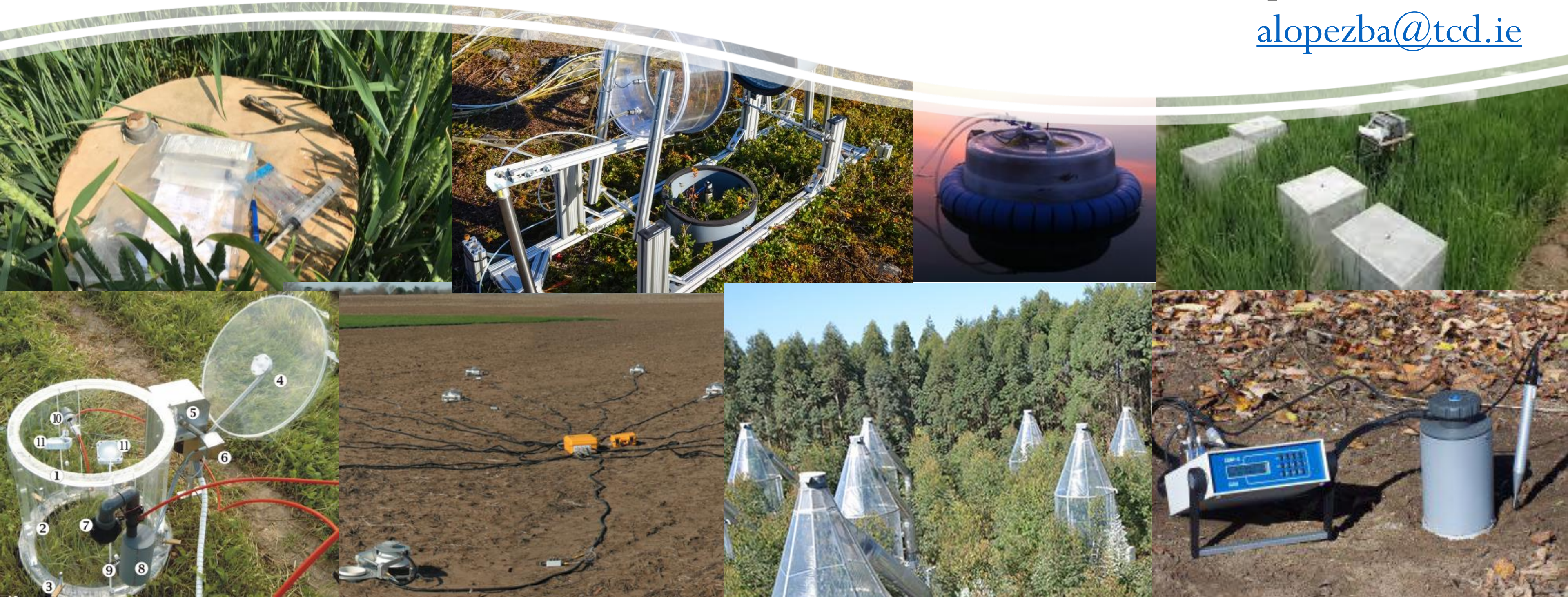
Measuring land-atmosphere GHG fluxes with the chamber technique

Dr Ana Lopez Ballesteros
alopezba@tcd.ie



Content

- Intro: soil GHG emissions
- Types of chambers
- Quality assurance & Quality control
- Spatial and temporal variability
- Study case

Objectives

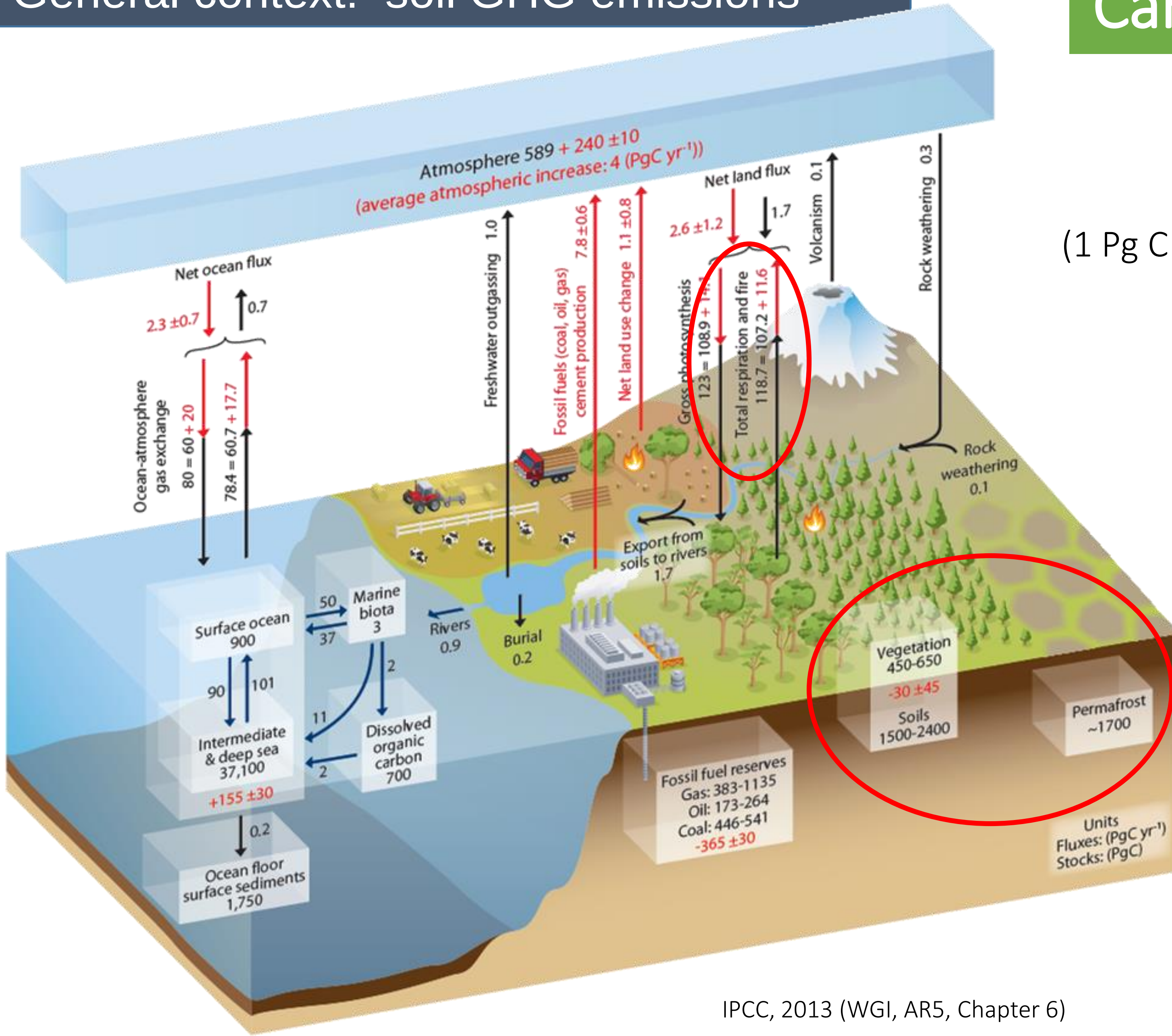
At the end of this session, you should be able to:

1. Classify the main types of chambers used to measure GHG fluxes
2. Explain the measurement principle behind each type of chamber
3. List pros & cons of using the chamber technique

General context: soil GHG emissions

Carbon

(1 Pg C = 10^{15} g C)

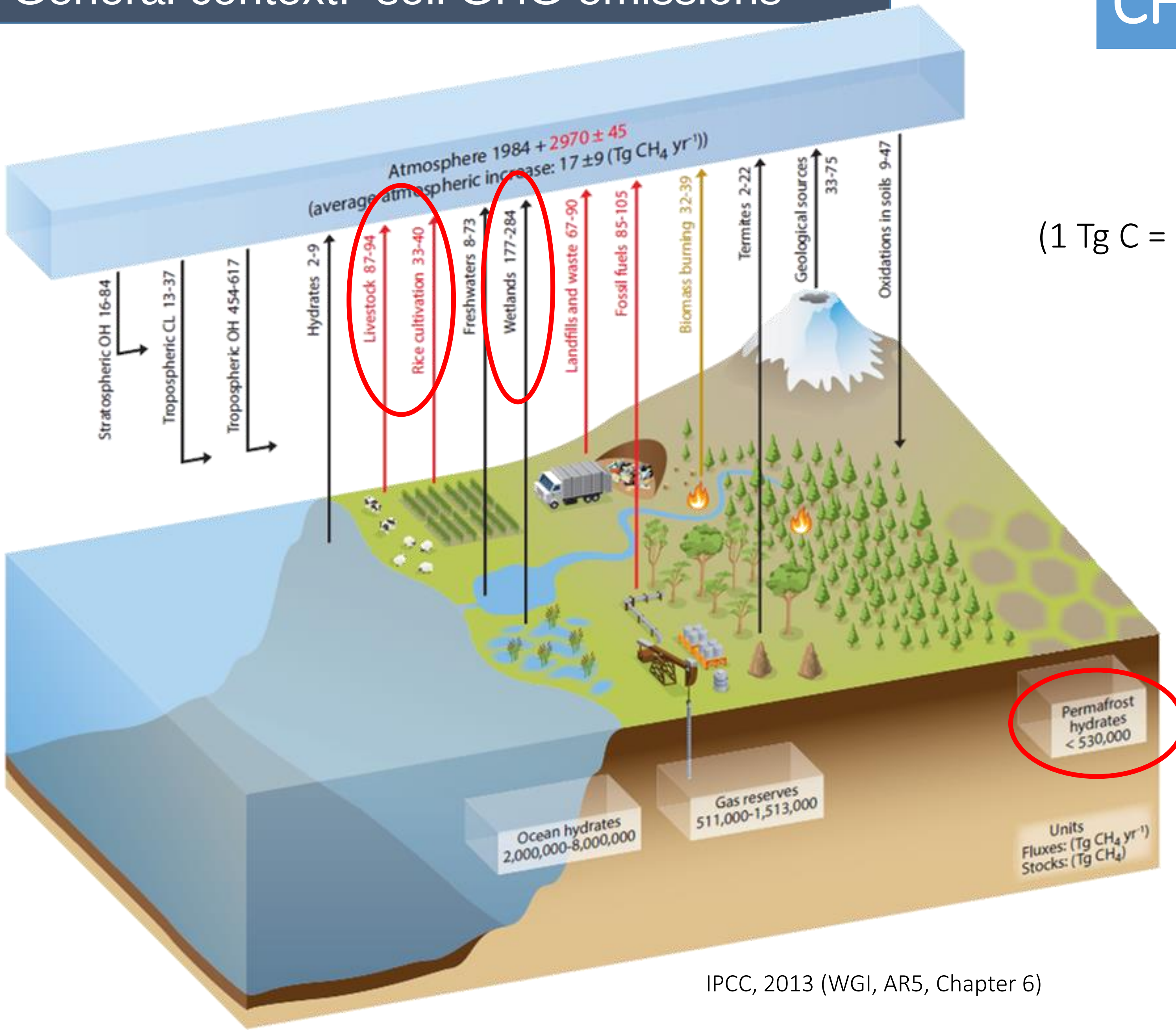


IPCC, 2013 (WGI, AR5, Chapter 6)

