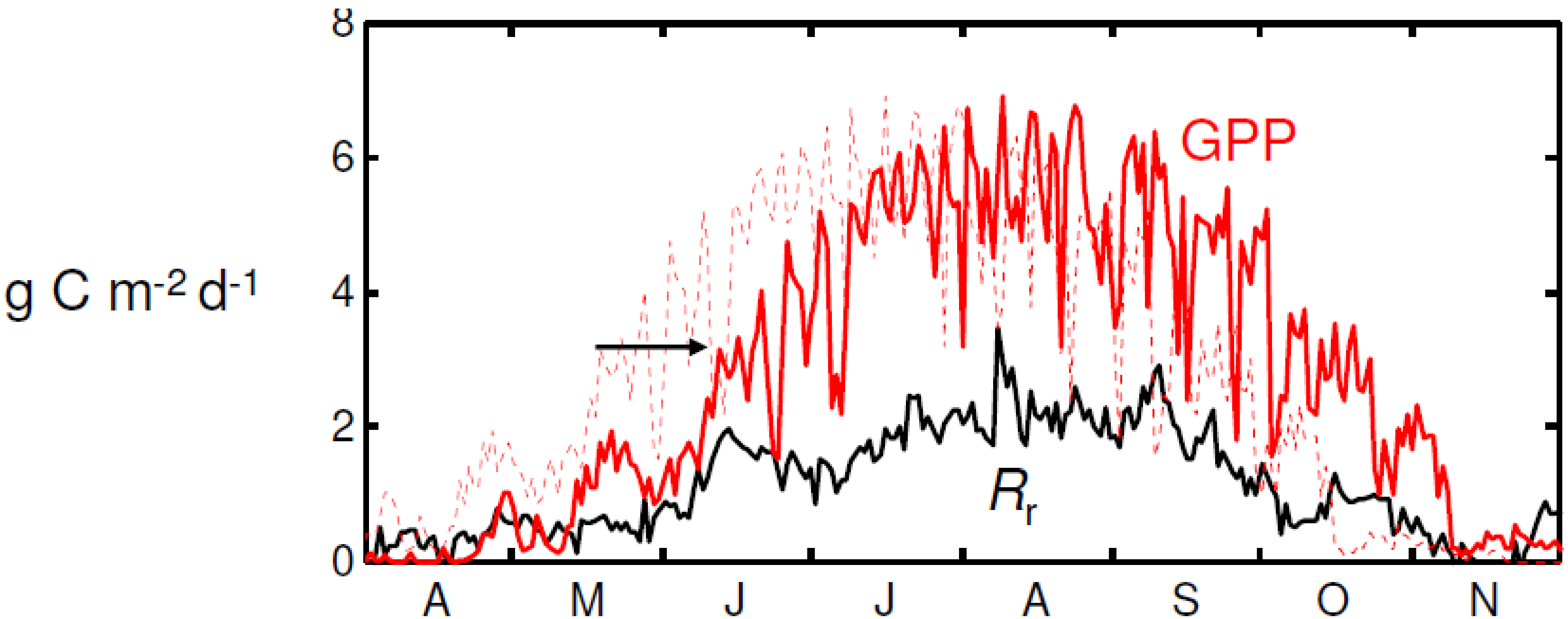
$$J = -D\frac{dC}{dx}$$

J = diffusive flux density of a gas [mg/m^{2}s]
D = diffusion coefficient [m^2/s]
dC/dx = gas concentration gradient [g/m^4]

Factors influencing R_{soil}

Substrate availability

1. Photosynthesis & below ground allocation of C → impacts root respiration & mychorrizae and rhizosphere organisms that utilize root exudates

