C and O isotope-specific CO_2 measurements with a tuneable diode laser (TDL) instrument

Dr. Nicolas Brüggemann

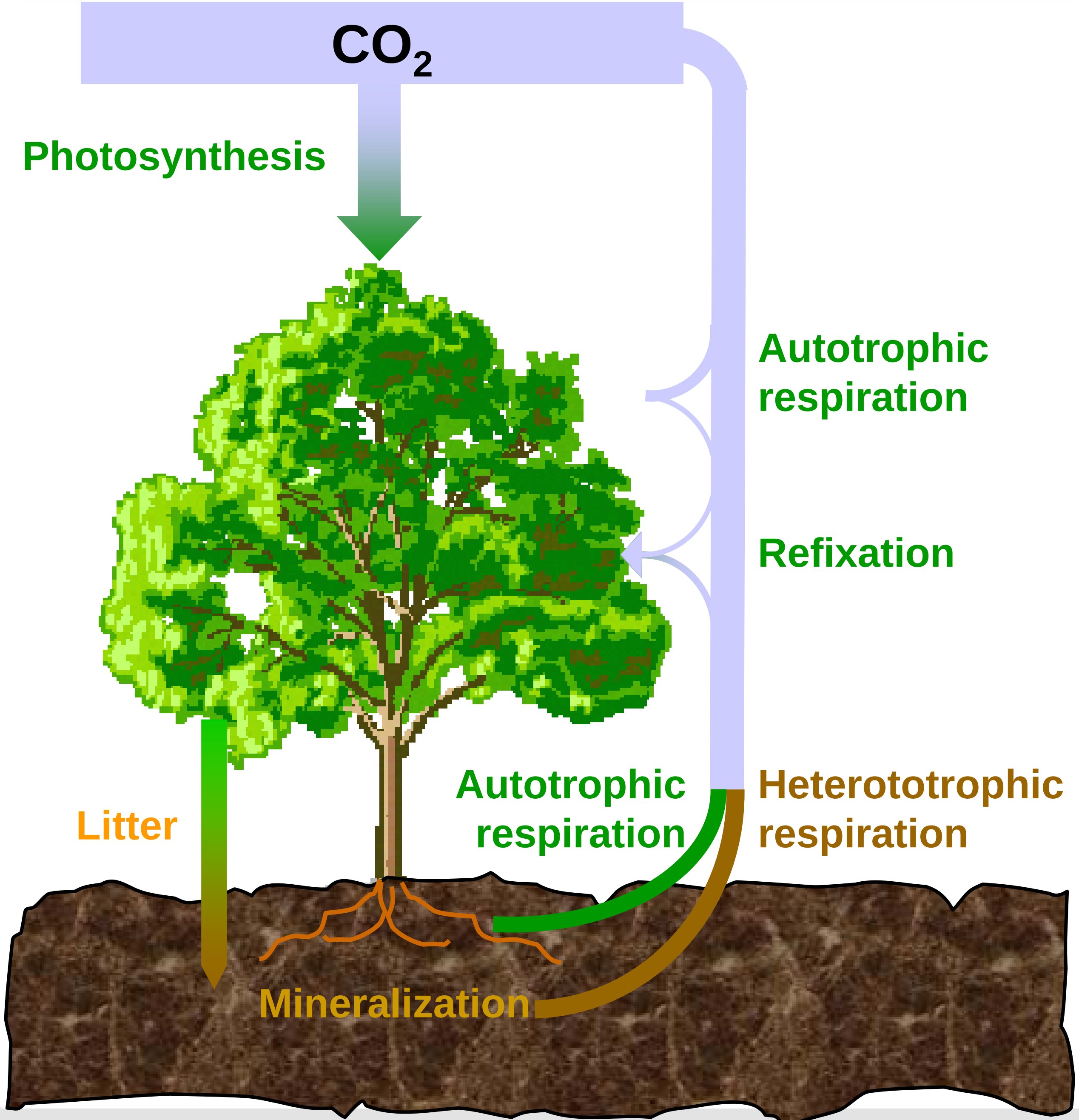
Center for Stable Isotopes (CSI)

Karlsruhe Research Center
Institute of Meteorology and Climate Research
Atmospheric Environmental Research (IMK-IFU)

Garmisch-Partenkirchen
Germany

Outline of the presentation

- **Introduction**
- **Instrumental and experimental setup**
- **Results obtained at natural abundance level**
  - Field study at a wheat and a maize field
  - Laboratory study with spruce saplings
- **Results from ^{13}C-labelling experiments**
  - Field study in an alpine grassland
- **Conclusions**



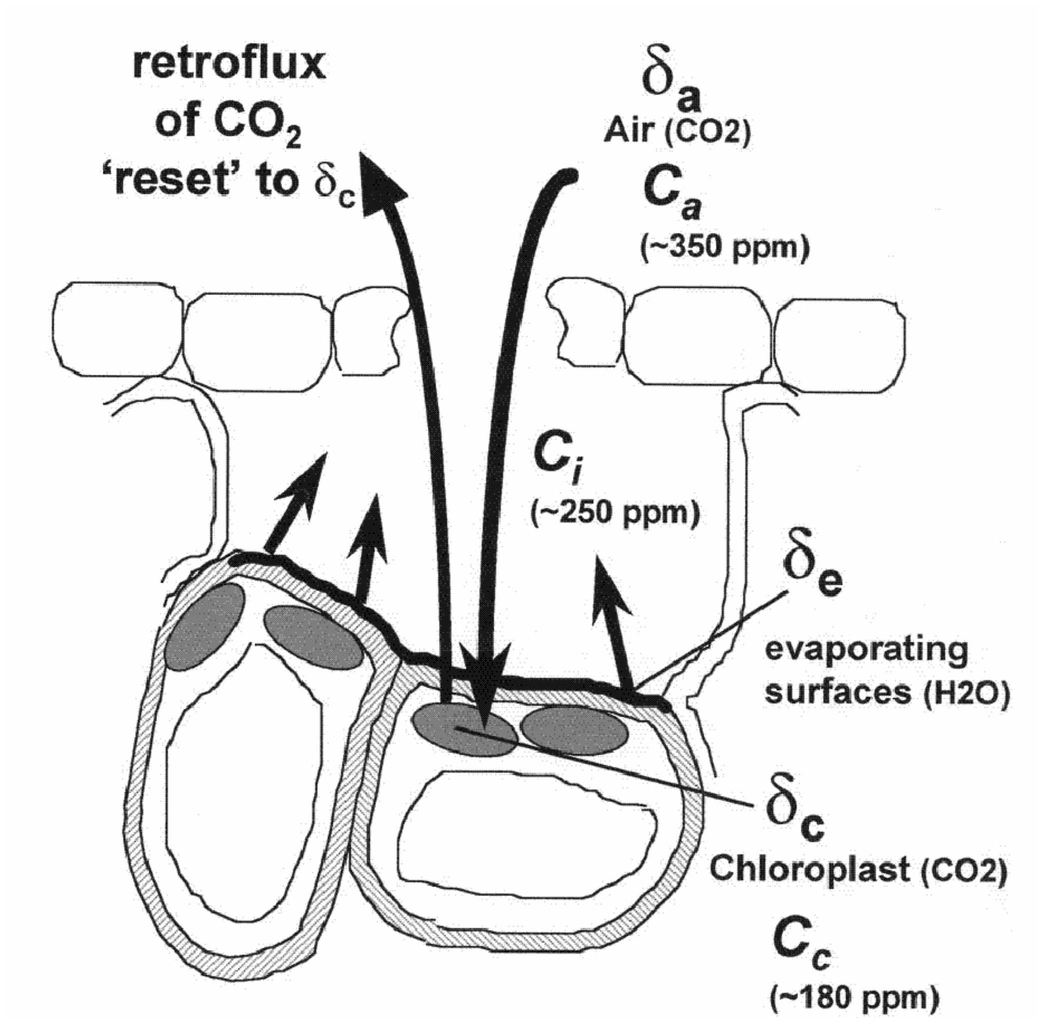
Challenge

? Disentangling ecosystem CO_2 component fluxes

? Understanding short-term dynamics of CO_2 exchange between ecosystem and atmosphere

? Understanding C fluxes into, within and out of ecosystem

Major steps involved in the ^{18}O isotopic exchange of CO_2 between a C_3 leaf and the atmosphere