General context: soil GHG emissions

CH_4

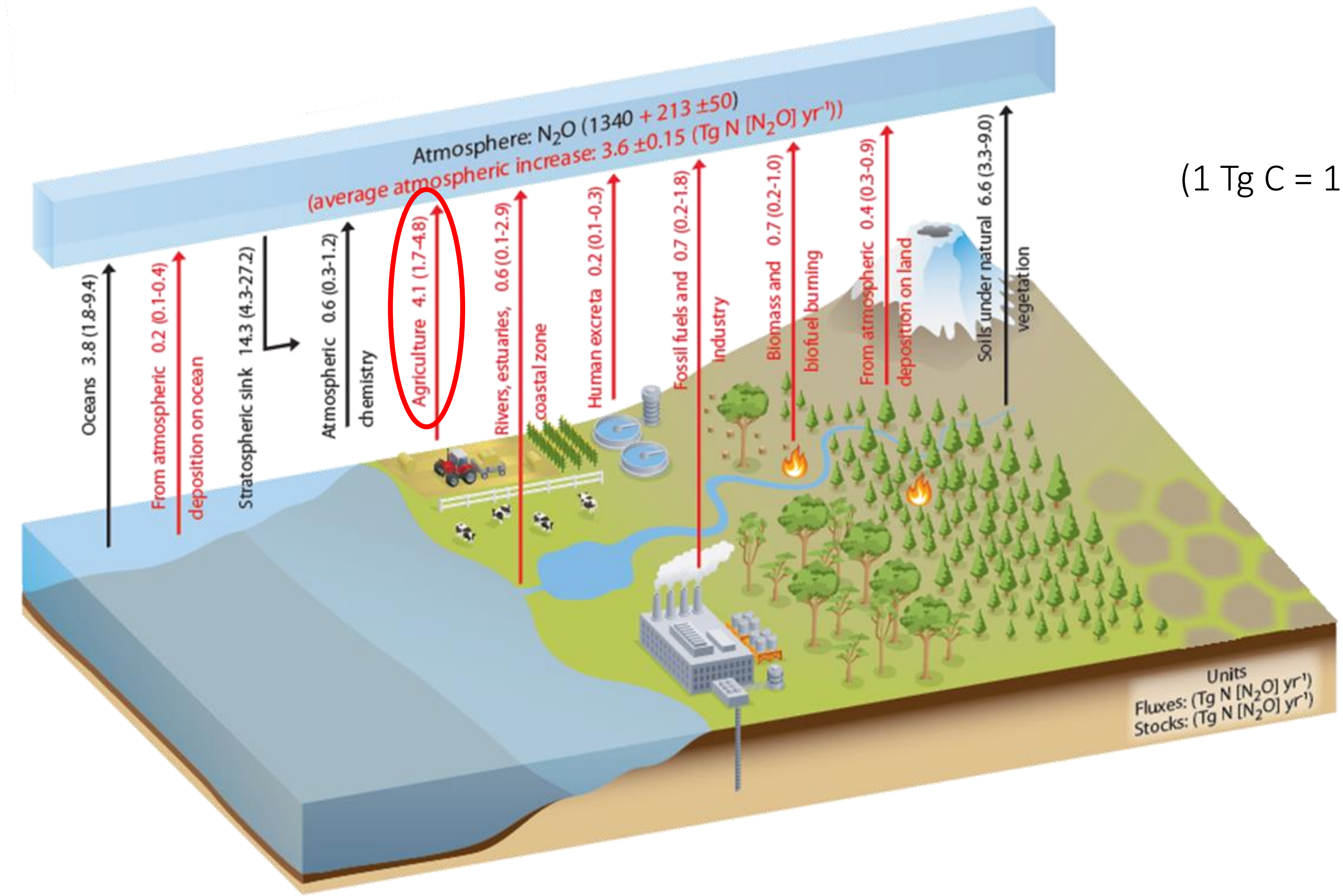
(1 Tg C = 10^{12} g C)



IPCC, 2013 (WGI, AR5, Chapter 6)

General context: soil GHG emissions

N_2O



(1 Tg C = 10^{12} g C)

IPCC, 2013 (WGI, AR5, Chapter 6)

Chamber types

❖ Measurement principle:

- Closed/static chambers
- Dynamic chambers

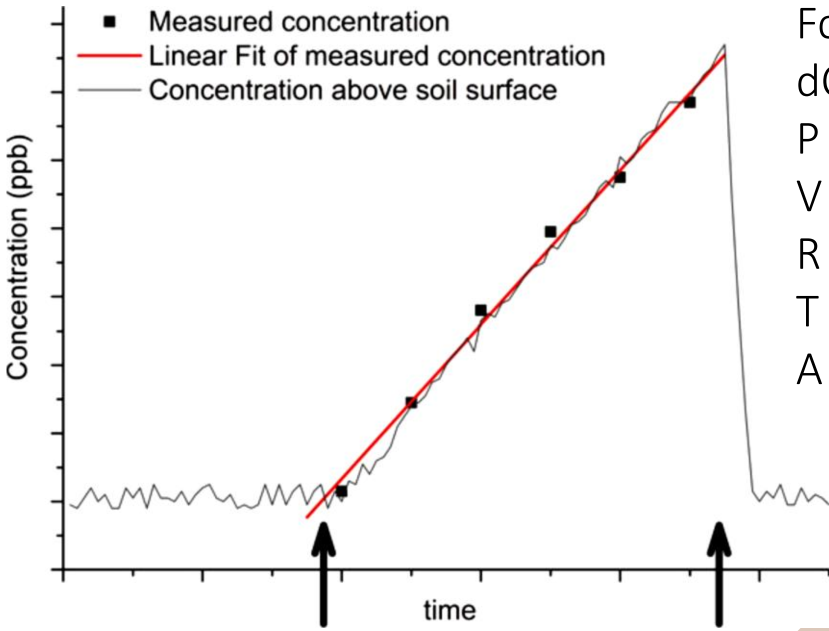
❖ Operational mode:

- Manual chambers
- Automatic chambers

Chamber types: Closed/static chambers

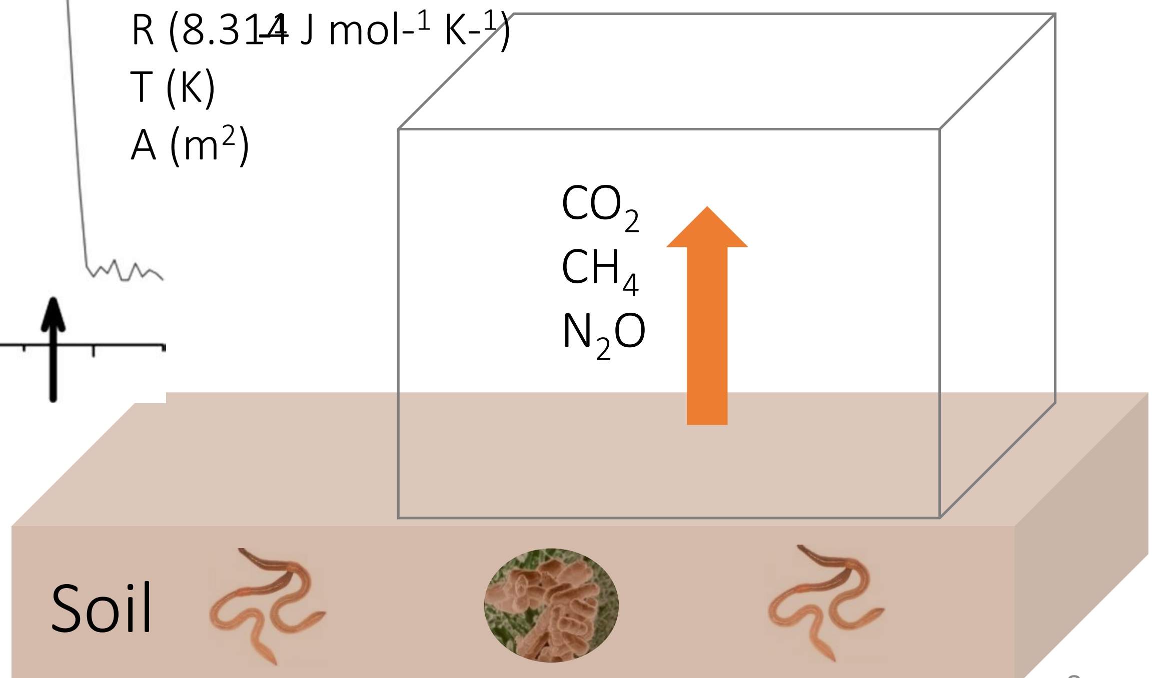
- Non-steady state → ambient conditions vary
- Measurement target is enclosed within the chamber volume
- Based on the Δgas (CO_2, CH_4 or N_2O) over time

$$F_c = \frac{dC}{dt}\frac{P\,V}{R\,T\,A}$$



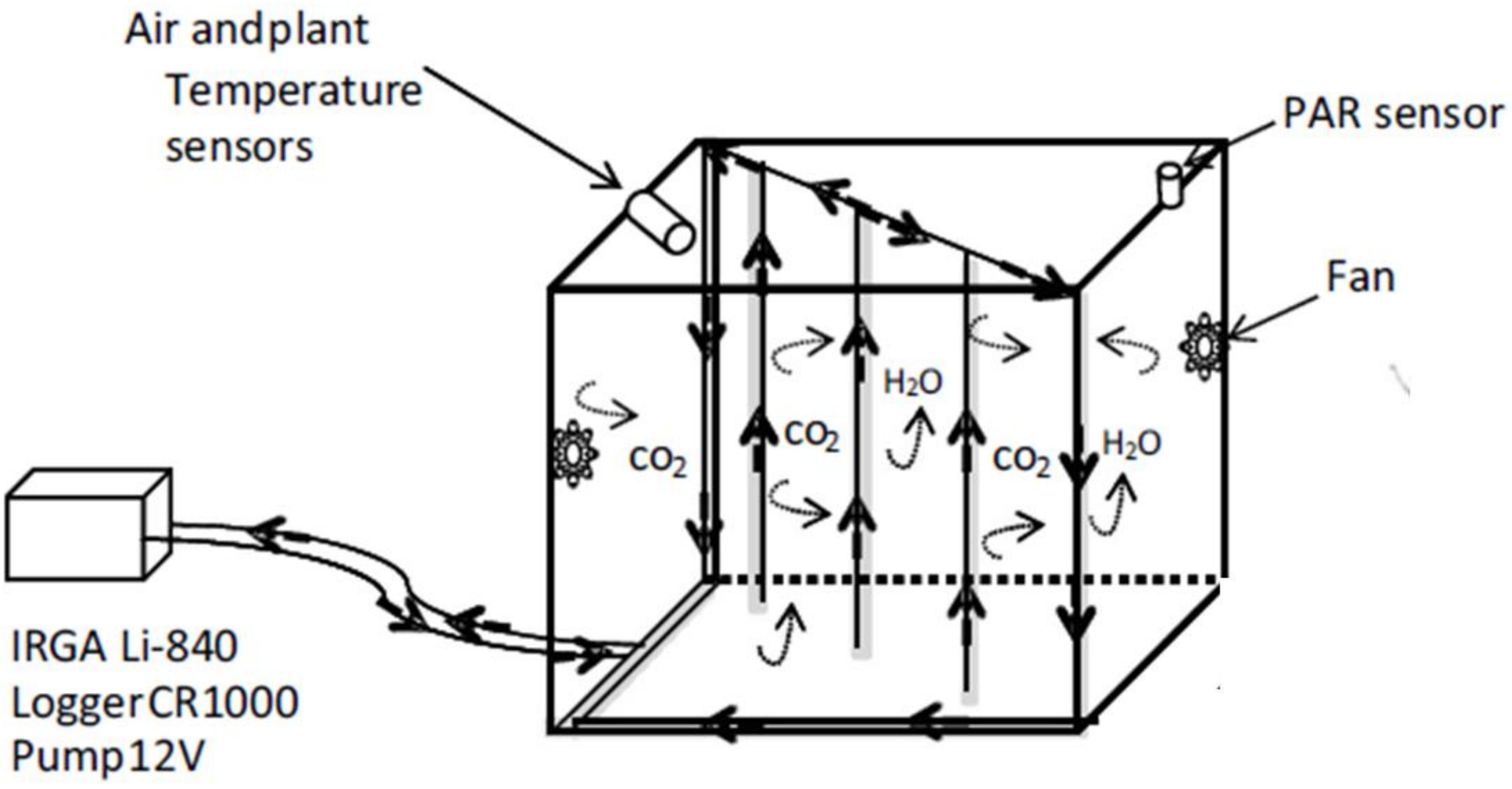
Butterbach Bahl et al 2016. Springer

Fc (μmol m^{-2} s^{-1})
dC/dt (μmol/mol dry air)
P (Pa)
V (m^3) = collar + chamber
R (8.314 J mol^{-1} K^{-1})
T (K)
A (m^2)



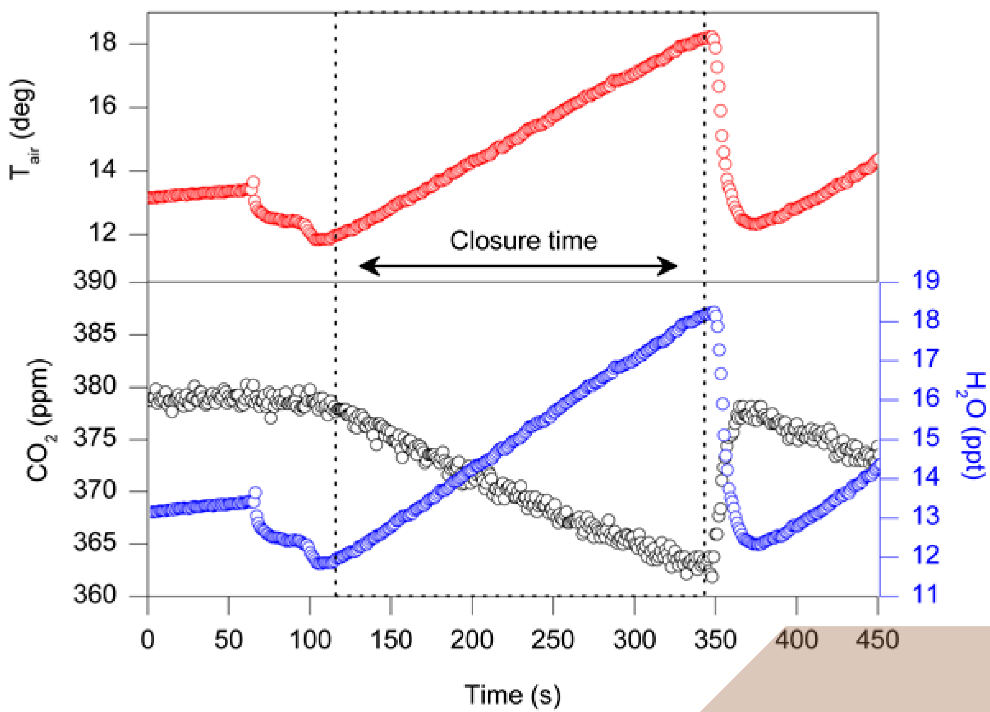
Chamber types: Closed/static chambers

- Non-steady state → ambient conditions vary
- Measurement target is enclosed within the chamber volume
- Based on the Δgas (CO_2, CH_4 or N_2O) over time