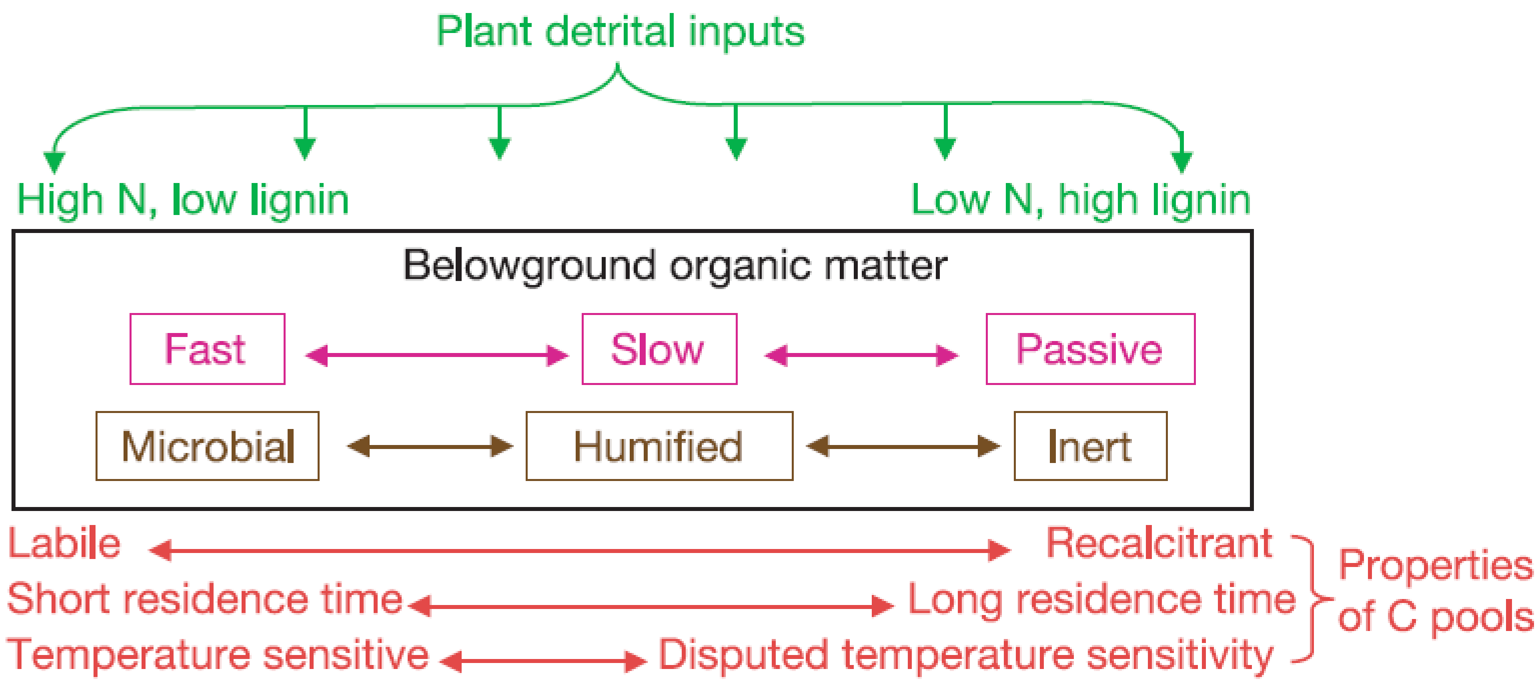


Source: SOB, UBC Biometeorology

Substrate availability & qualtiy

2. Litterfall

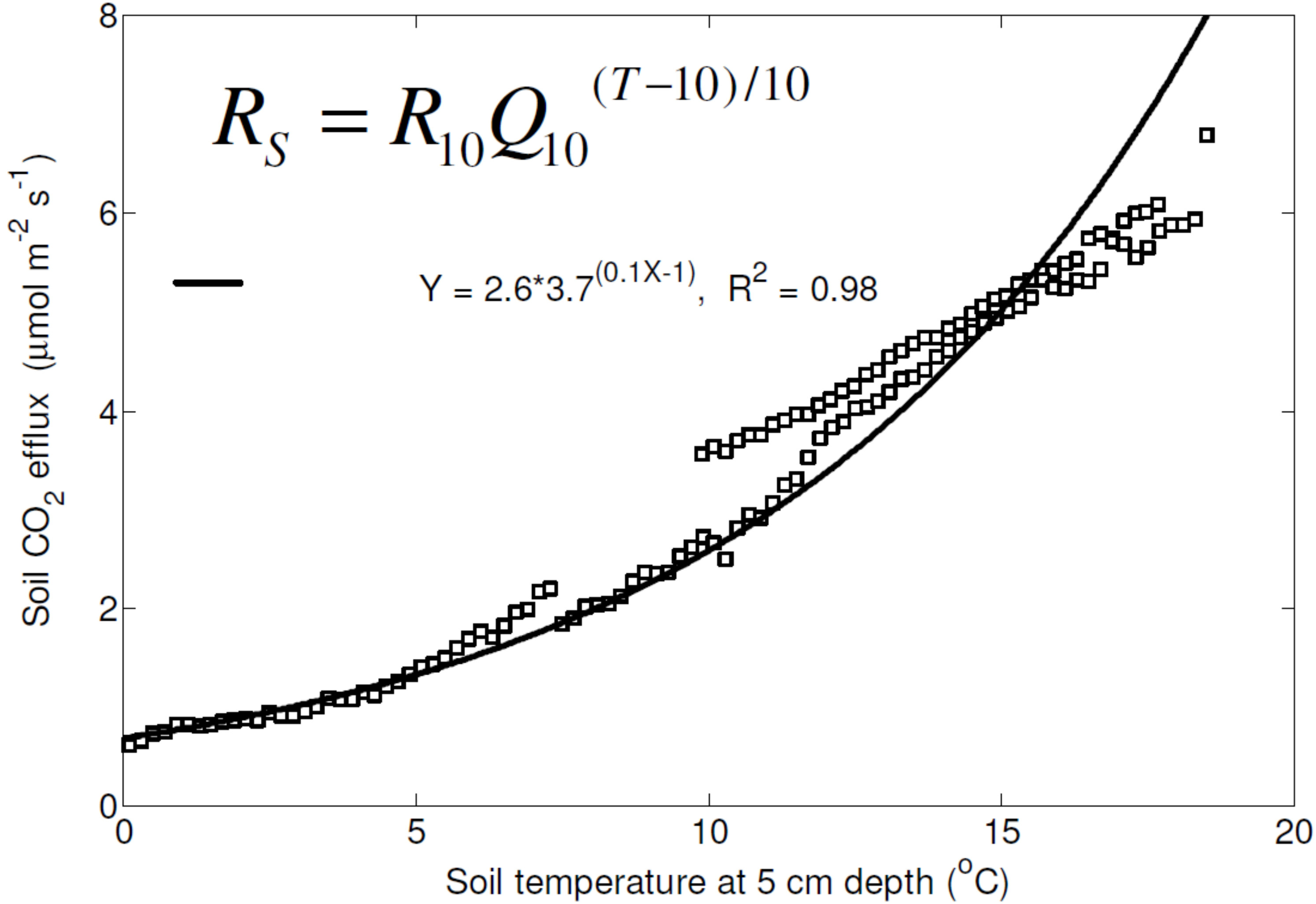
3. SOM pools



Source: Davidson 2006, Nature

Soil Temperature

Soil respiration (Rs) approximately doubles for every 10 ^oC



Source: Jassal et al. 2008

Q_{10} model

$$R = R_{ref}\, Q_{10}^{\left(\frac{T_s - T_{ref}}{10}\right)}$$

where: R = soil respiration
R_{ref} = R at reference temperature (T_{ref})
Q_{10} = relative increase in R with a 10 ^oC increase in T