Yakir & Sternberg (2000), Oecologia 123, 297–311

Thermodynamic equilibration

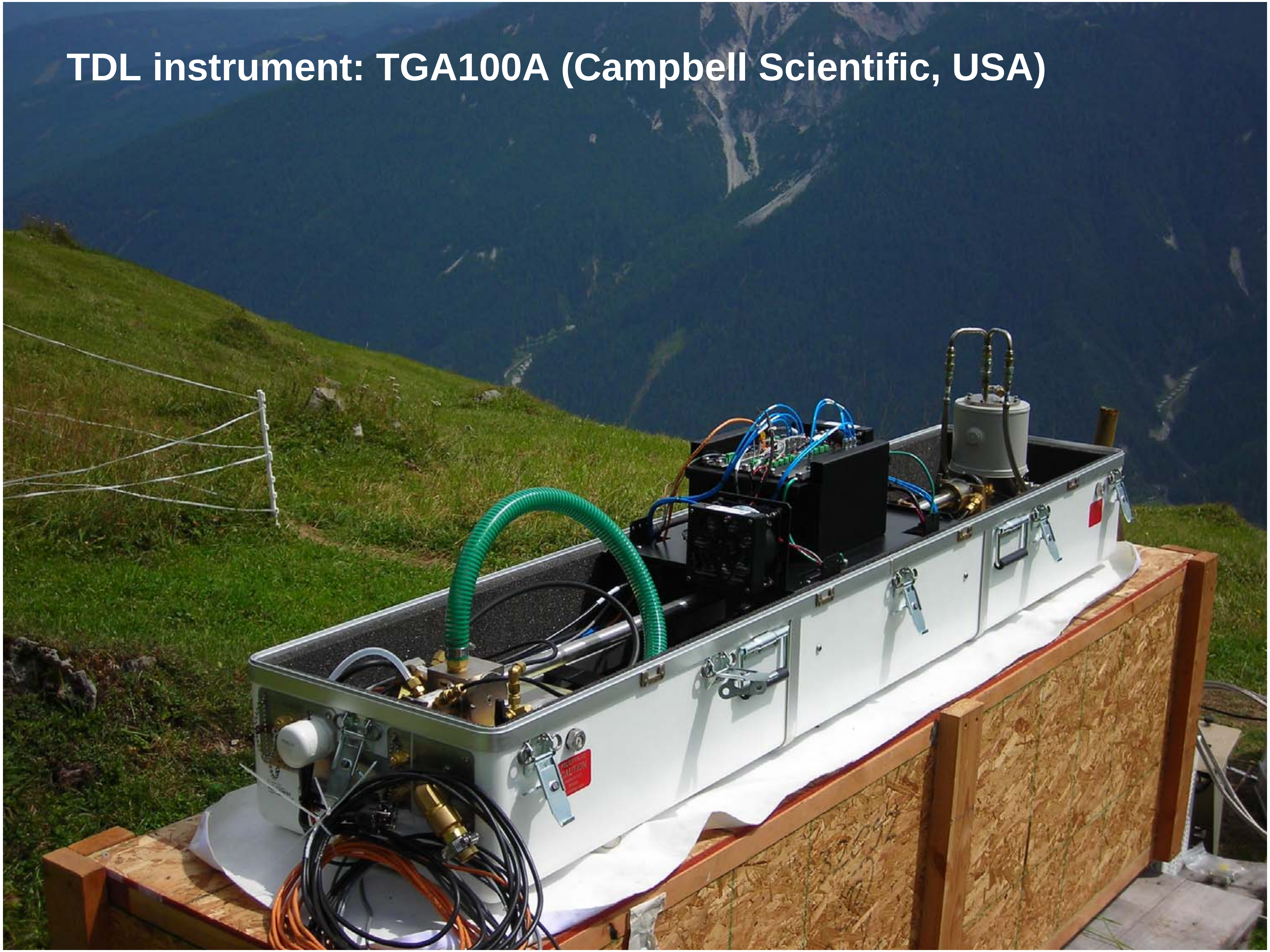
$$H_2{}^{16}O + C^{18}O^{16}O$$

$$\leftrightarrow H_2{}^{18}O + C^{16}O^{16}O$$

catalyzed by carbonic anhydrase

As soil water and leaf water have significantly different $^{18}O/^{16}O$ ratios, a differentiation between plant and soil CO_2 fluxes is possible

TDL instrument: TGA100A (Campbell Scientific, USA)



TDL instrument: TGA100A (Campbell Scientific, USA)

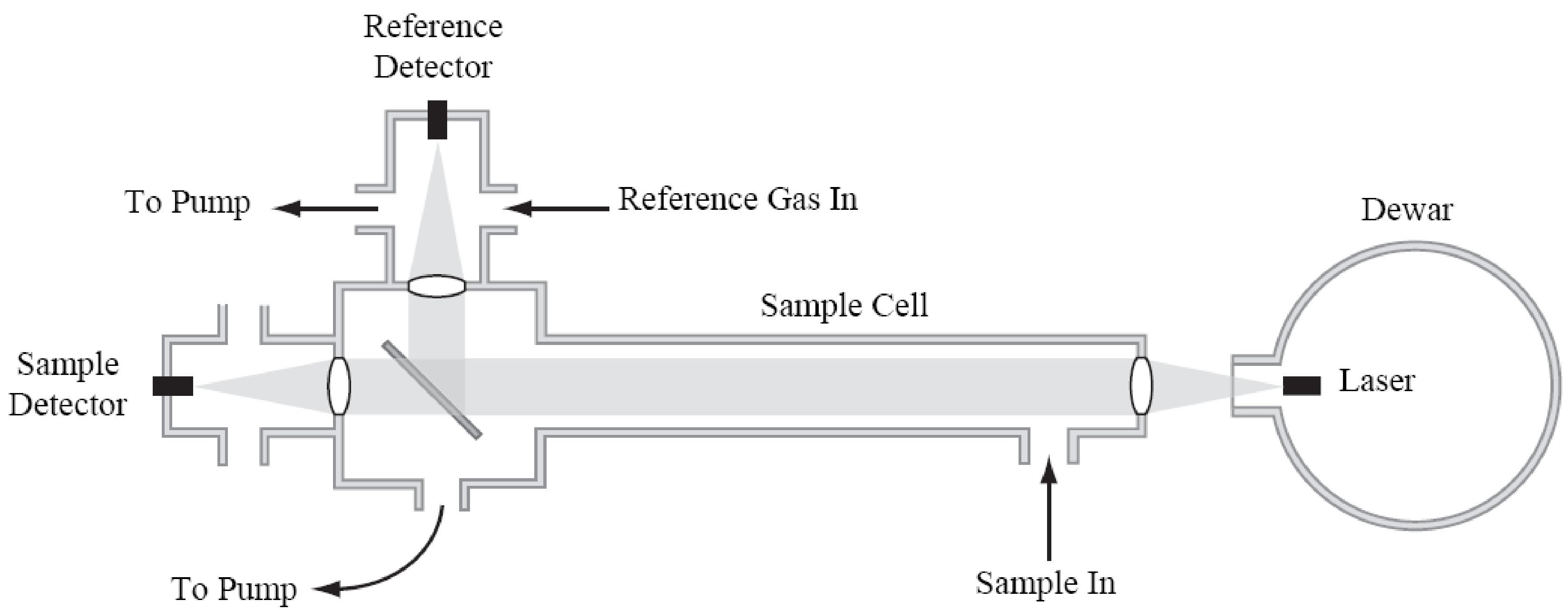


FIGURE OV2.1-1. Schematic Diagram of TGA100A Optical System

Absorption lines and noise of CO_2 isotope ratio measurements with the TGA100A

Gas	Isotope Ratio	Wavenumber (cm^{-1})	10 Hz Noise	Calibrated Noise
Carbon Dioxide, $\delta^{13}C$ only	CO_2	2293.881	0.2 ppm	0.05 ppm
	$\delta^{13}C$	2294.481	0.5 ‰	0.1 ‰
Carbon Dioxide, $\delta^{13}C$ and $\delta^{18}O$	CO_2	2308.225	0.6 ppm	0.15 ppm
	$\delta^{13}C$	2308.171	2.0 ‰	0.4 ‰
	$\delta^{18}O$	2308.416	2.0 ‰	0.4 ‰
Water, δD only	H_2O	1501.846	10 ppm	2 ppm
	δD	1501.813	8 ‰	2 ‰
Water, $\delta^{18}O$ and δD	H_2O	1500.546	10 ppm	2 ppm
	$\delta^{18}O$	1501.188	2 ‰	0.5 ‰
	δD	1501.116	20 ‰	5 ‰