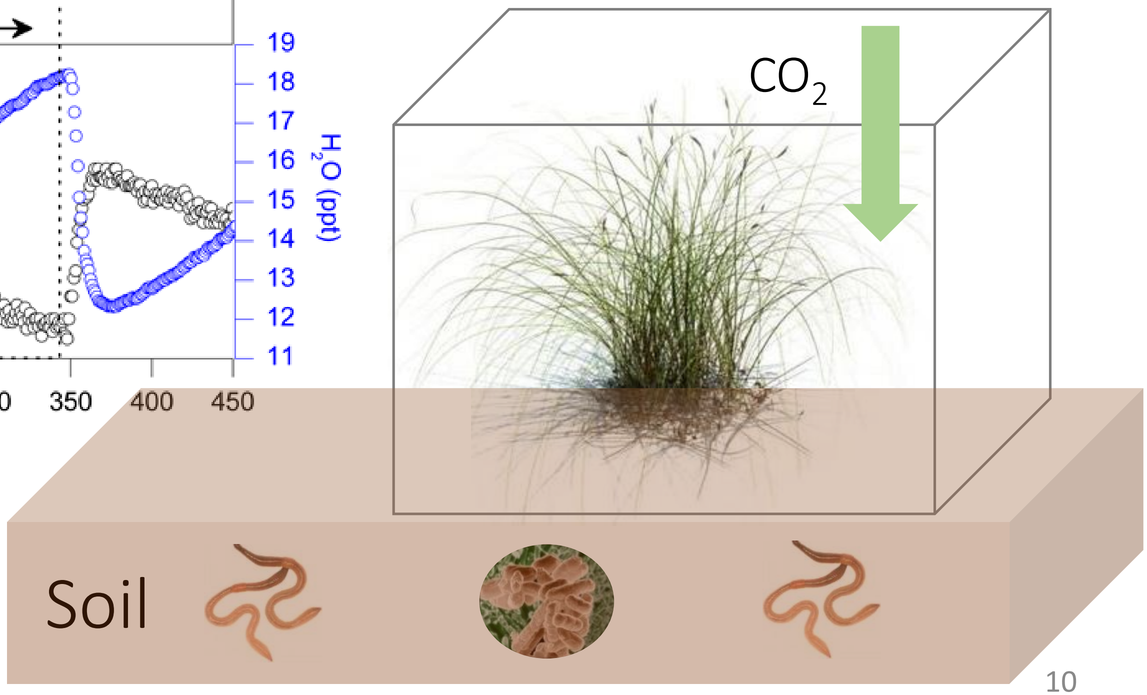
Chamber types: Closed/static chambers

- Non-steady state → ambient conditions vary
- Measurement target is enclosed within the chamber volume
- Based on the Δgas (CO_2, CH_4 or N_2O) over time



López-Ballesteros, 2017

$$F_c = \frac{dC}{dt}\frac{P\,V}{R\,T\,A}$$



Chamber types: Closed/static chambers

$$F_c = \frac{dC}{dt}\frac{P\,V}{R\,T\,A}$$

Flux calculation: Linear fit vs Polynomial fit

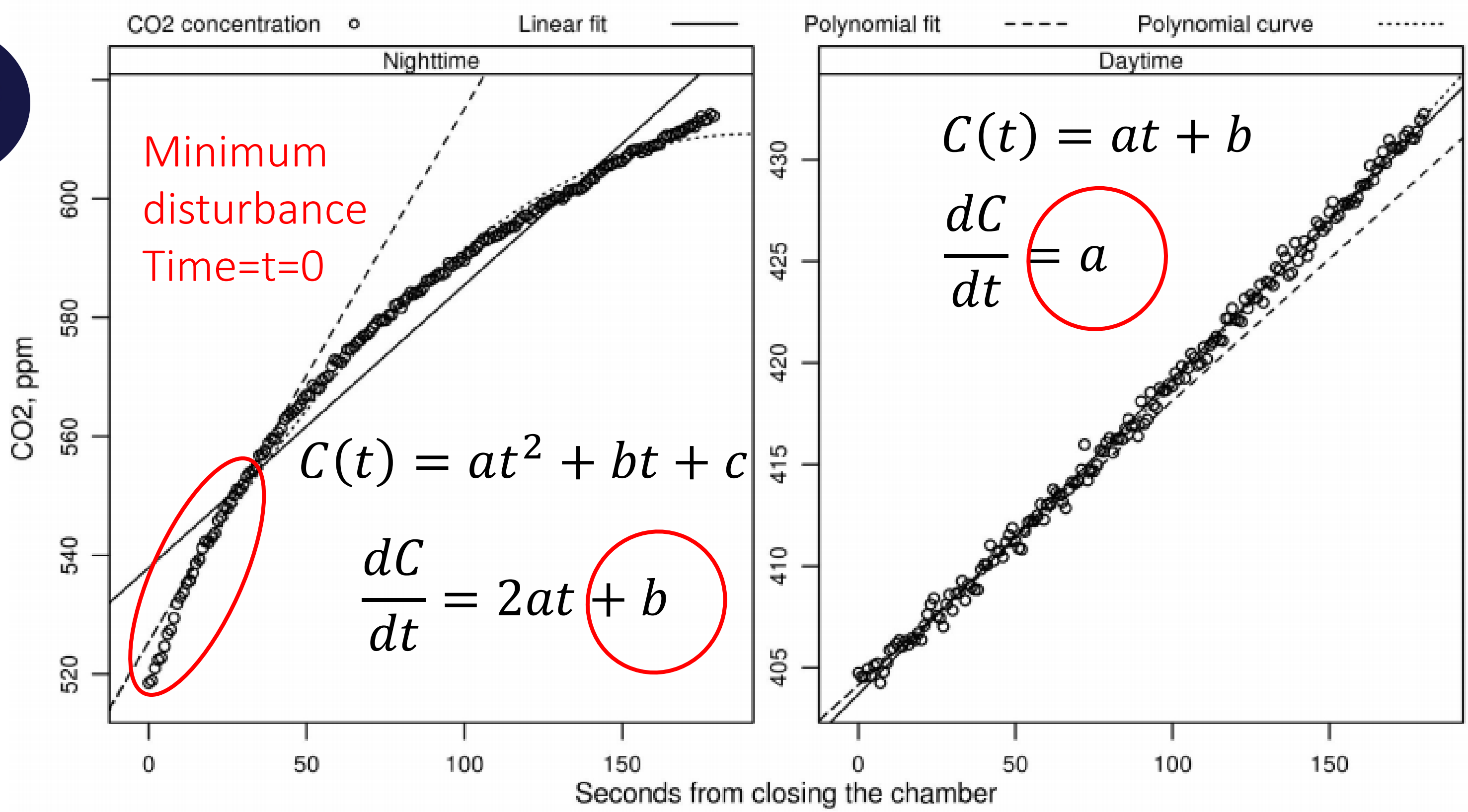


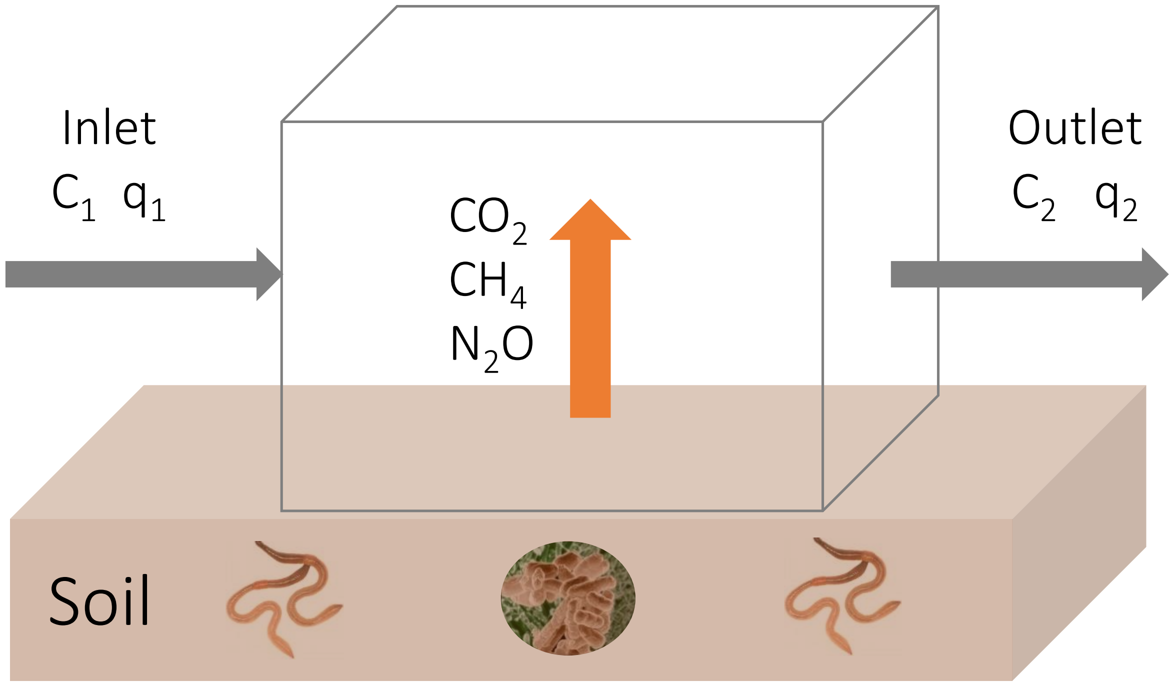
Fig. 5. Example of high initial flux in night-time versus normal daytime respiration measurement in CO_2 concentration development at the Kalevansuo site. Night-time measurement from 29 June 2011, 3 a.m. local time, daytime respiration measurement from 19 June 2012, 12 a.m. Note the differing *y* axis scales. Both fits are made to all visible data.