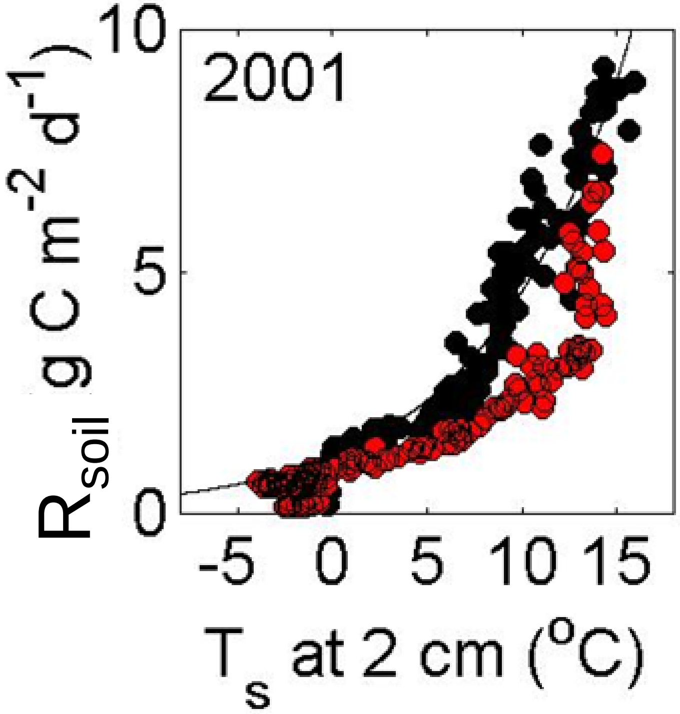
e.g.

$$\left.\begin{array}{l} T_{ref} = 10\ ^oC \\ T_{soil} = 20\ ^oC \\ Q_{10} = 2 \end{array}\right\} \quad R = 2^1 R_{ref} = 2\ R_{ref}$$

Soil moisture

Activity of aerobic decomposers is maximum when ≈ 60% pore space occupied by water

e.g.