Laser scanning and concentration calculation

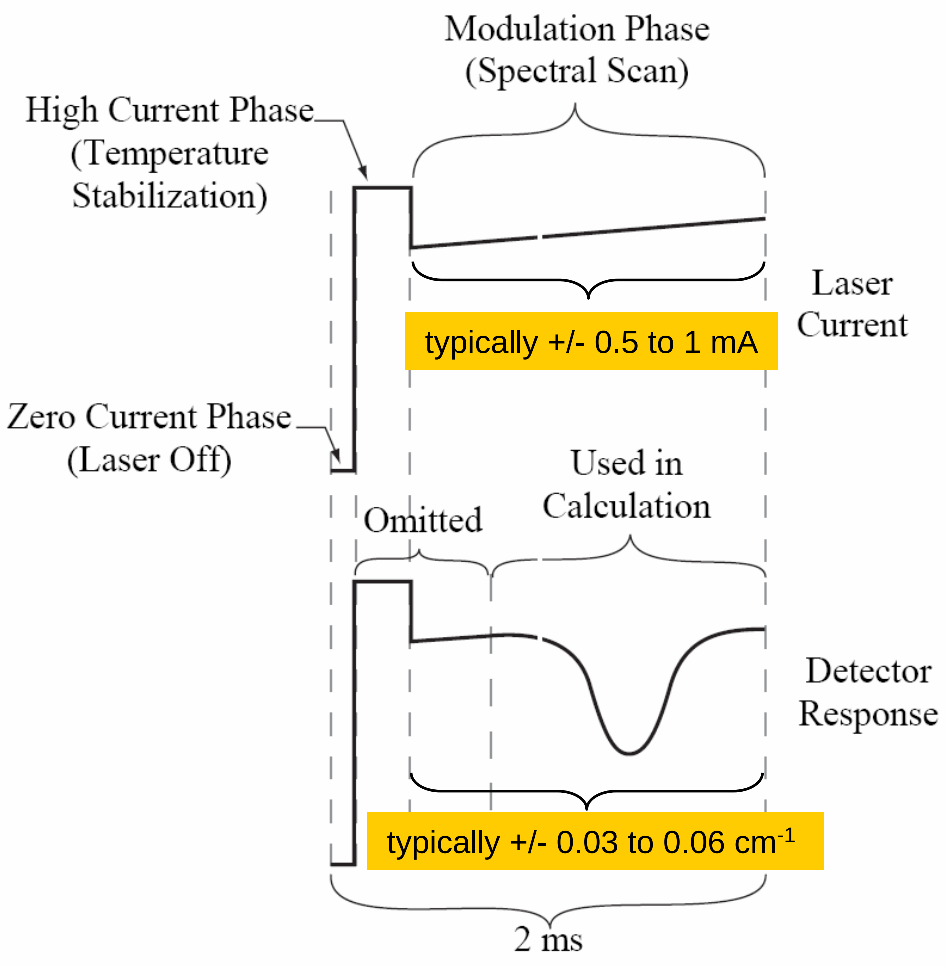


FIGURE OV2.2-1. TGA100A Laser Scan Sequence

$$C_s = \frac{(C_R)(L_R)(D)}{L_S + L_A(1-D)}$$

where

C_S = concentration of the sample, ppm

C_R = concentration of reference gas, ppm

L_R = length of the short reference cell, cm

L_S = length of the short sample cell, cm

L_A = length of the long sample cell, cm

D = ratio of sample to reference absorbance

Instrumental setup for CO_2 isotope measurements

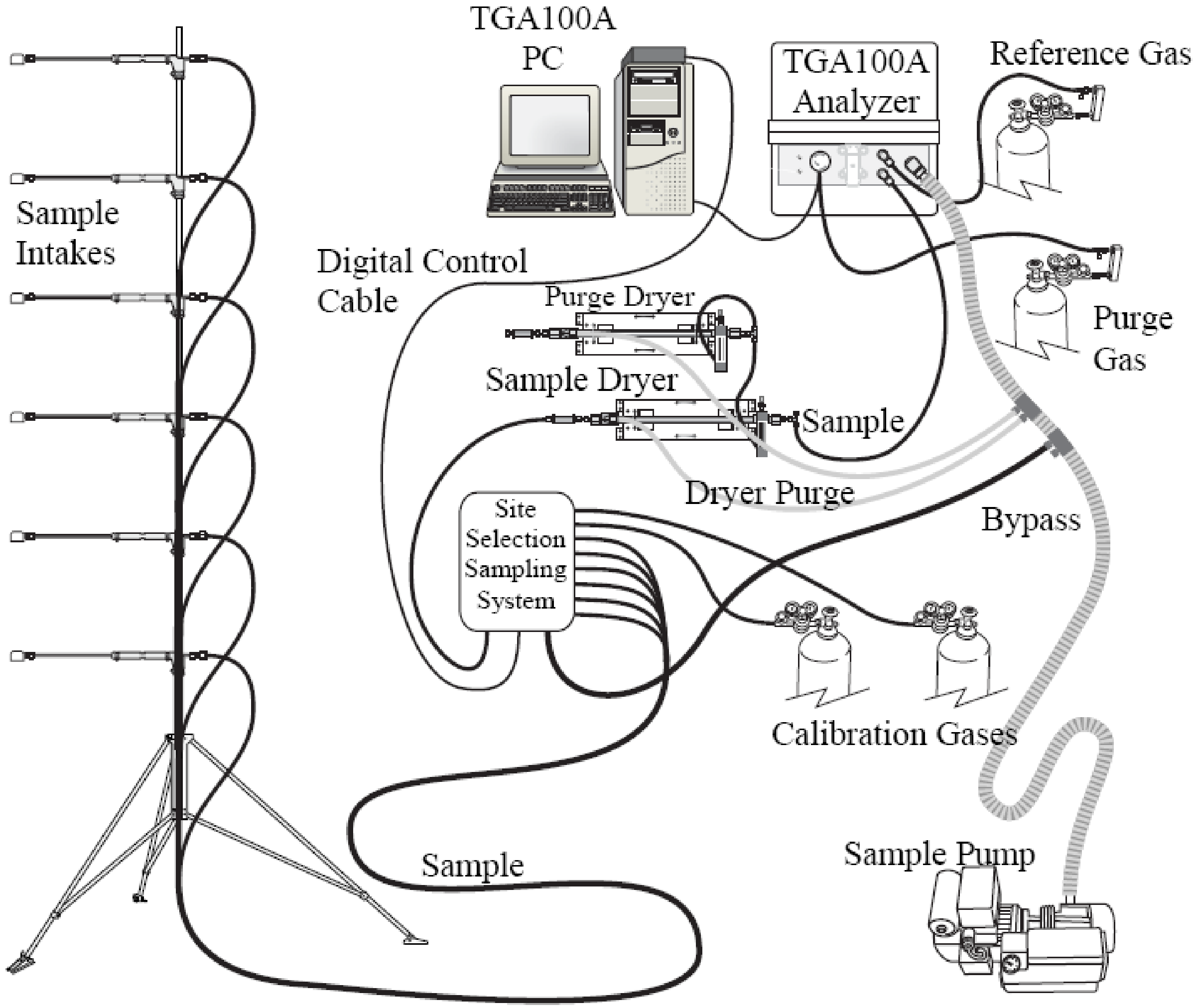
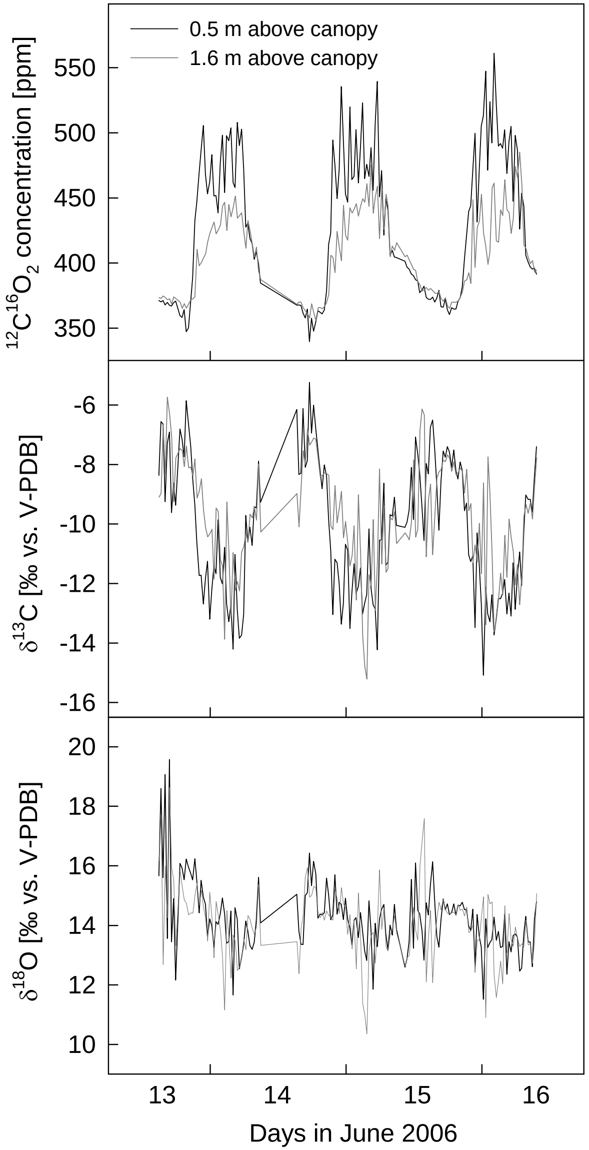