Koskinen *et al.* 2014 *Biogesciences*

Chamber types: Dynamic chambers

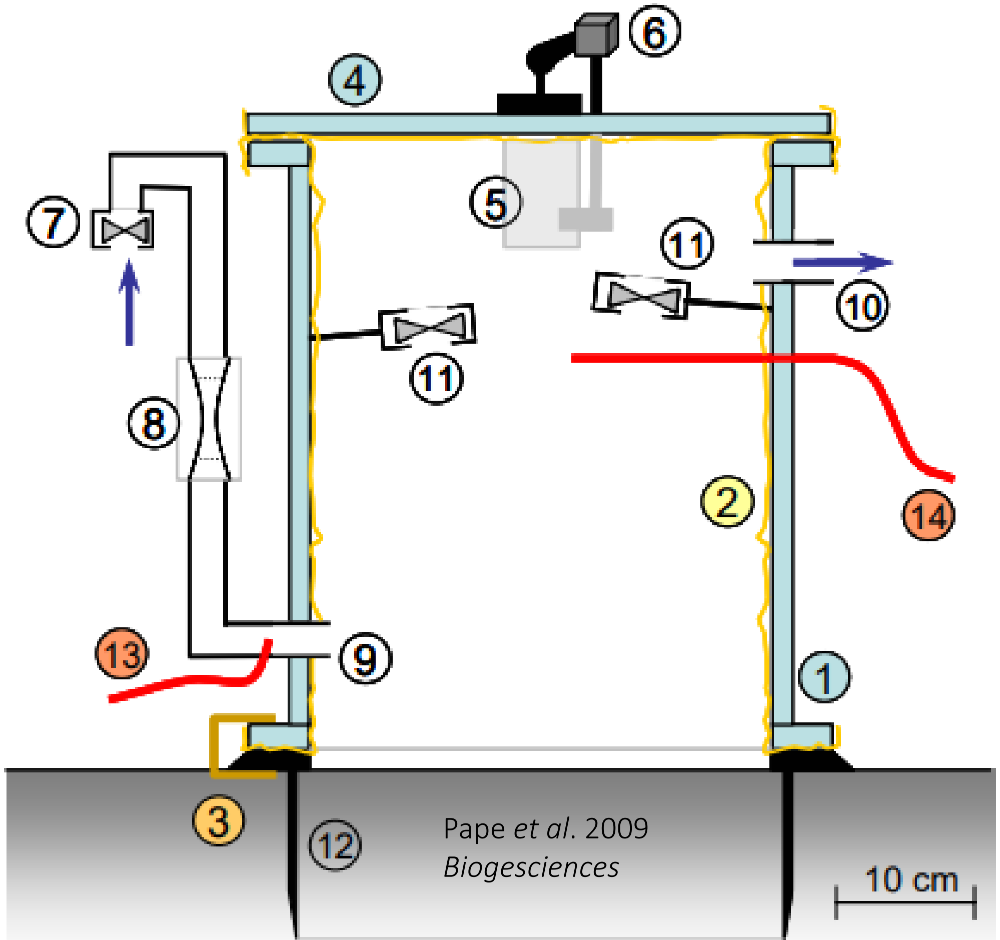
- Steady state → ambient conditions vary
- Measurement target is not totally enclosed. There a known gas flow through the chamber
- Based on the Δgas concentration (CO_2, CH_4 or N_2O) between the inlet and outlet

$$F_c = \frac{(C_2 q_2 - C_1 q_1)}{A}$$



Chamber types: Dynamic chambers

- Steady state → ambient conditions vary
- Measurement target is not totally enclosed. There a known gas flow through the chamber
- Based on the Δgas concentration (CO_2, CH_4 or N_2O) between the inlet and outlet



Pape *et al.* 2009
Biogesciences

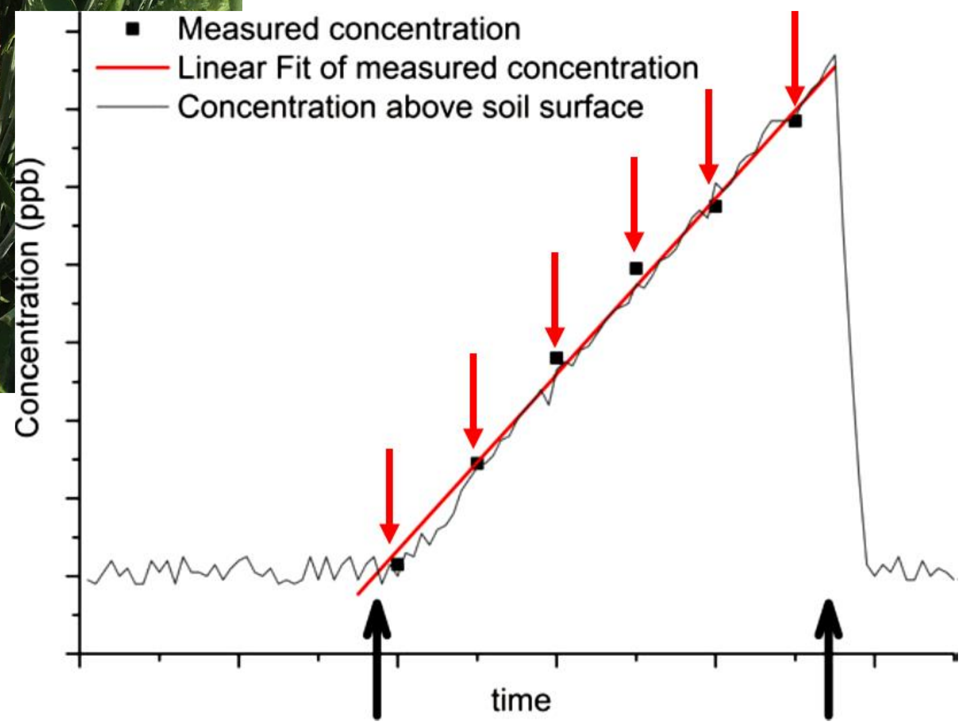
(1) acrylic glass frame,
(2) transparent FEP film (yellow parts in the scheme)
(3) clamp to attach chamber to soil frame,
(4) moving lid, (5) lid motor, (6) lid inclinometer,
(7) purging fan with ambient air inlet
(8) mass flow meter,
(9) chamber air inlet,
(10) chamber air outlet
(11) mixing fan,
(12) soil frame,
(13) sample tube for ambient air,
(14) sample tube for chamber air.

Chamber types: Manual vs automatic chambers

Chamber types: Manual vs automatic chambers

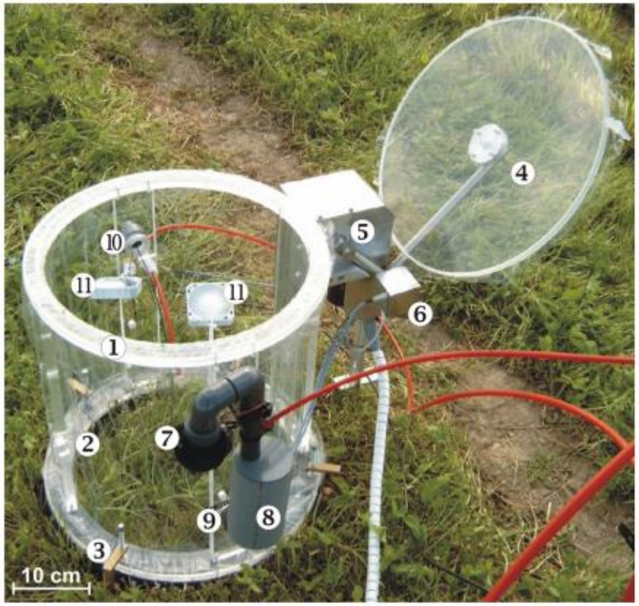
Gas pooling technique

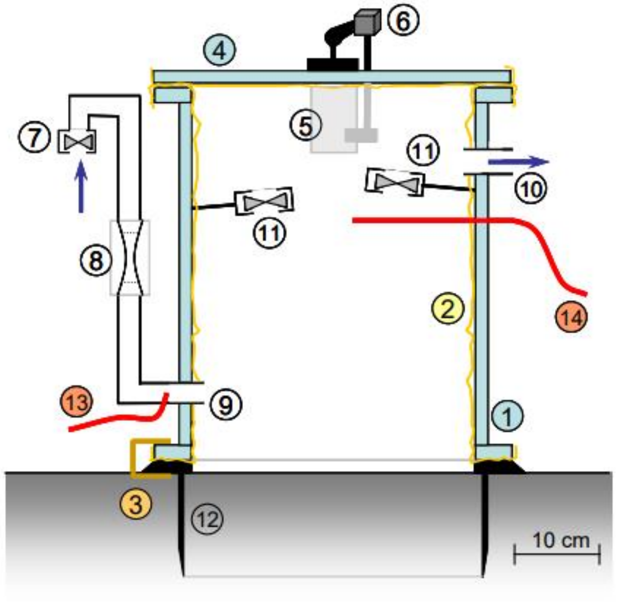
$t_1, t_2, \ldots, t_6$



Butterbach Bahl et al 2016. Springer

Chamber types: Manual vs automatic chambers



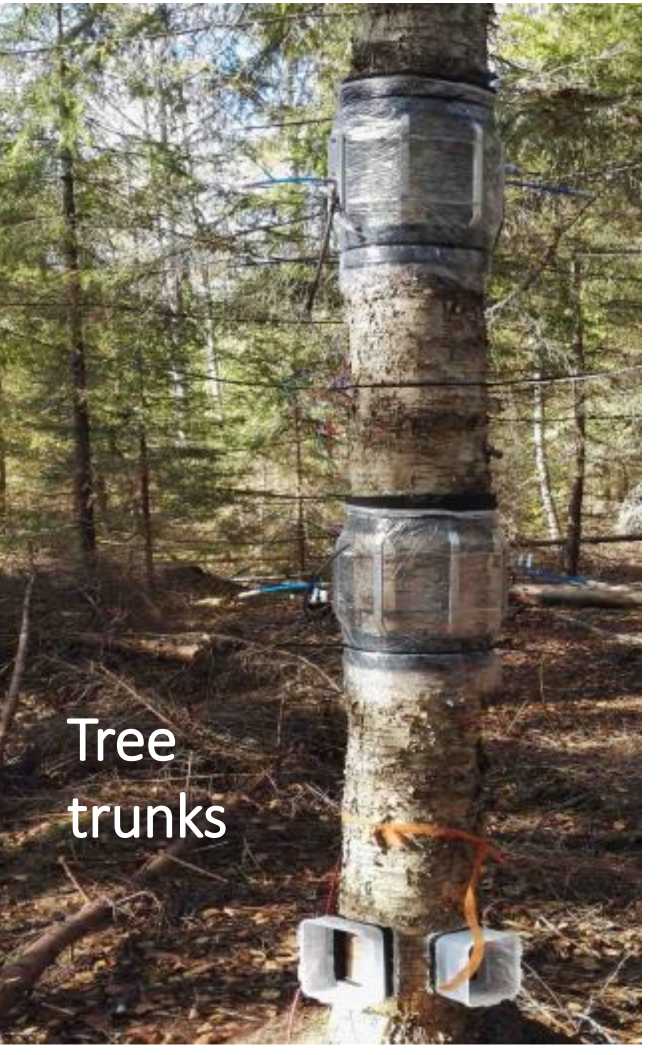


Pape *et al*. 2009
Biogesciences

Chamber types: Manual vs automatic chambers

Chamber types: measurement target

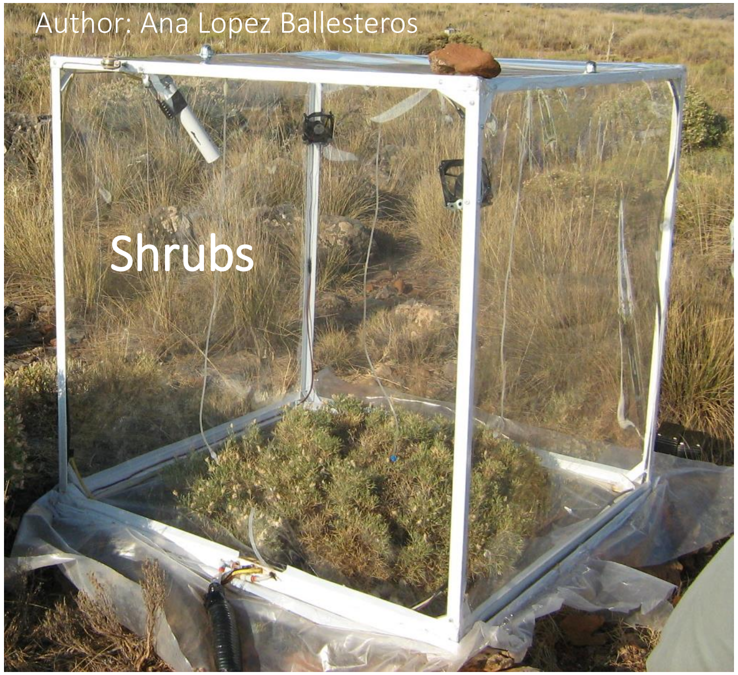
Source: http://www.hiilipuu.fi/articles?page=1



Source: Pyykko_Petteri_Pro_gradu_2019.pdf

Source: https://www.westernsydney.edu.au/hie/EucFACE/whole_tree_chambers

Chamber types: measurement target



What is will affected while doing the chamber measurements?