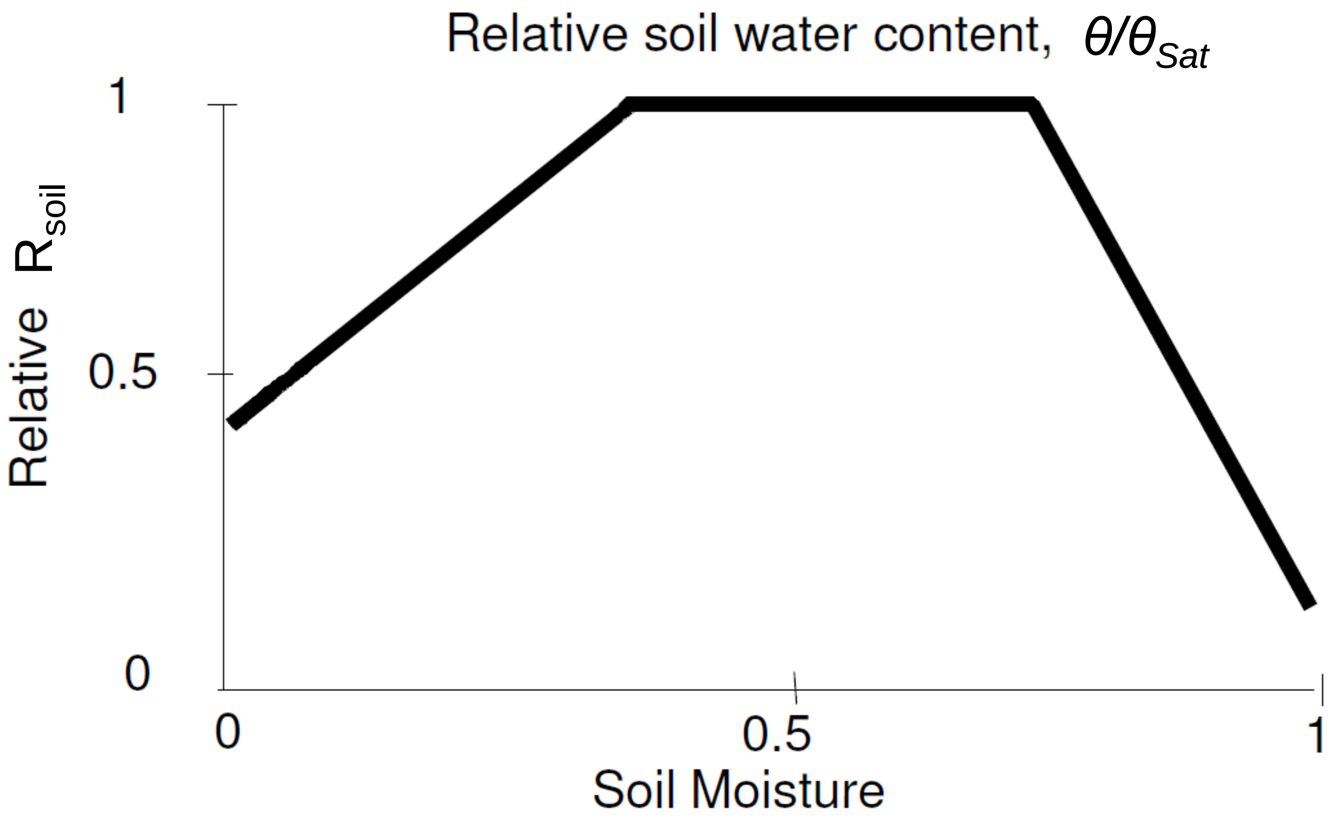


Old Aspen site

- High moisture soil
- Low moisture soil

Source: Jassal et al. 2005

Soil moisture



R_{soil} = f(root & microbial biomass,
substrate supply, temperature
& soil moisture)

Measuring soil respiration

Source: UBC Biometeorology

Non-steady state chamber method

Automated chamber system

Portable chamber system

http://soilweb.landfood.ubc.ca/labmodules/respiration/respiration

Non-steady state chamber method

Main principle:

- measure rate of change CO_2 concentration in the chamber headspace following closure of lid
- over a short time interval, CO_2 concentration rises linearly → measured CO_2 efflux representative of soil CO_2 efflux

Soil CO2 efflux

$$F = \frac{\rho V}{A}\frac{dC}{dt}$$

where: F = CO_2 efflux (µmol m^2 s^{-1})

ρ = molar density of air = 40 mol m^{-3} at 25 ^oC

V = volume chamber (L)

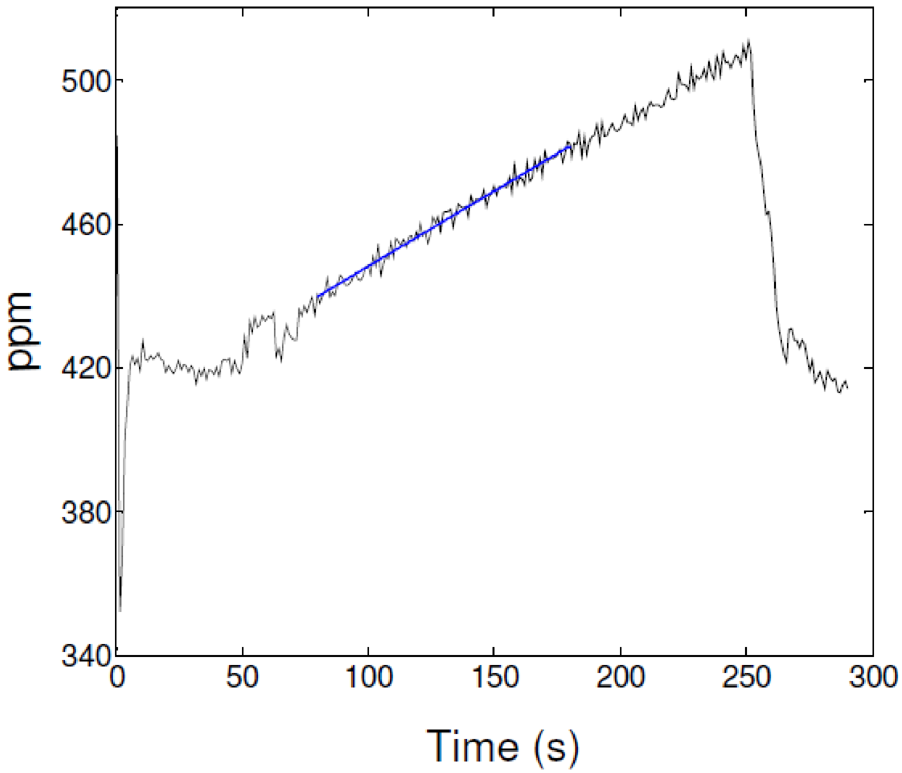
A = surface area covered by the chamber (m^2)