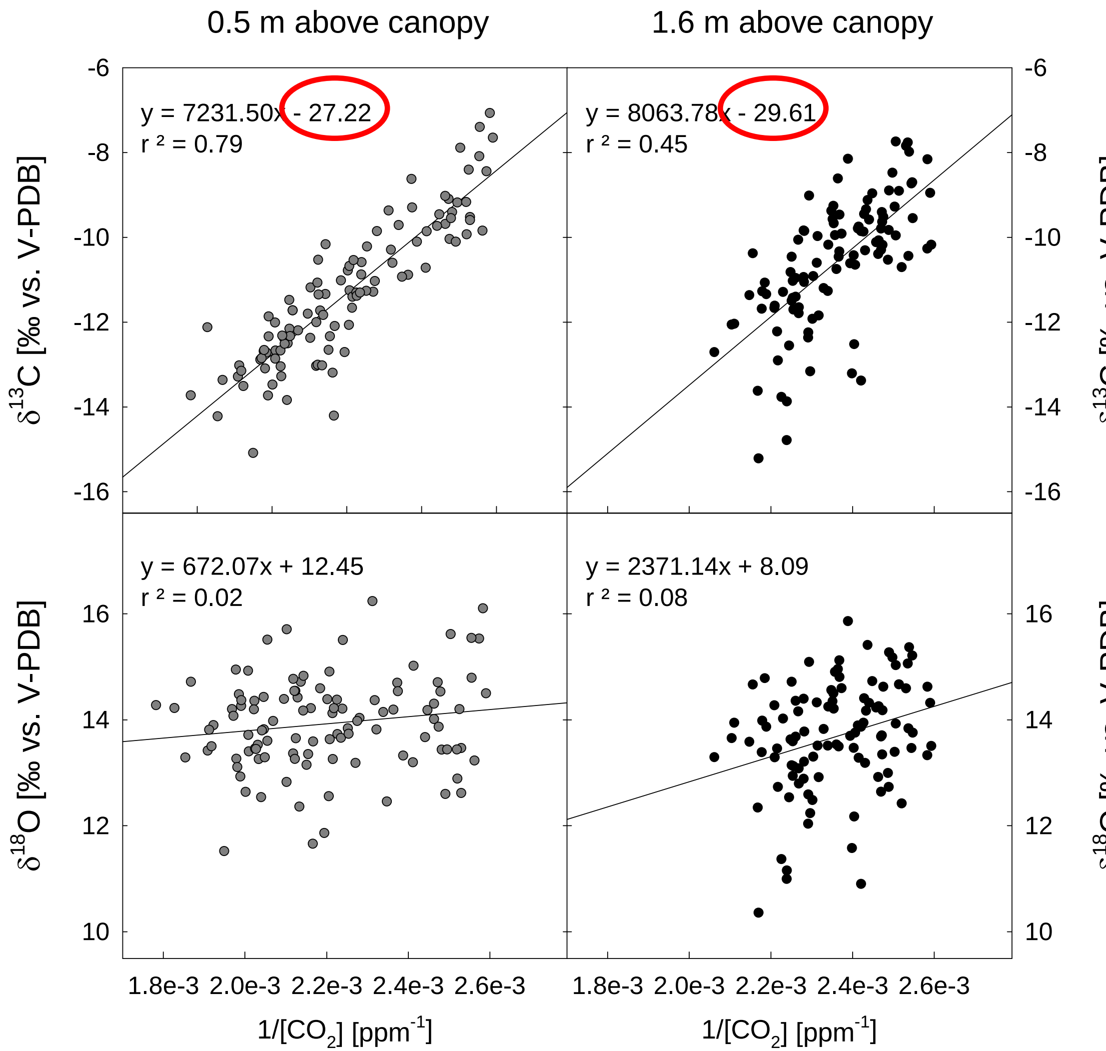
FIGURE OV6.4-1. Example CO_2 Isotope Application

CO_2 isotope measurements above wheat (C_3) and maize (C_4)

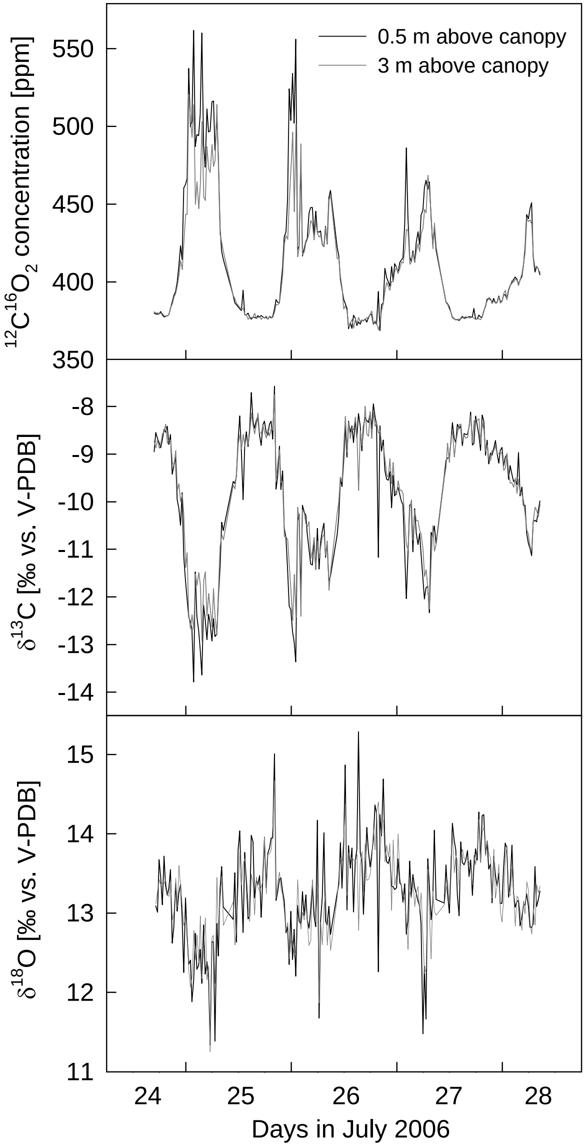
- Measurements at natural abundance level
- Wheat and maize grown on field exclusively planted with C_3 crops in the past
- Continuous measurements in different heights above the ground over several days

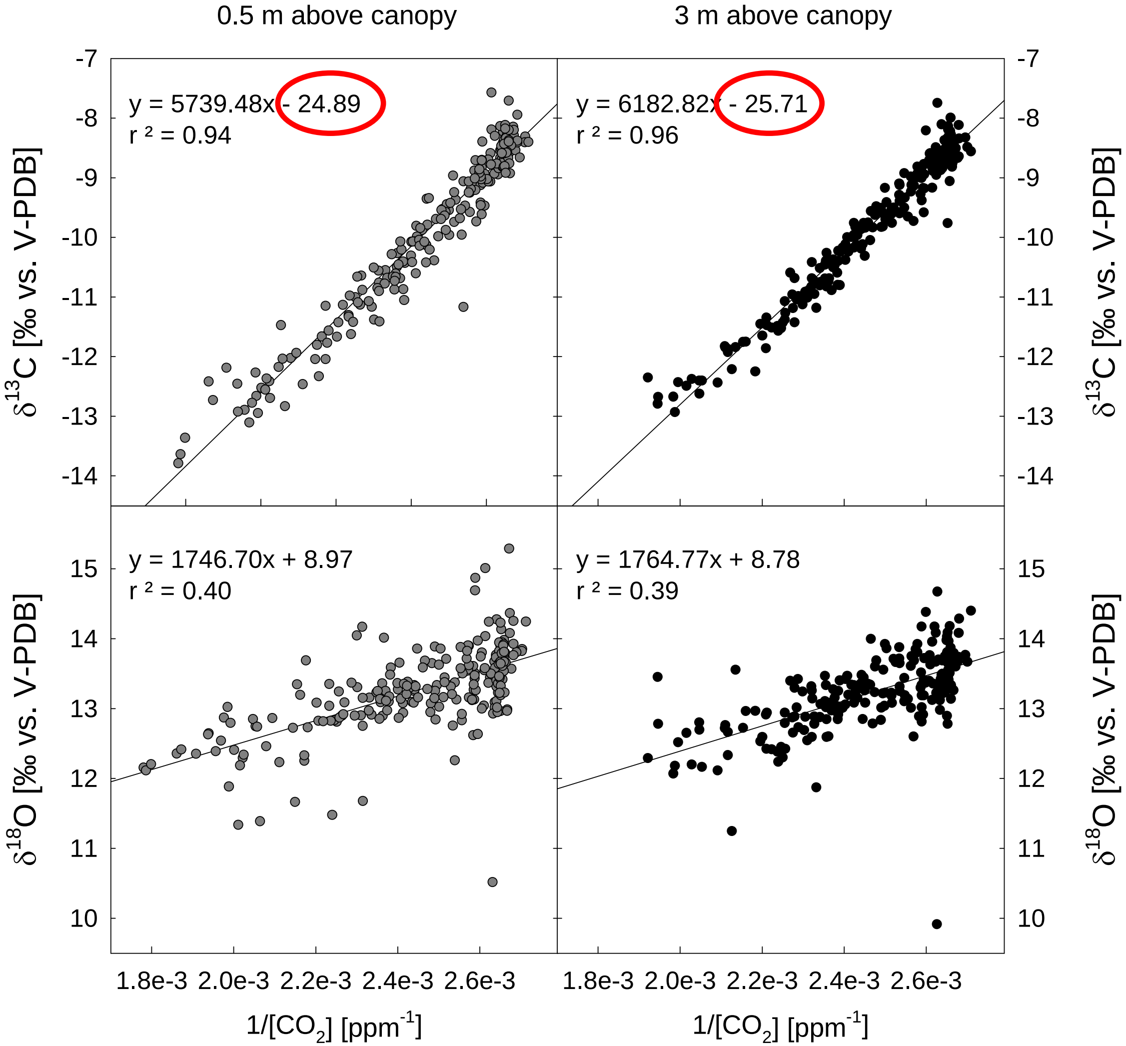
CO_2 isotope measurements above a wheat field (C_3)