Quality Assurance & Quality Control

- Influence on ambient conditions:
  - Air temperature
  - Pressure
  - Wind and turbulence
  - Water vapour
  - Radiation

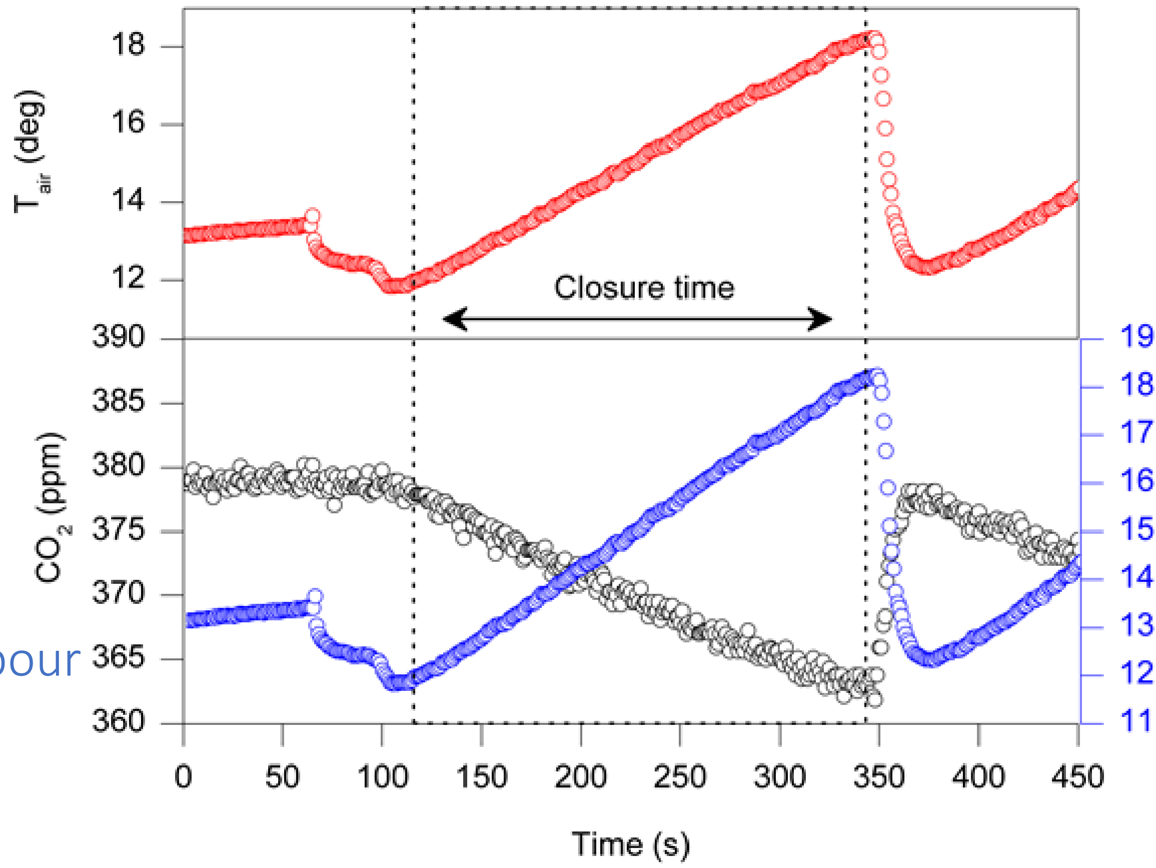
Quality Assurance & Quality Control

- Influence on ambient conditions:
  - Air temperature
  - Pressure
  - Wind and turbulence
  - Water vapour
  - Radiation

✓ Dilution correction

$$X_i = \frac{X'_i}{1 - X_d}$$

✓ Physical barrier for water vapour at the IRGA inlet



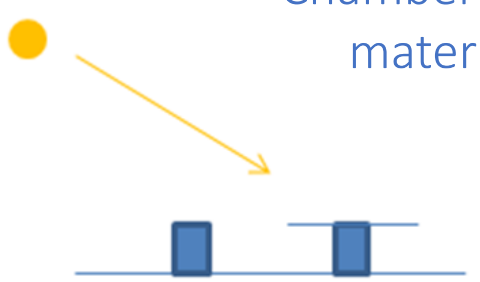
López-Ballesteros, 2017

✓ Some IRGAs correct it by default!

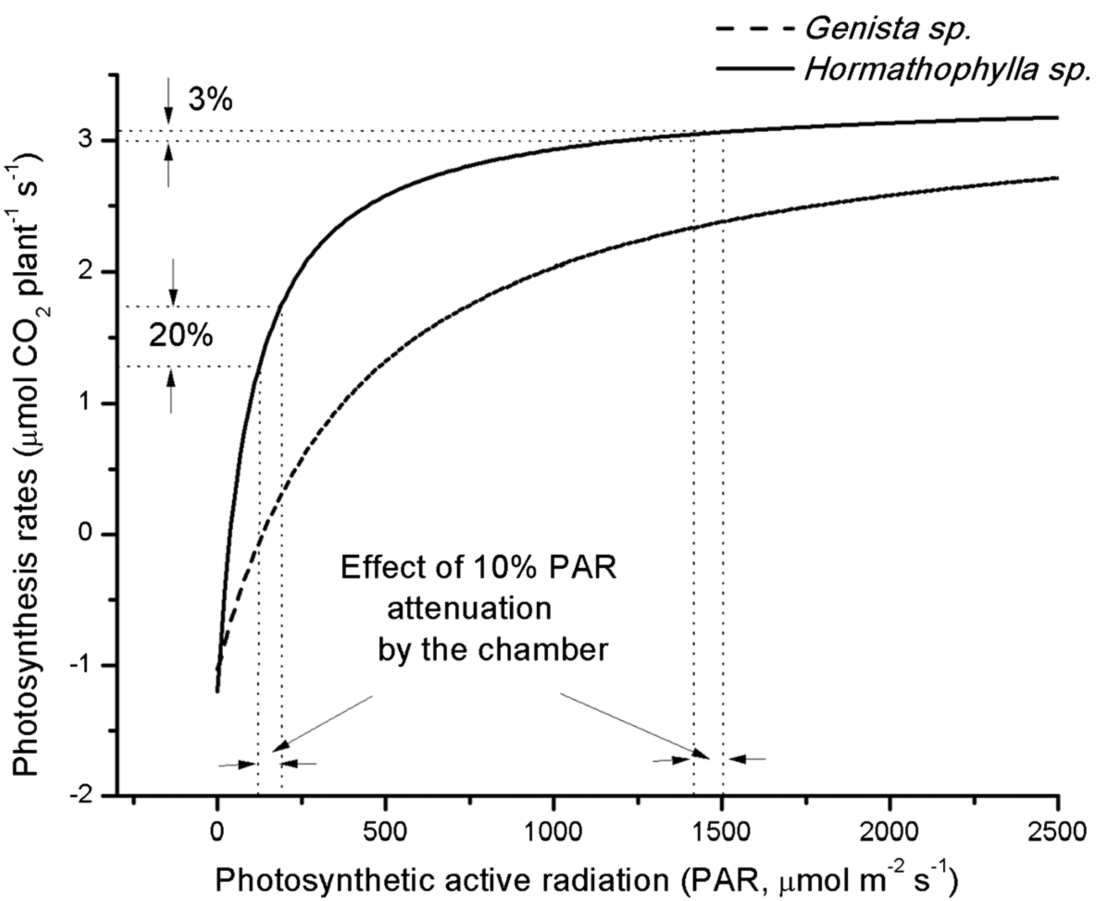
Quality Assurance & Quality Control

- Influence on ambient conditions:
  - Air temperature
  - Pressure
  - Wind and turbulence
  - Water vapour
  - Radiation

Chamber walls material



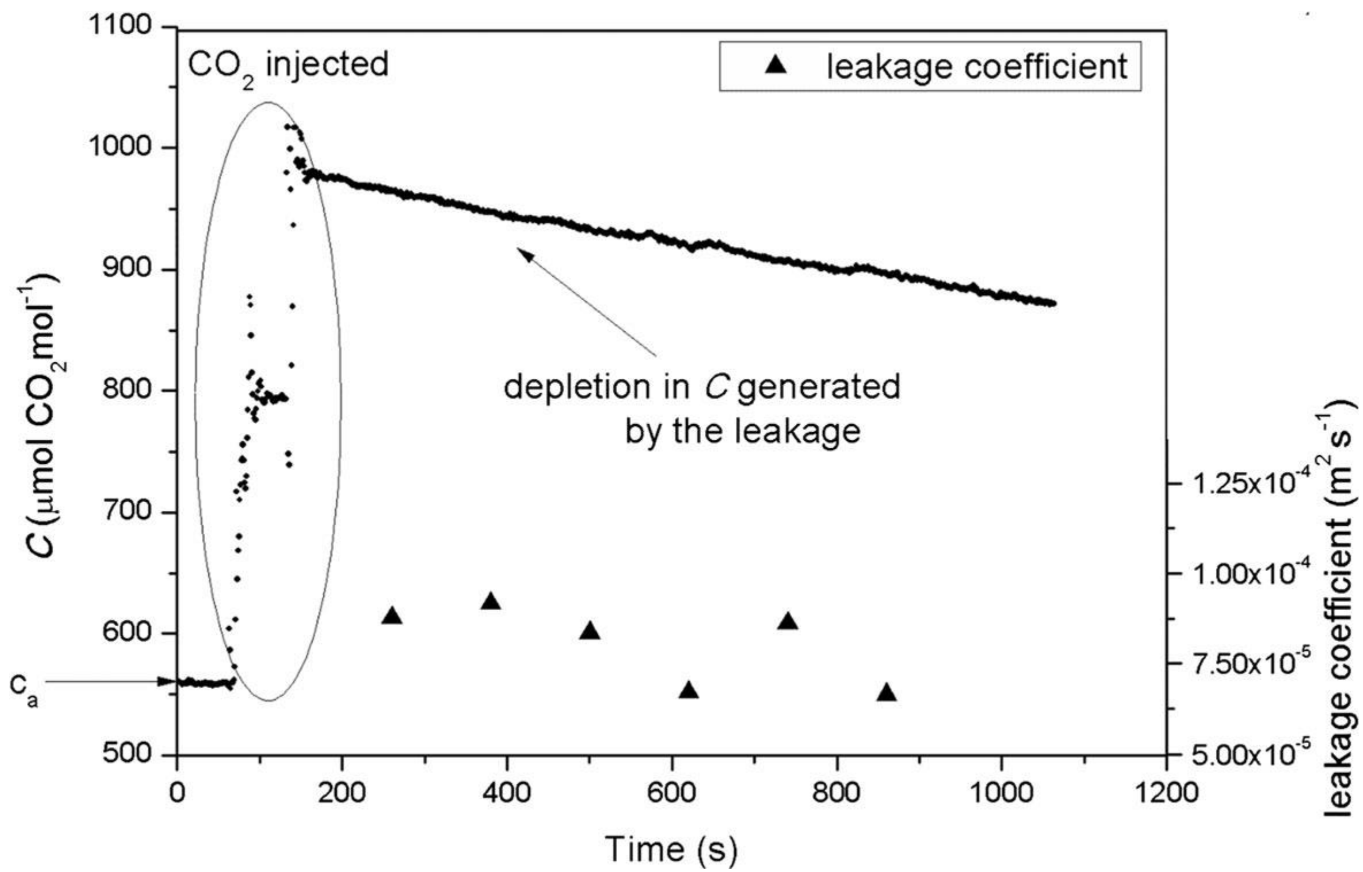
Radiation sensors



Pérez-Priego et al. 2015 Plant & Soil

Quality Assurance & Quality Control

- Leakage & adsorption (static/closed chambers)



Pérez-Priego et al. 2015 Plant & Soil

Quality Assurance & Quality Control

- Influence on ambient conditions:
  - Air temperature
  - Pressure
  - Wind and turbulence
  - Water vapour
  - Radiation

Measurement period = **short enough** to minimize disturbance in ambient conditions and target but **long enough** to acquire accurate flux measurements

- Leakage & adsorption (static/closed chambers)

- Influence on the target:
  - Root activity
  - Soil/plant disturbance
  - Soil/plant temperature
  - Soil moisture