dC/dt = change in CO2 concentration in the chamber headspace (µmol mol^{-1} s^{-1})

Soil CO2 efflux measurement with non-steady state chamber

Measuring the rate of change in CO_2 concentration in the chamber head space

$$F = \rho \frac{V}{A} \frac{dC}{dt}$$

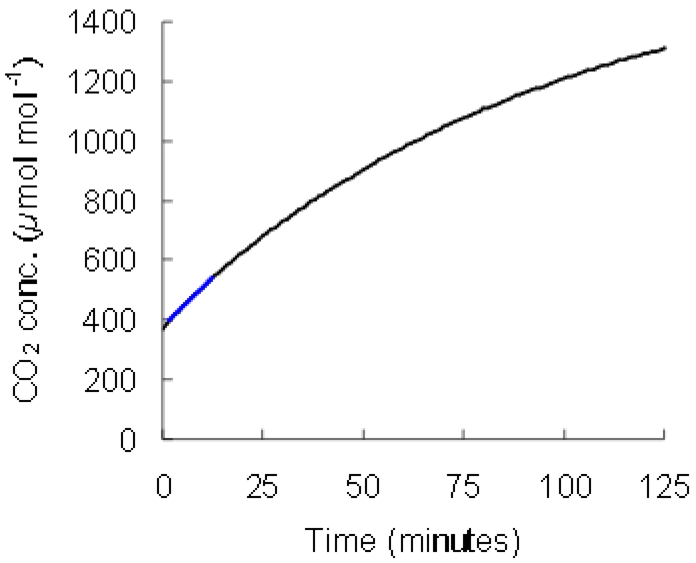


ρ = 40 mol m^{-3} at 25 ^{o}C
V = 60 L = 0.06 m^3
A = 0.2 m^3
$dC/dt = 0.4$ ppm $s^{-1} = 0.4$ μmol mol^{-1} s^{-1}

$F = 4.8$ μmol m^{-2} s^{-1}

Factors influencing chamber measurements

Time of measurement



- short time periods (< 2 min.) linear relationship
- long time periods exponential relationship

Factors influencing chamber measurements

Seal / leakage

- → underestimating R_{soil}
- sealing
  - pneumatic solenoid
  - foam gasket

Source: UBC Biometeorology

Factors influencing chamber measurements

Humidity

- calculation based on dry air
- humidity → under estimate of CO_2 flux

- may need to use **correction factor** in flux calculation to account for water vapour (Jassal et al. 2012)

Pressure fluctuations

- turbulence induced ΔP → increase gas flux across soil surface

- **venting tube** → minimize ΔP

Factors influencing chamber measurements

Soil surface temperature

- Q10: small ΔT_{soil} in chamber → impact measured soil R
- **short deployment (< 2 minutes lid closed)**

Air temperature

- ΔT_{air} in chamber → Δ air pressure or volume in the chamber → alter gas flux
- **venting tube**

Factors influencing chamber measurements

Chamber air mixing

- chamber F_{CO2} based on the mean $[CO_2]_{chamber}$
- adequate mixing → representative samples