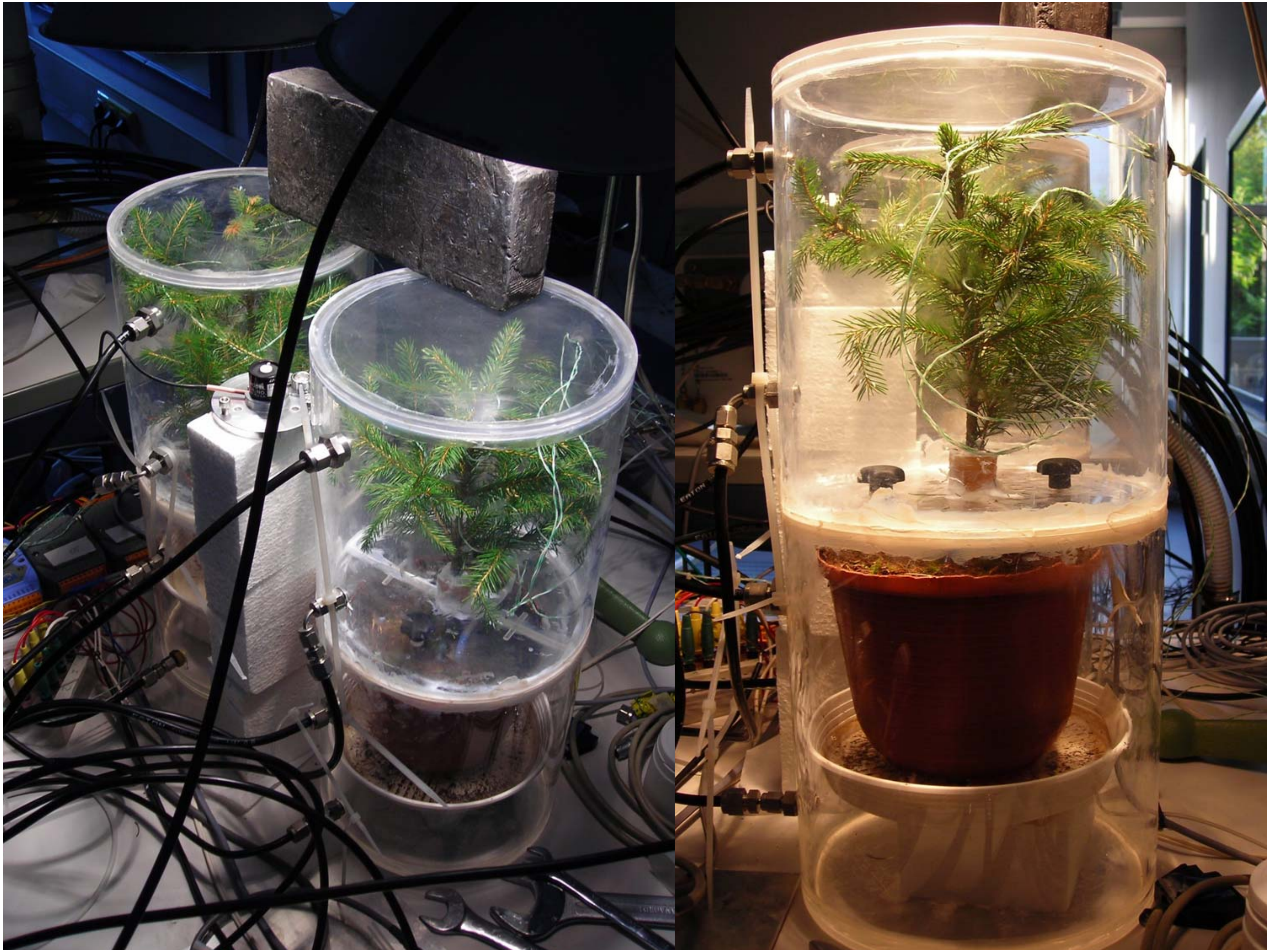
CO_2 isotope measurements above a maize field (C_4)





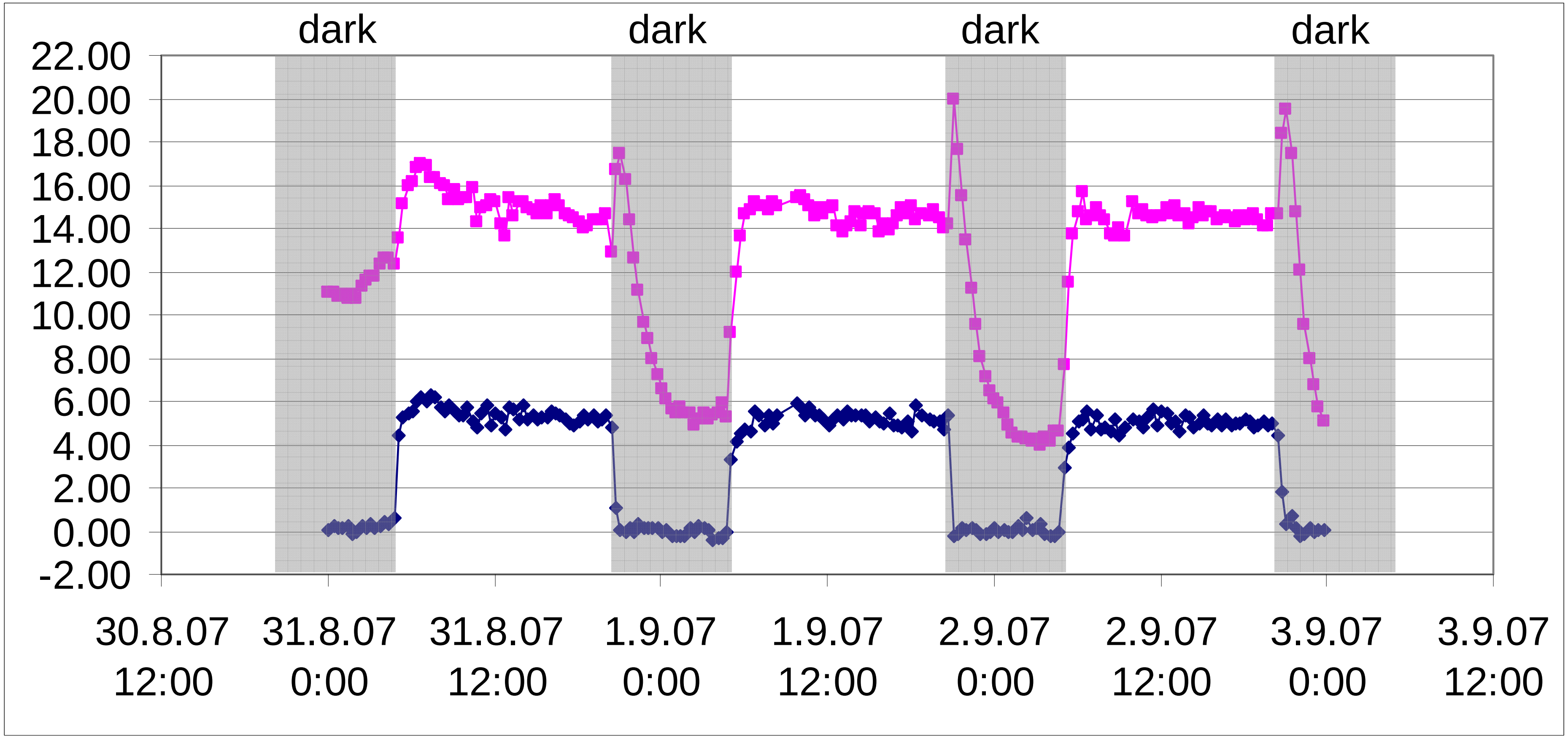
CO_2 isotope measurements on Norway spruce saplings