Systematic errors should be quantified whenever is possible

Spatial & Temporal Variability

Journal of Geophysical Research: Biogeosciences

RESEARCH ARTICLE

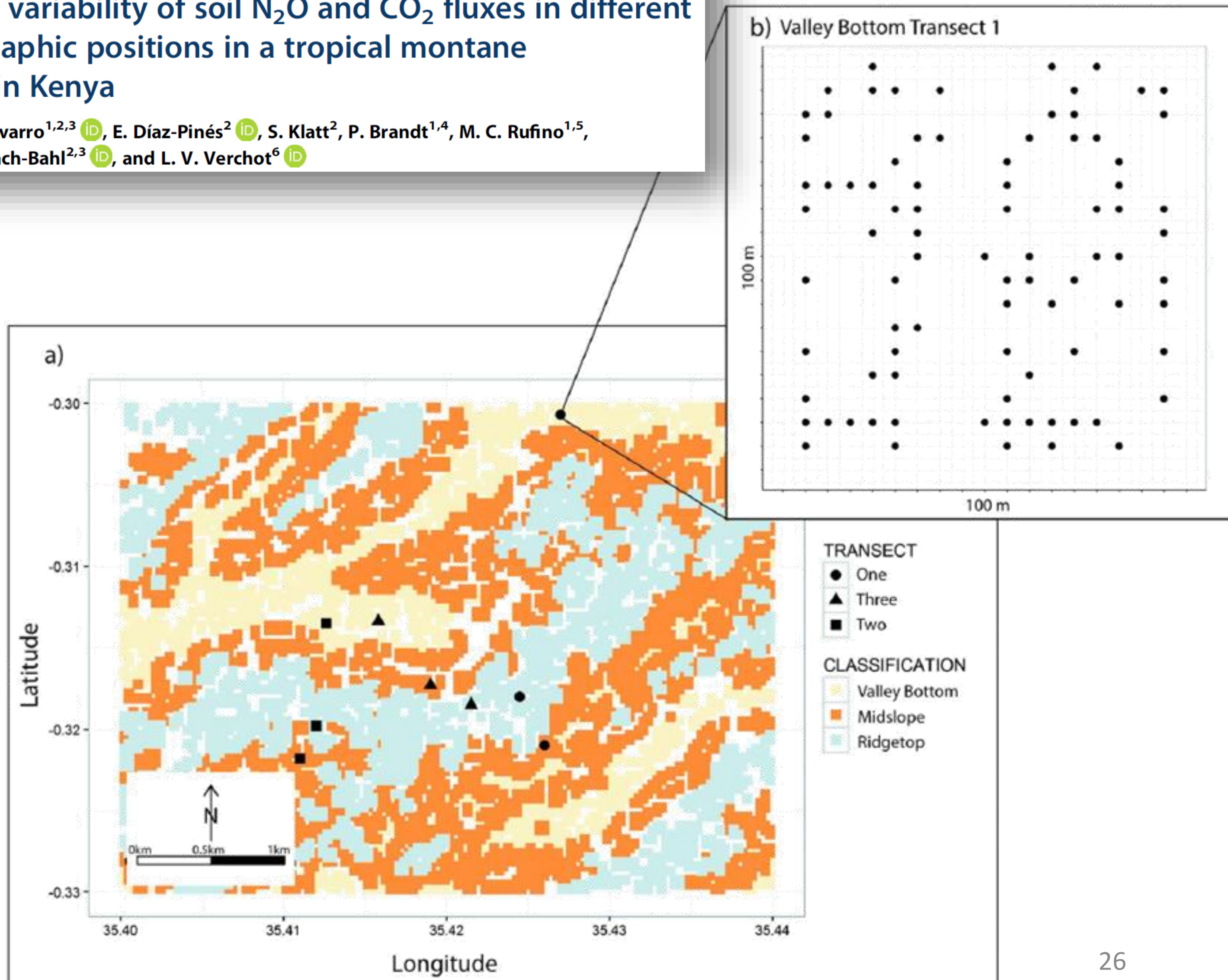
10.1002/2016JG003667

Key Points:

- We evaluated the spatial variability of soil CO_2 and N_2O emissions and their relation to topography in a tropical montane forest

Spatial variability of soil N_2O and CO_2 fluxes in different topographic positions in a tropical montane forest in Kenya

C. Arias-Navarro[1,2,3], E. Díaz-Pinés[2], S. Klatt[2], P. Brandt[1,4], M. C. Rufino[1,5], K. Butterbach-Bahl[2,3], and L. V. Verchot[6]



Spatial & Temporal Variability

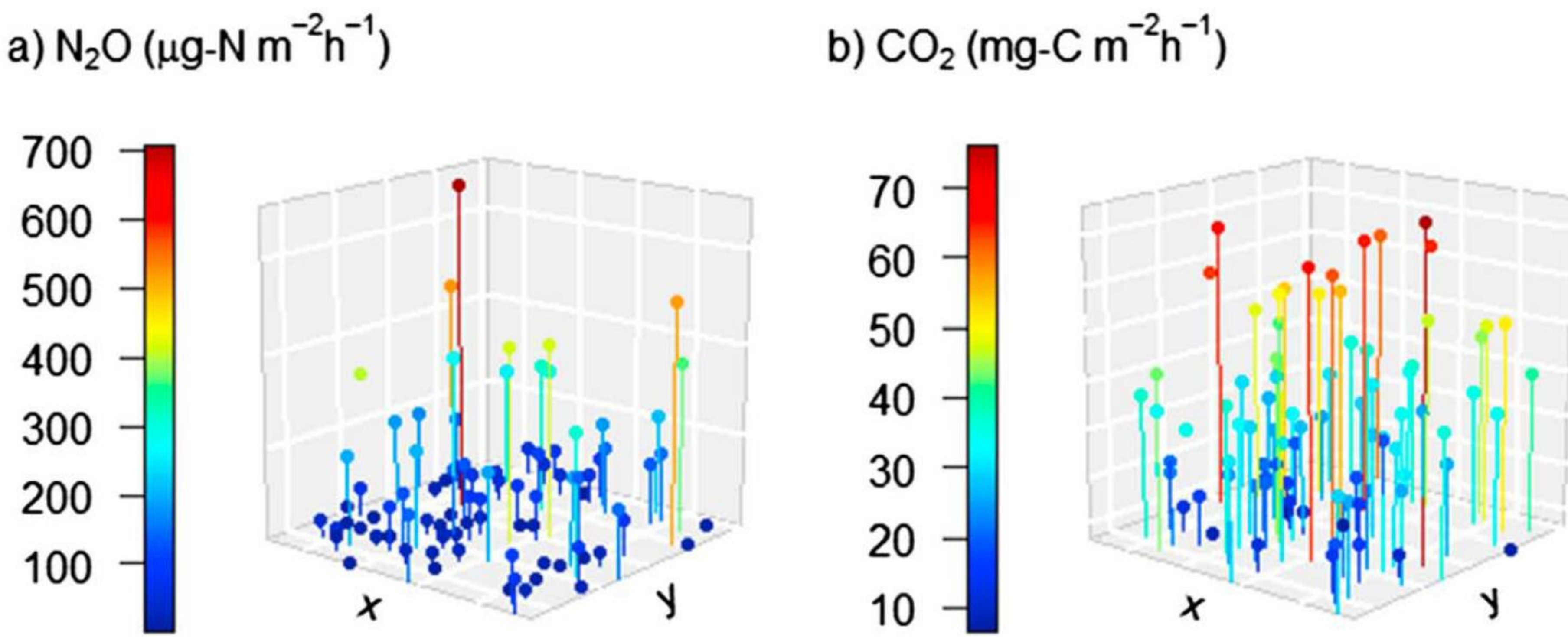
Journal of Geophysical Research: Biogeosciences

RESEARCH ARTICLE
10.1002/2016JG003667

Key Points:
- We evaluated the spatial variability of soil CO_2 and N_2O emissions and their relation to topography in a tropical montane forest

Spatial variability of soil N_2O and CO_2 fluxes in different topographic positions in a tropical montane forest in Kenya

C. Arias-Navarro[1,2,3], E. Díaz-Pinés[2], S. Klatt[2], P. Brandt[1,4], M. C. Rufino[1,5], K. Butterbach-Bahl[2,3], and L. V. Verchot[6]



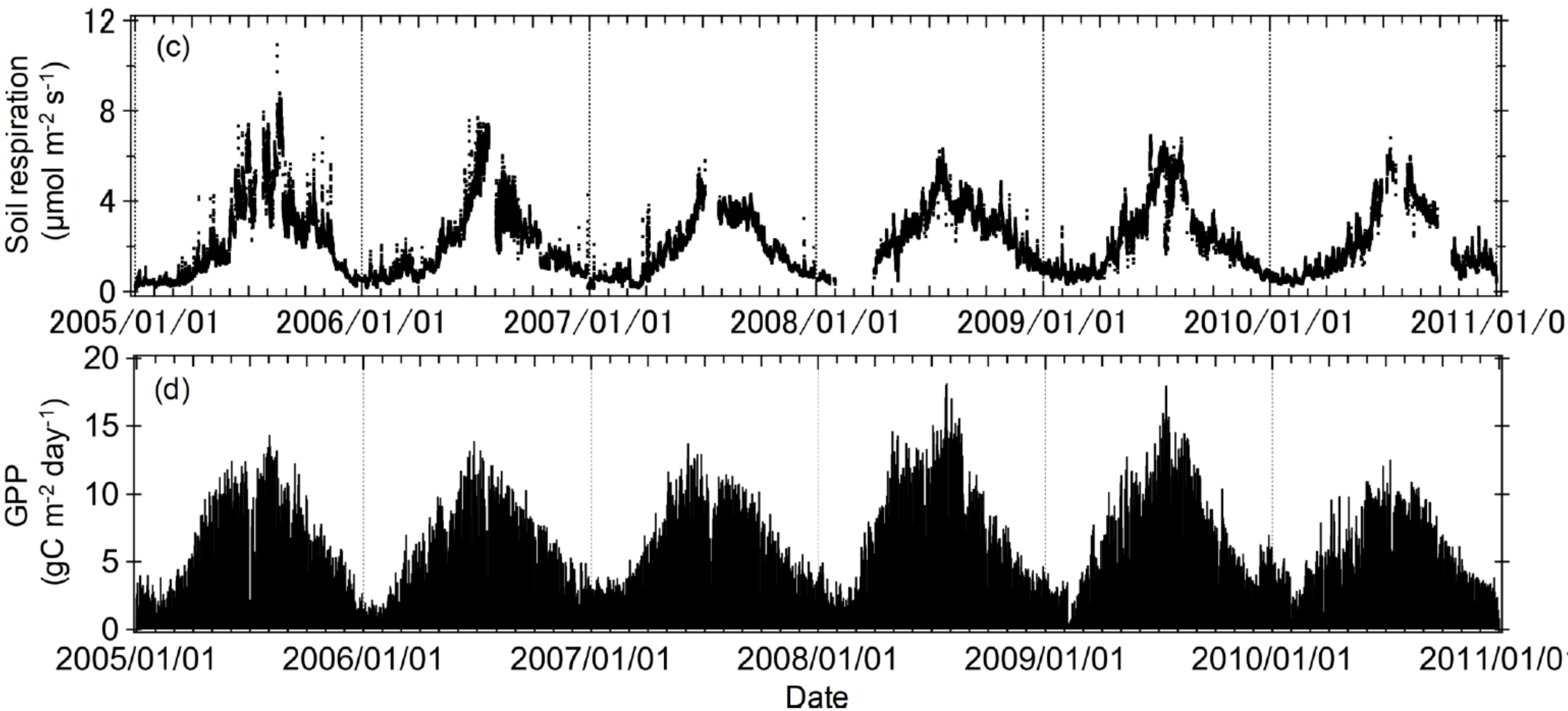
Spatial & Temporal Variability


PLOS | ONE

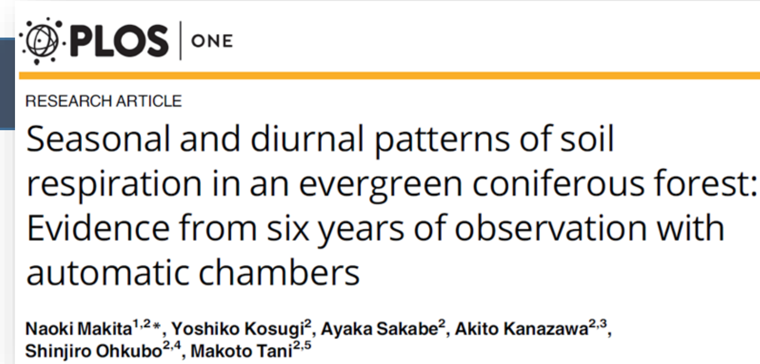
RESEARCH ARTICLE

Seasonal and diurnal patterns of soil respiration in an evergreen coniferous forest: Evidence from six years of observation with automatic chambers

Naoki Makita[1,2]*, Yoshiko Kosugi[2], Ayaka Sakabe[2], Akito Kanazawa[2,3], Shinjiro Ohkubo[2,4], Makoto Tani[2,5]