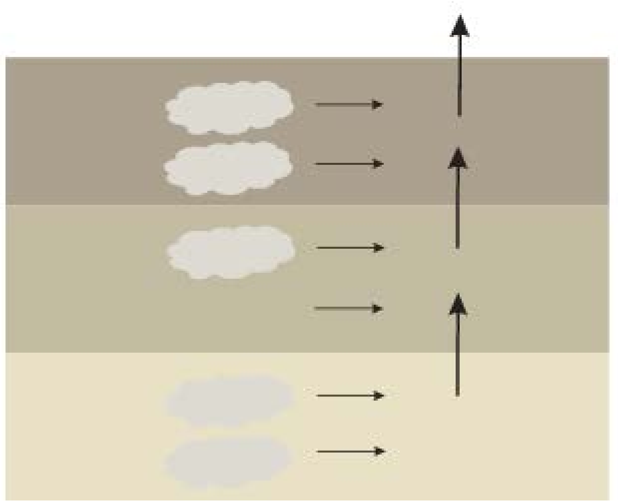
fan → increase mixing

Chamber headspace CO2 concentrations

- accumulation of CO2 in chamber → reduce concentration gradient; reduced measured flux
- concern with non-flow through systems
- **short deployment**

Soil gradient method

- CO_2 concentration in soil is often an order of magnitude greater than in the atmosphere



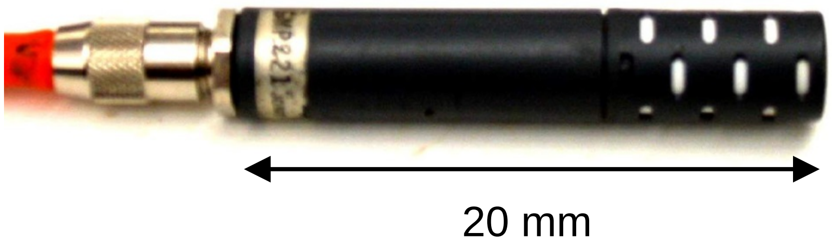
- According to Fick's law:
  - the gas flux is dependent on the concentration gradient
  - and the diffusivity of the soil