- **Measurements at natural abundance level**
- **Above-ground (needle) and below-ground (root) compartment separated gas-tight**
- **Flushed with ~380 ppm CO_2, $\delta^{13}C$ = 30.5‰ vs. V-PDB**
- **Continuous measurements over several days**



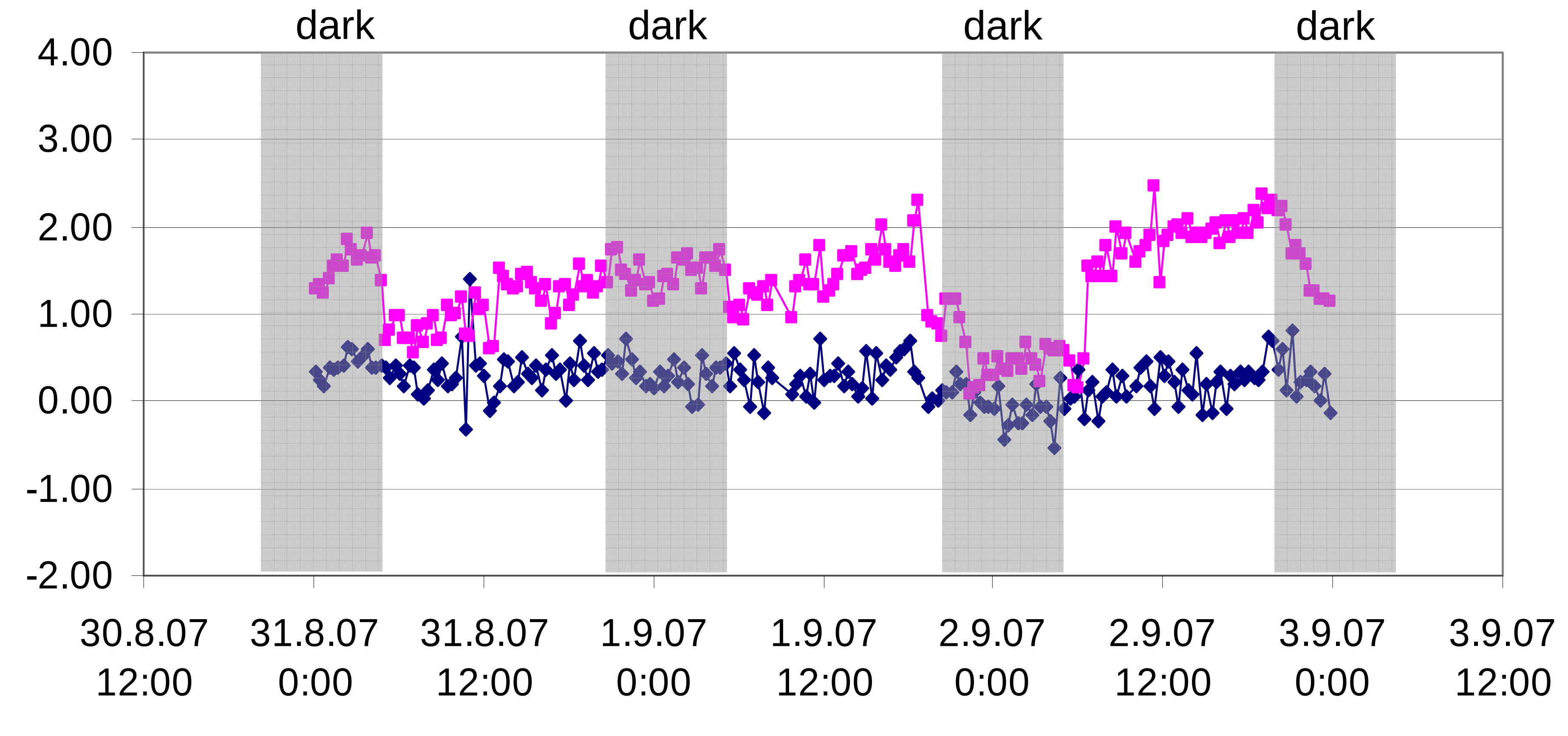
Potted Norway spruce (*Picea abies*): above-ground CO_2

$\Delta\delta^{13}C$ and $\Delta\delta^{18}O$ of CO_2 of needle compartment [outlet–inlet]

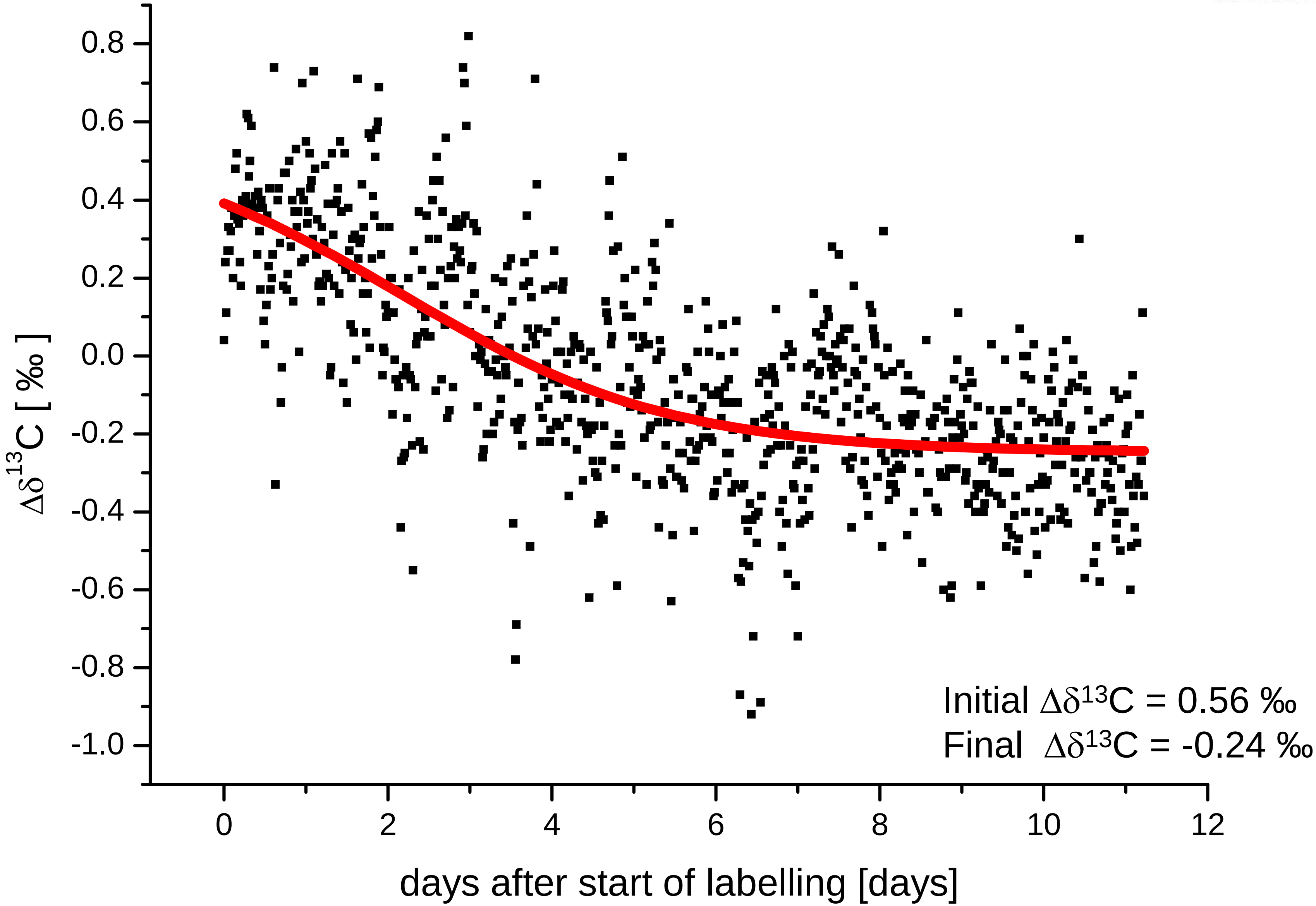


Potted Norway spruce (*Picea abies*): below-ground CO_2

$\Delta\delta^{13}C$ and $\Delta\delta^{18}O$ of CO_2 of root compartment [outlet–inlet]