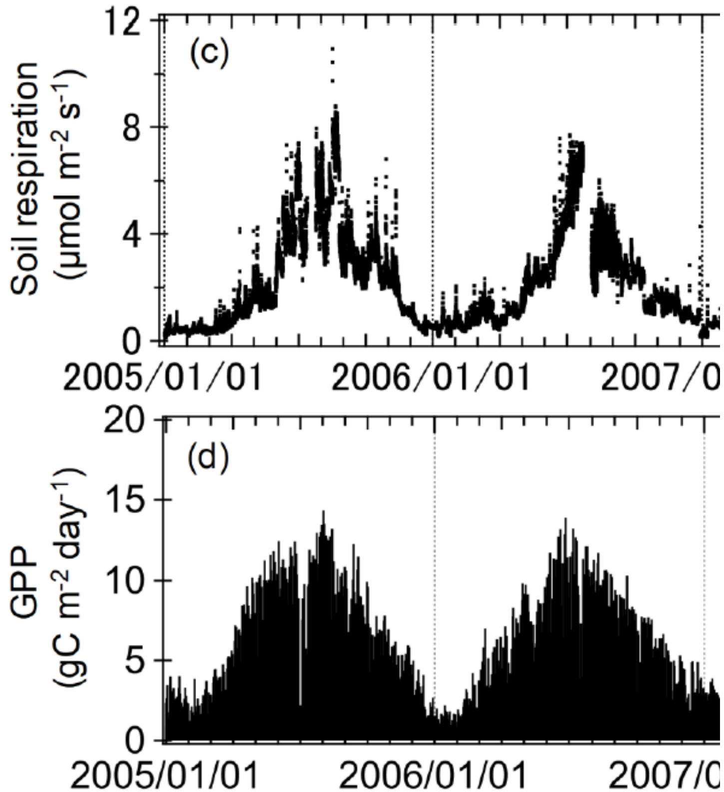
Spatial & Temporal Variability

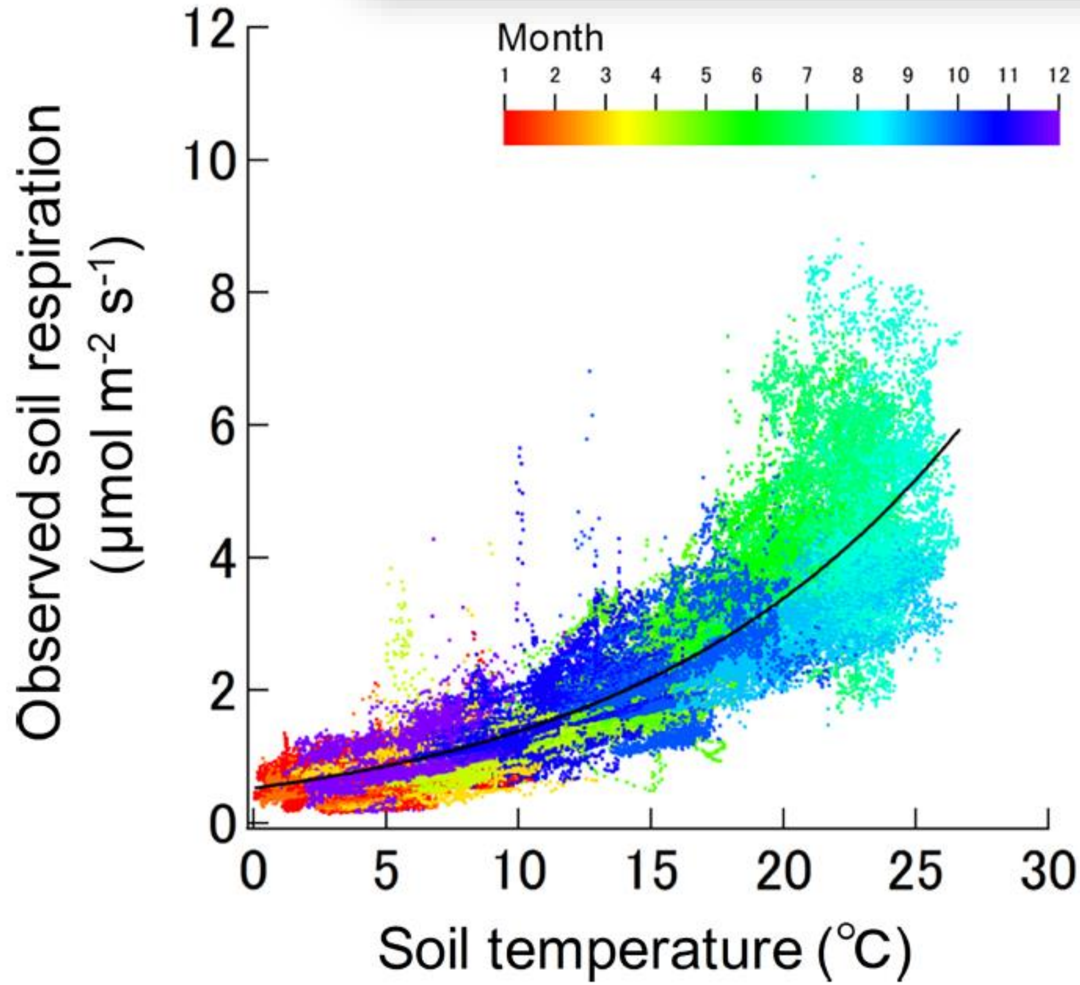

PLOS | ONE

RESEARCH ARTICLE

Seasonal and diurnal patterns of soil respiration in an evergreen coniferous forest: Evidence from six years of observation with automatic chambers

Naoki Makita[1,2]*, Yoshiko Kosugi[2], Ayaka Sakabe[2], Akito Kanazawa[2,3], Shinjiro Ohkubo[2,4], Makoto Tani[2,5]





Spatial & Temporal Variability

SCIENTIFIC REPORTS

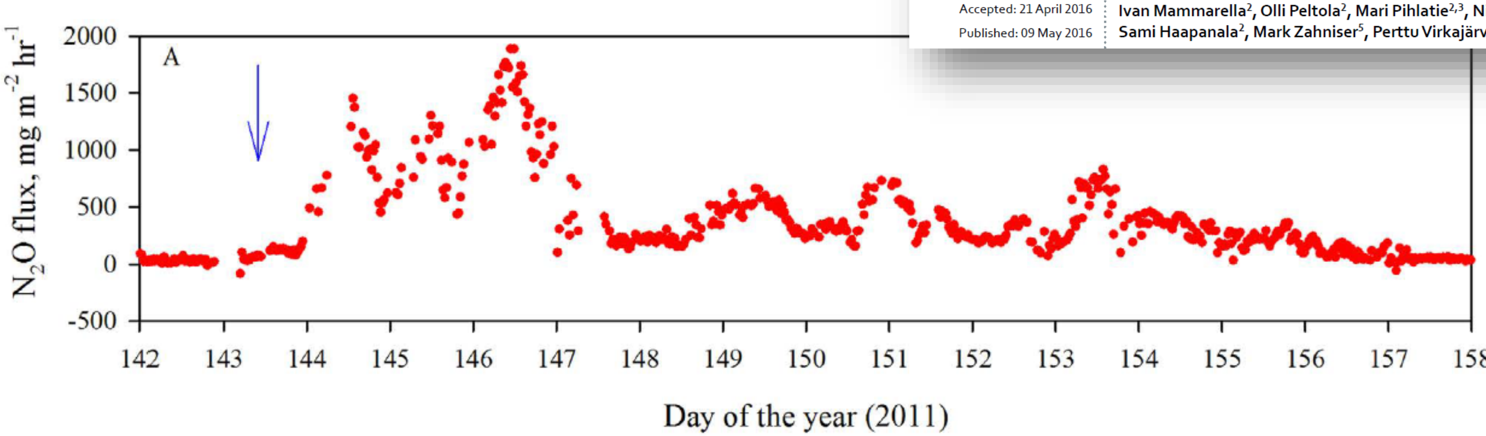
OPEN

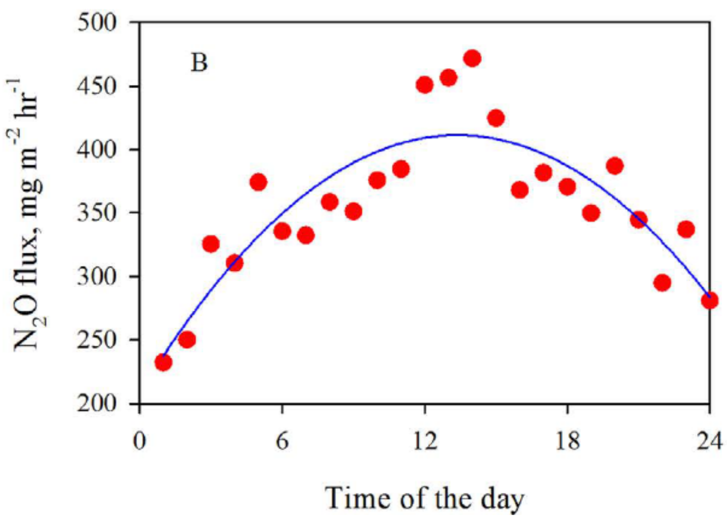
Neglecting diurnal variations leads to uncertainties in terrestrial nitrous oxide emissions

Received: 19 March 2015
Accepted: 21 April 2016
Published: 09 May 2016

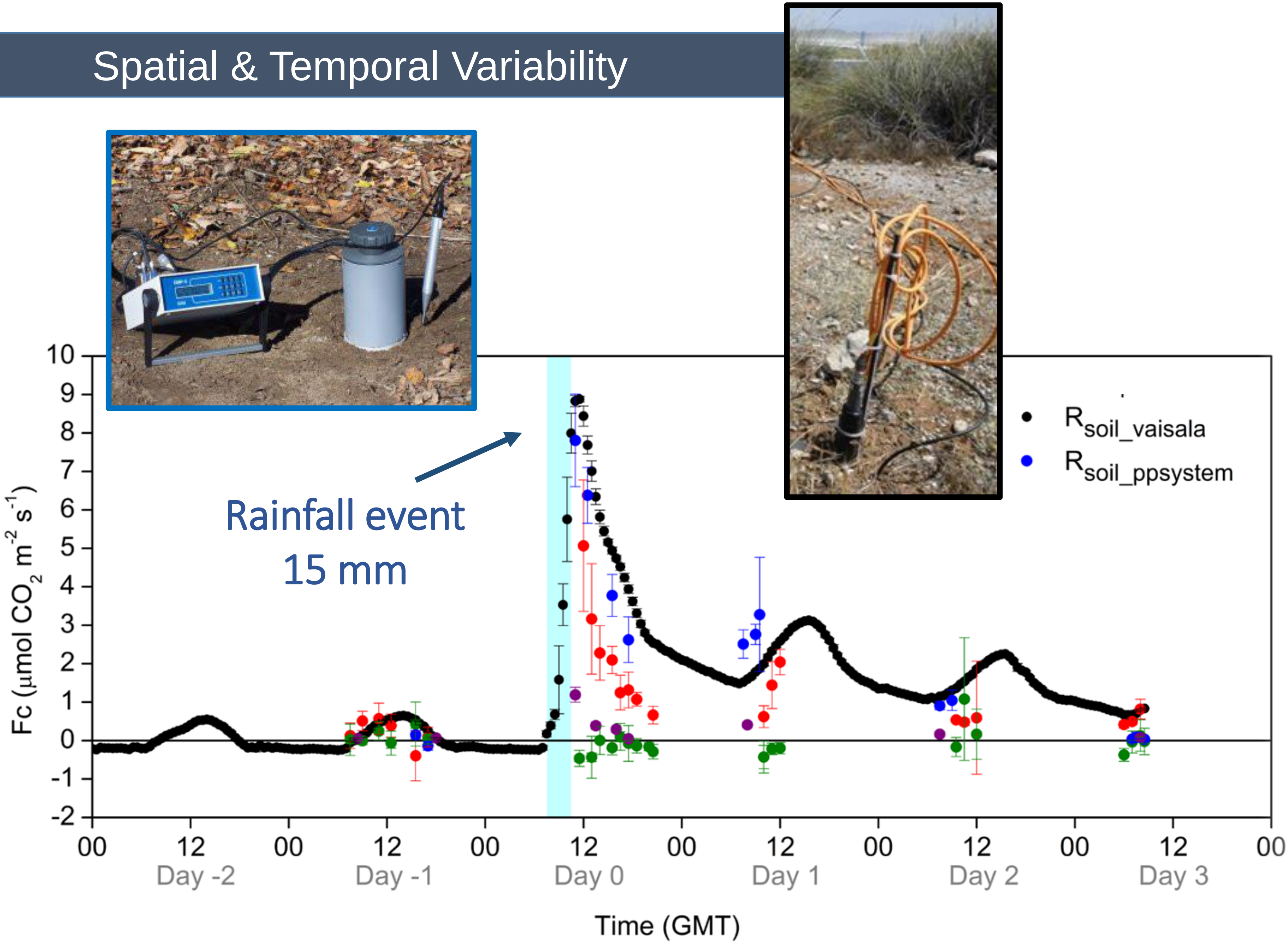
Narasinha J. Shurpali[1], Üllar Rannik[2], Simo Jokinen[1], Saara Lind[1], Christina Biasi[1], Ivan Mammarella[2], Olli Peltola[2], Mari Pihlatie[2,3], Niina Hyvönen[1], Mari Räty[4], Sami Haapanala[2], Mark Zahniser[5], Perttu Virkajärvi[4], Timo Vesala[2,6,7] & Pertti J. Martikainen[1]

Fertilization





Spatial & Temporal Variability



López-Ballesteros et al. 2016 JGR

Chamber technique: pros & cons

- Easy to use
- Cheaper than other techniques (EC)
- Spatial coverage
- Fast measurements
- Net flux components
- Test many treatments at low cost
- Several gases can be measured simultaneously
- Hand-made, infinite prototypes

- Disturbances in ambient conditions
- Disturbances in measurement target – long-term experiments
- Difficult to use under harsh conditions (frozen or rocky soils, windy days)
- Differences between chamber types requires calibration
- Location and periodicity of the measurements can lead to under-/over-estimation of fluxes