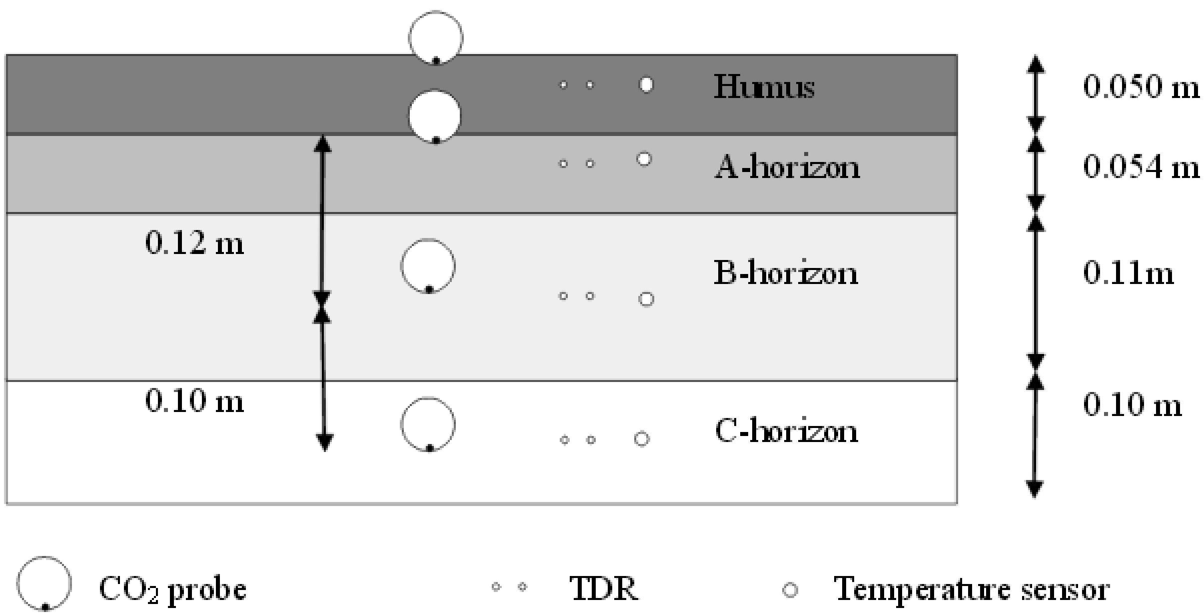
Using Fick's law to calculate efflux

$$F = -D\frac{\partial C}{\partial z}$$

F = Soil CO_2 efflux or soil respiration
D = CO_2 diffusivity in soil
$\frac{\partial C}{\partial z}$ = CO_2 concentration gradient

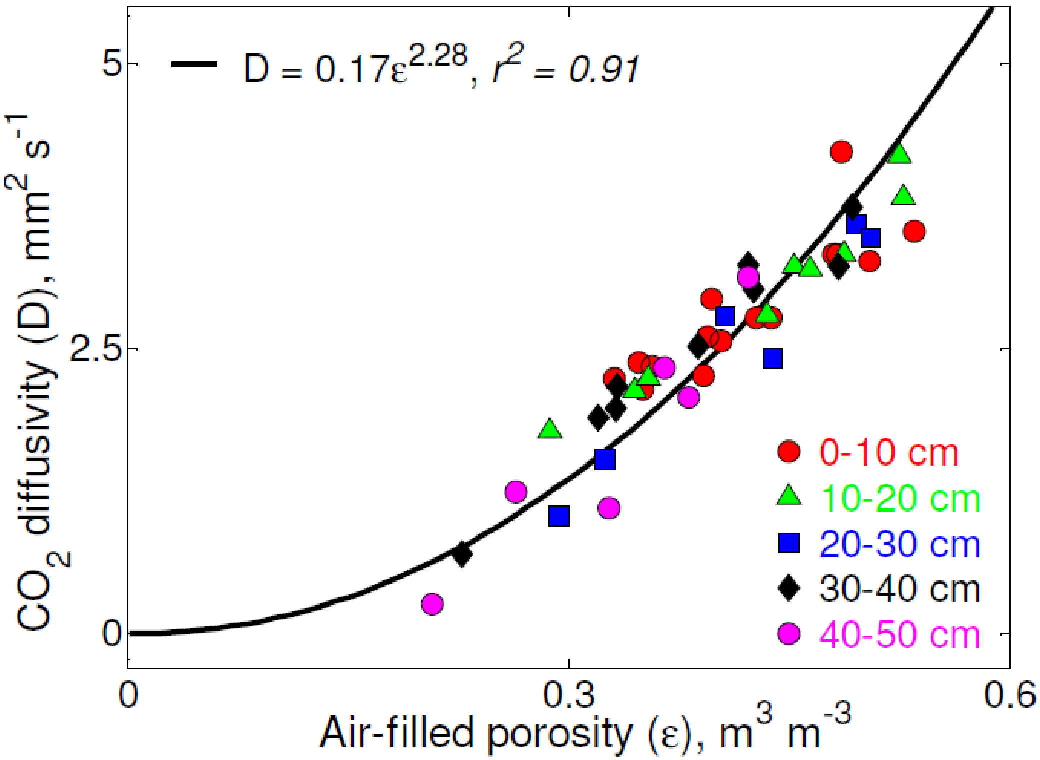
Measuring soil CO_2 concentration





Diffusivity

- Soil diffusivity is related to air filled porosity



Diffusivity measurement apparatus

Source: Jassal et al. 2005

Syringe method

- portable, closed chamber system
- sample GHG using syringe → analyze concentration in lab
- seasonal or spatial changes in CO_2 concentrations

Source: UBC Soil Landscapes Lab

Static chamber method