$\Delta\delta^{13}C$ of root-respired CO_2 in spruce

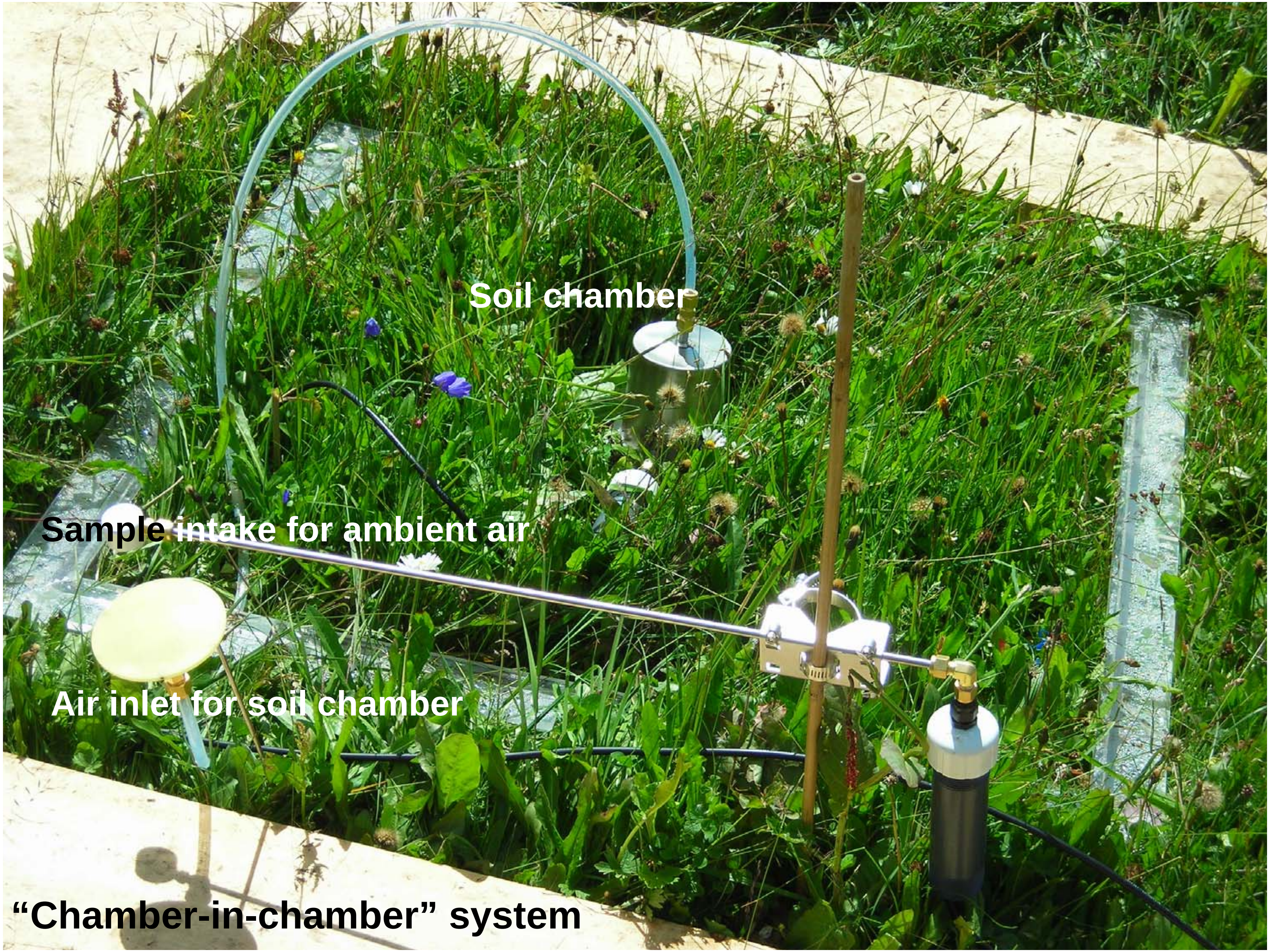


Karlsruhe Institute of Technology

CO_2 isotope measurements in alpine grassland, Austrian (not Australian!) Alps

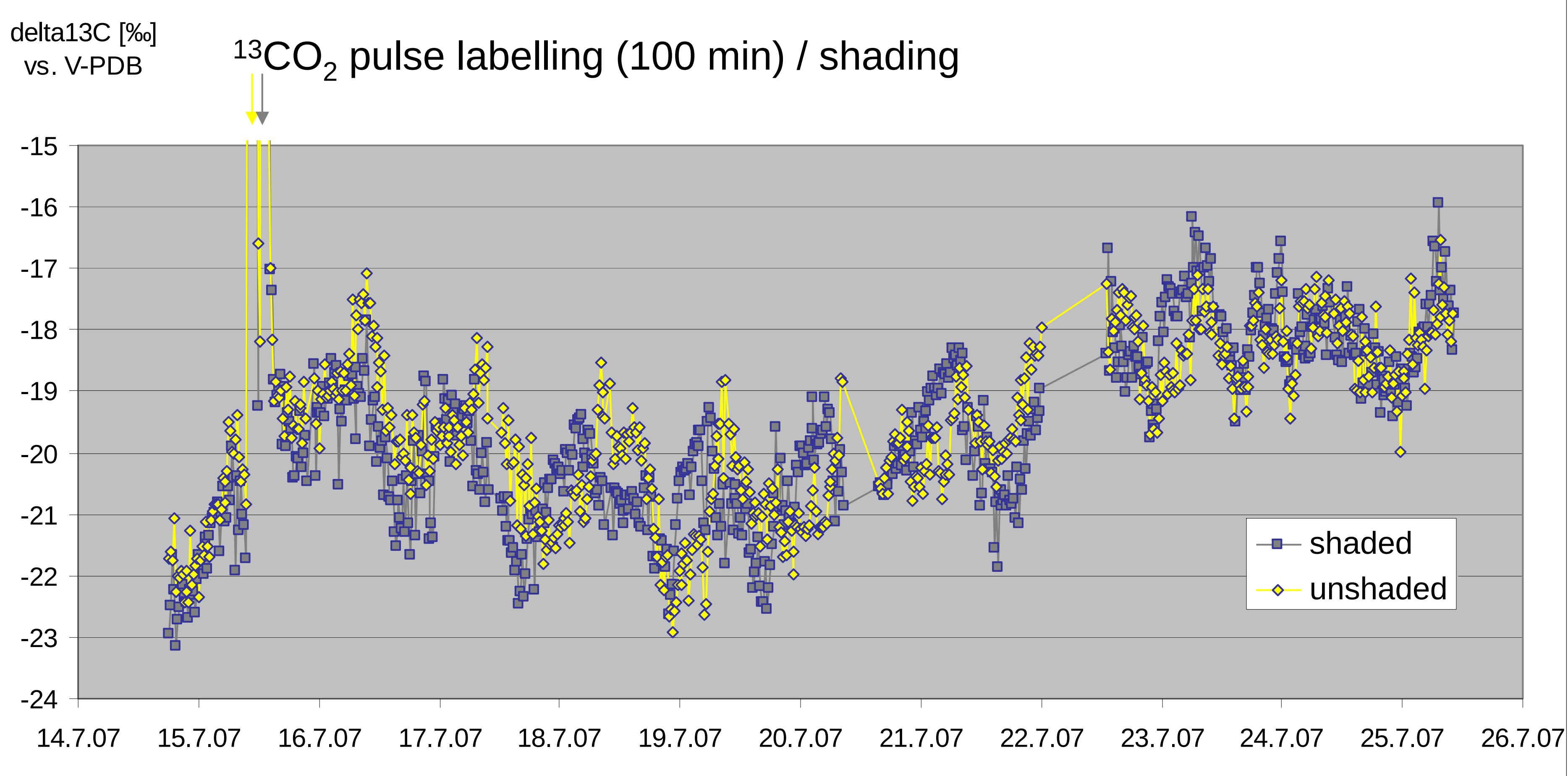
- $^{13}CO_2$ pulse labelling of 1m x 1m plots
- One half of the plots shaded (–90% light reduction) immediately after labelling, the other half unshaded (3 replicates and 3 controls each)
- Continuous measurements of soil-respired CO_2 over several days

$^{13}CO_2$ labelling of alpine grassland, Stubaital, Austria, July-August 2007

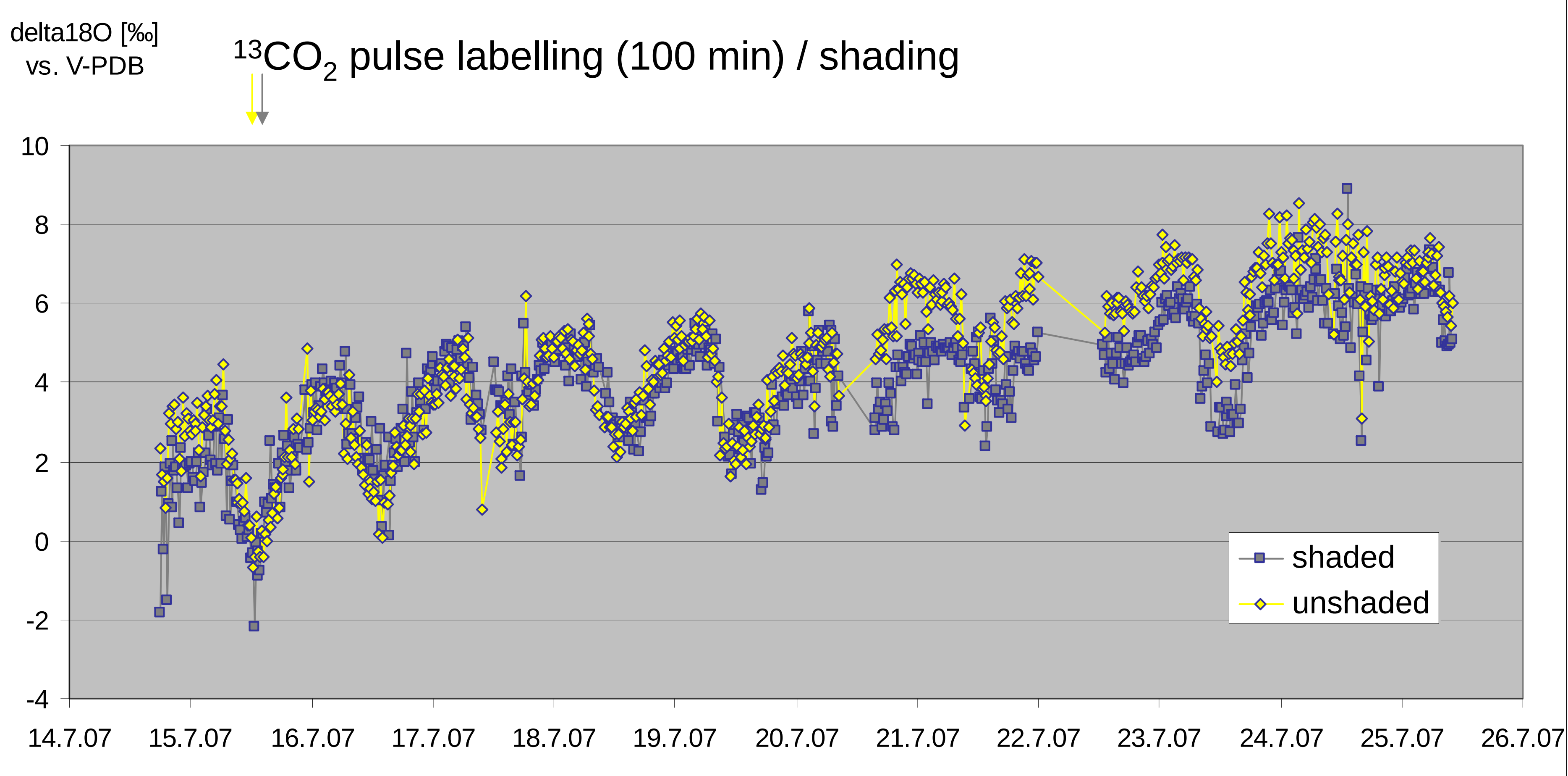

Soil chamber
Sample intake for ambient air
Air inlet for soil chamber
“Chamber-in-chamber” system


Custom-made stainless steel
soil respiration chambers,
i.d. 10 cm, height 13 cm
3/8“ inlet, ¼“ outlet

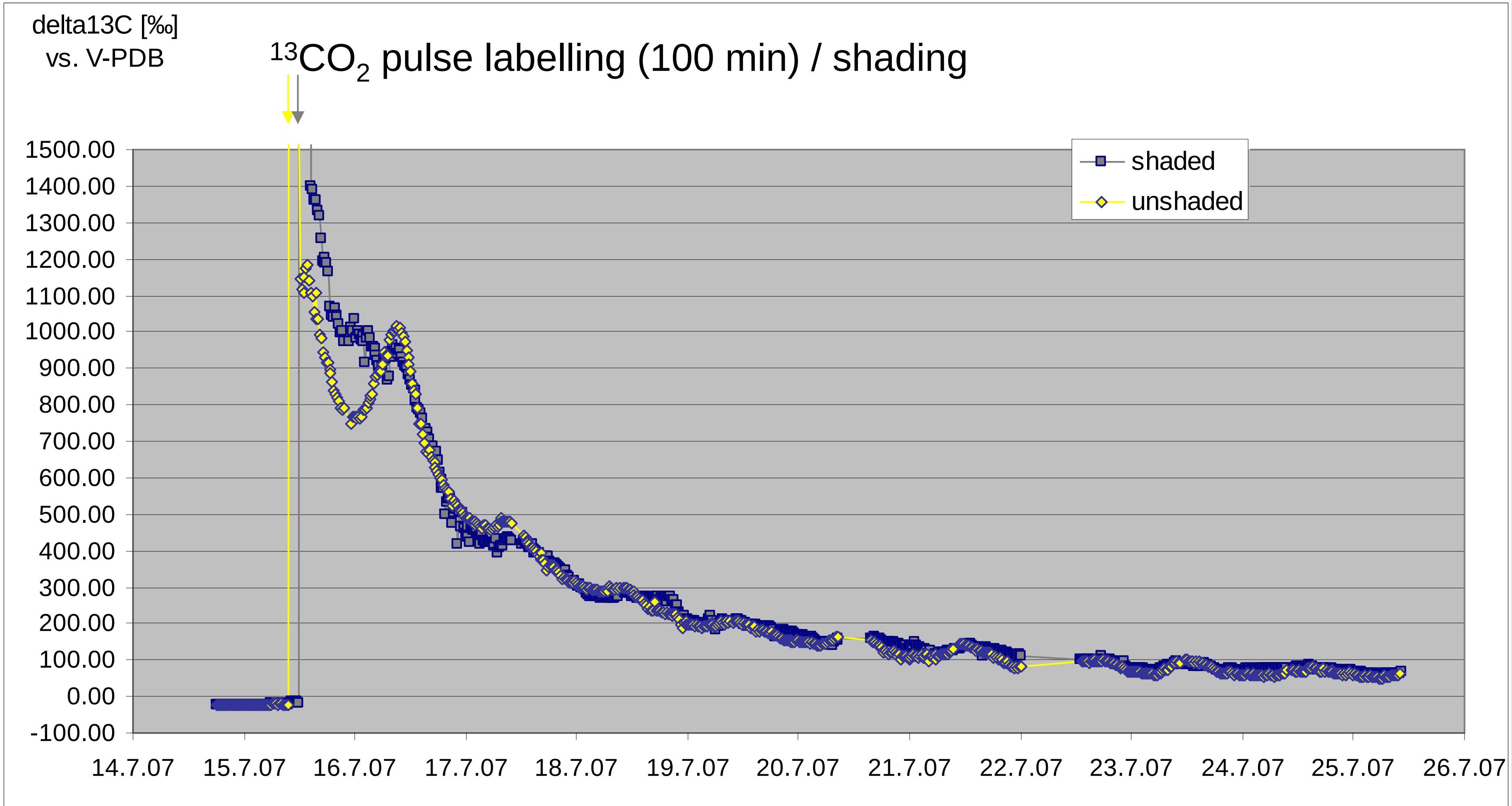
$\delta^{13}C$ of soil-respired CO_2 in <u>shaded</u> and <u>unshaded</u> alpine grassland after $^{13}CO_2$ pulse labelling: unlabelled control



$\delta^{18}O$ of soil-respired CO_2 in <u>shaded</u> and <u>unshaded</u> alpine grassland after $^{13}CO_2$ pulse labelling: unlabelled control



$\delta^{13}C$ of soil-respired CO_2 in <u>shaded</u> and <u>unshaded</u> alpine grassland after $^{13}CO_2$ pulse labelling: labelled plots



Conclusions

Tuneable diode laser (TDL) instruments provide a versatile means for measuring CO_2 C and O isotope-specifically with high time resolution not only in the laboratory, but also in the field.

TDL measurements with high-time resolution provide invaluable insight into the short-term dynamics of plant, soil and ecosystem processes and fluxes that are inaccessible with isotope-ratio mass spectrometer measurements alone.