Study case

Study case

Journal of Geophysical Research: Biogeosciences

RESEARCH ARTICLE
10.1002/2015JG003091

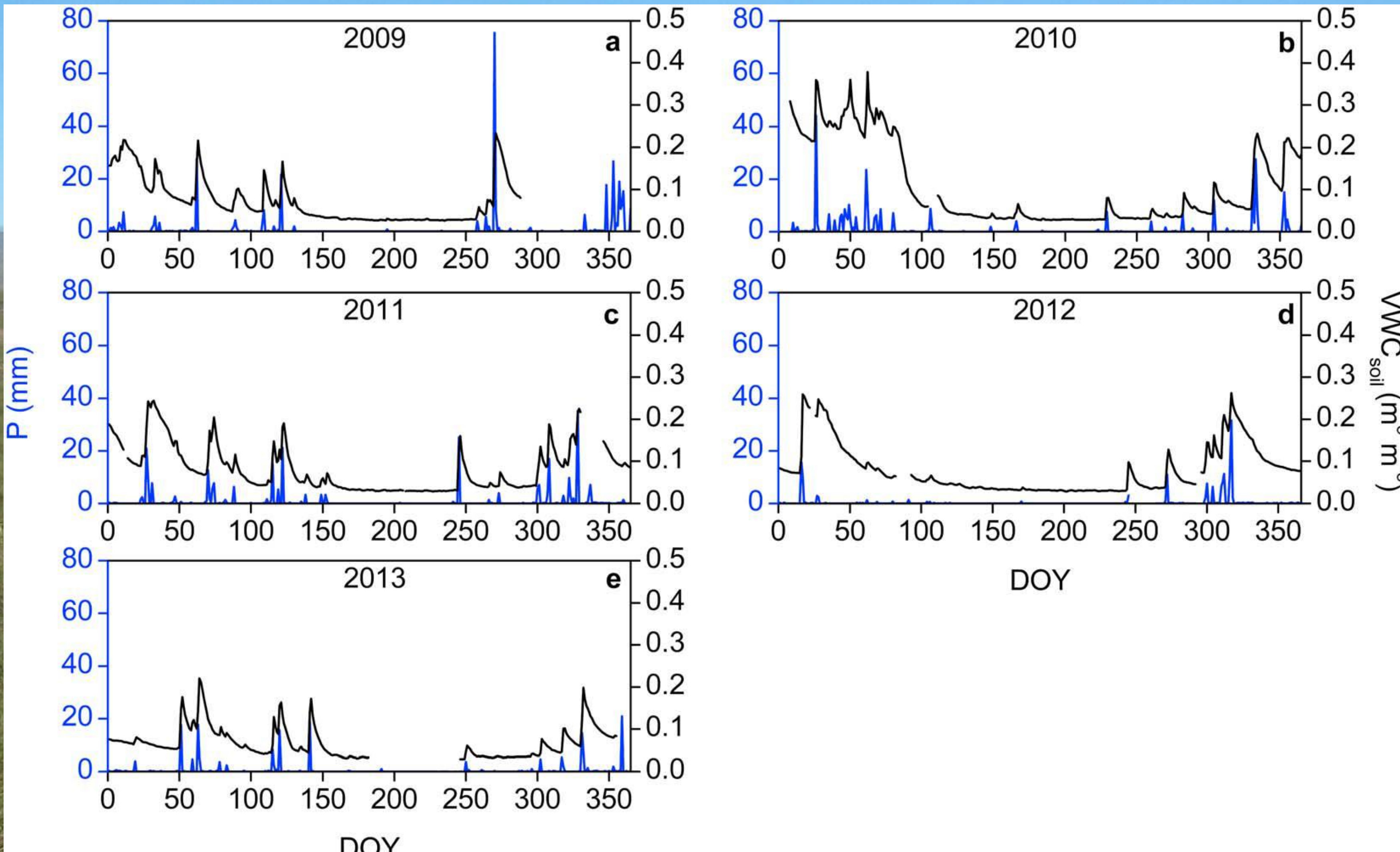
Enhancement of the net CO_2 release of a semiarid grassland in SE Spain by rain pulses

Ana López-Ballesteros[1,2], Penélope Serrano-Ortiz[2,3], Enrique P. Sánchez-Cañete[2,4], Cecilio Oyonarte[5,6], Andrew S. Kowalski[2,7], Óscar Pérez-Priego[8], and Francisco Domingo[1]

Key Points:
- Rain pulses promote net CO_2 emissions over the dry season

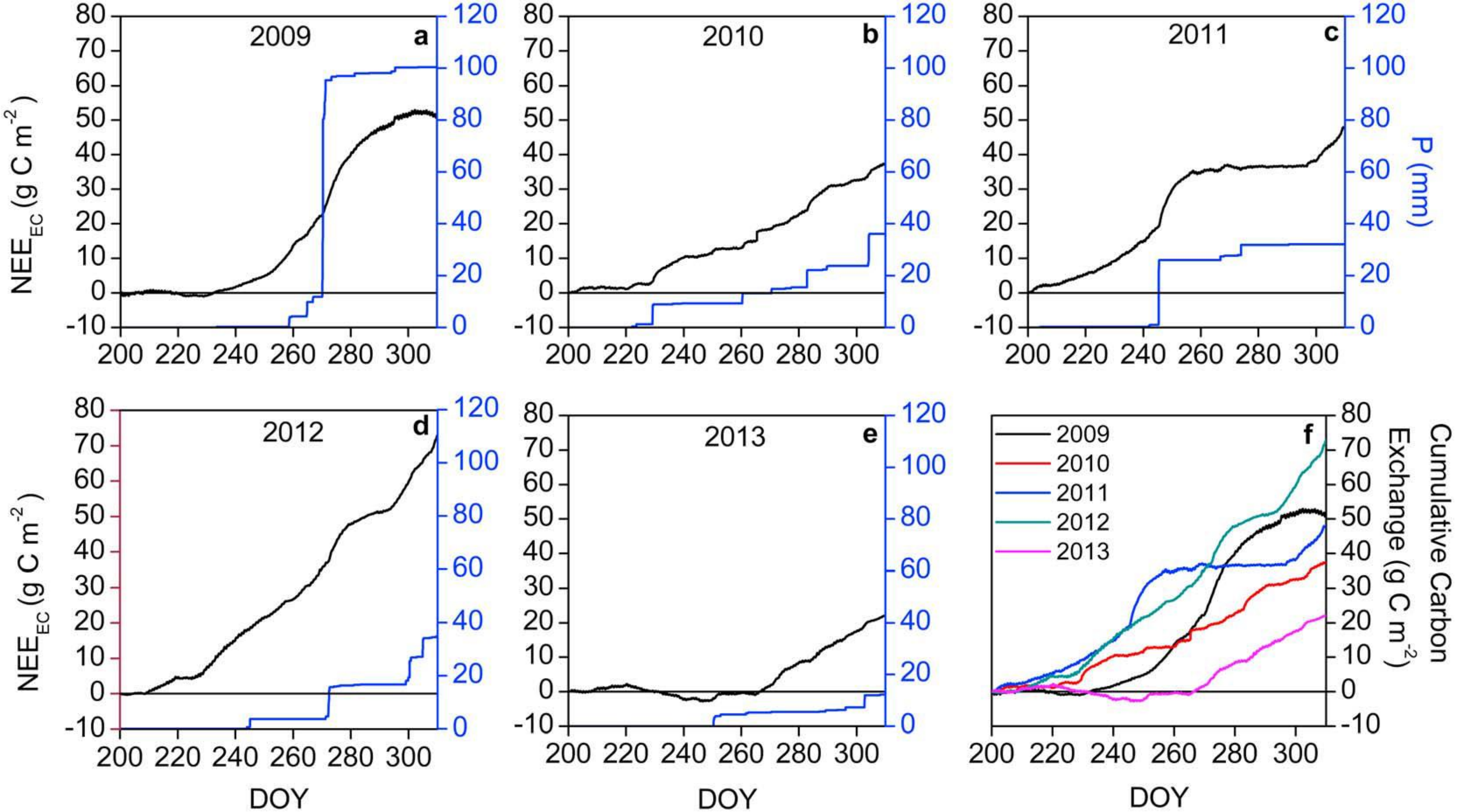
EC site (ES-Agu)	BALSABLANCA
Localization	Almería (SE Spain) 36º56’ 0’’N 2º1’58’’O
Altitude (m)	208
Distance from sea (km)	6.3 km
Climate	dry subtropical semiarid
Mean annual T (°C)	18
Mean annual precipitation (mm)	220
Predominant spp	*Machrocloa tenacissima (60% v. cover)*
Soil type	Leptosol Lithic Mollic (Calcaric)

Study case


2009
a
2010
b
2011
c
2012
d
2013
e
P (mm)
VWC$_{soil}$ (m^3 m^{-3})
DOY
DOY
0 50 100 150 200 250 300 350
0 20 40 60 80
0.0 0.1 0.2 0.3 0.4 0.5

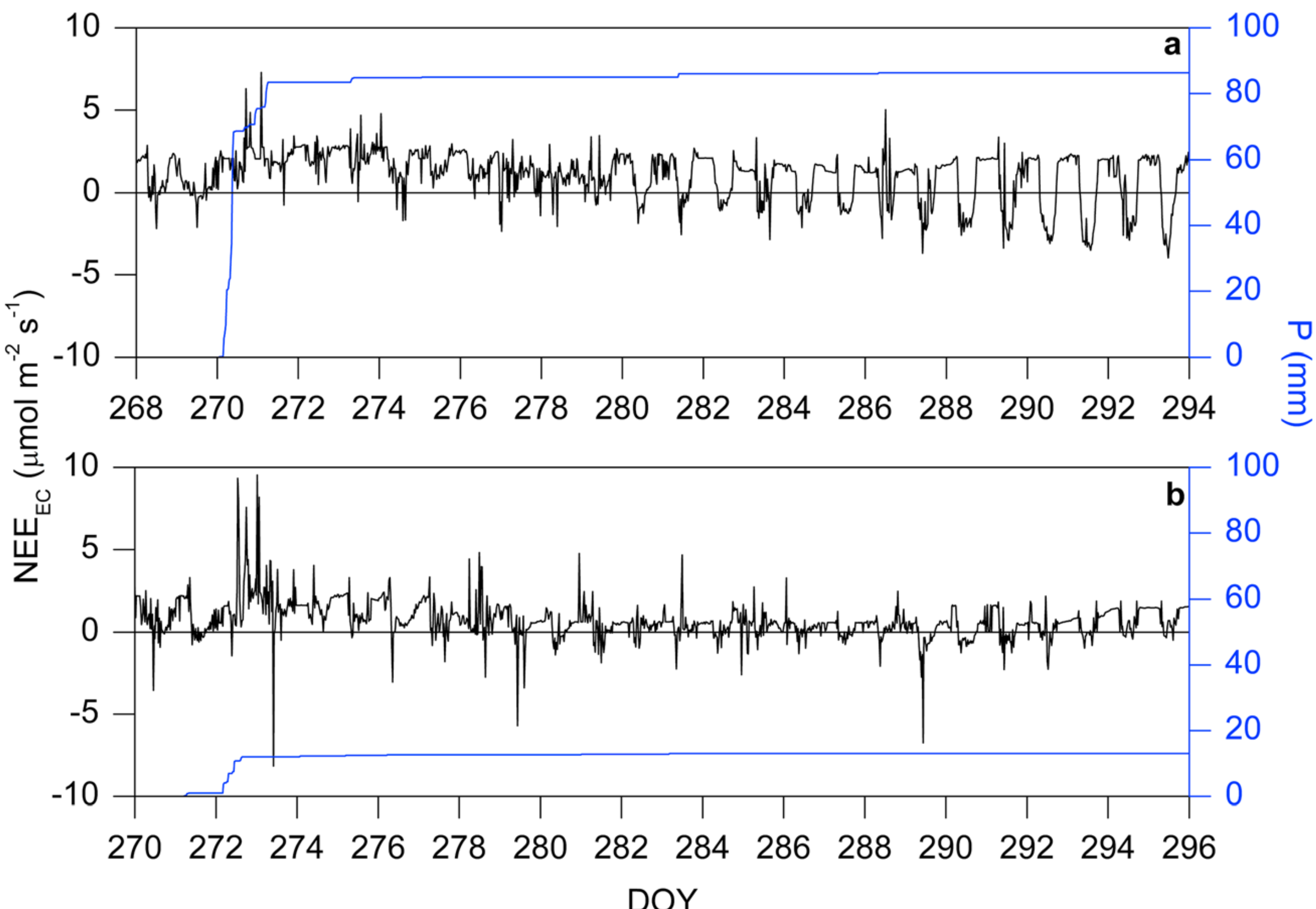
Study case

Rain pulses provoked 9 - 58% total dry season C emission



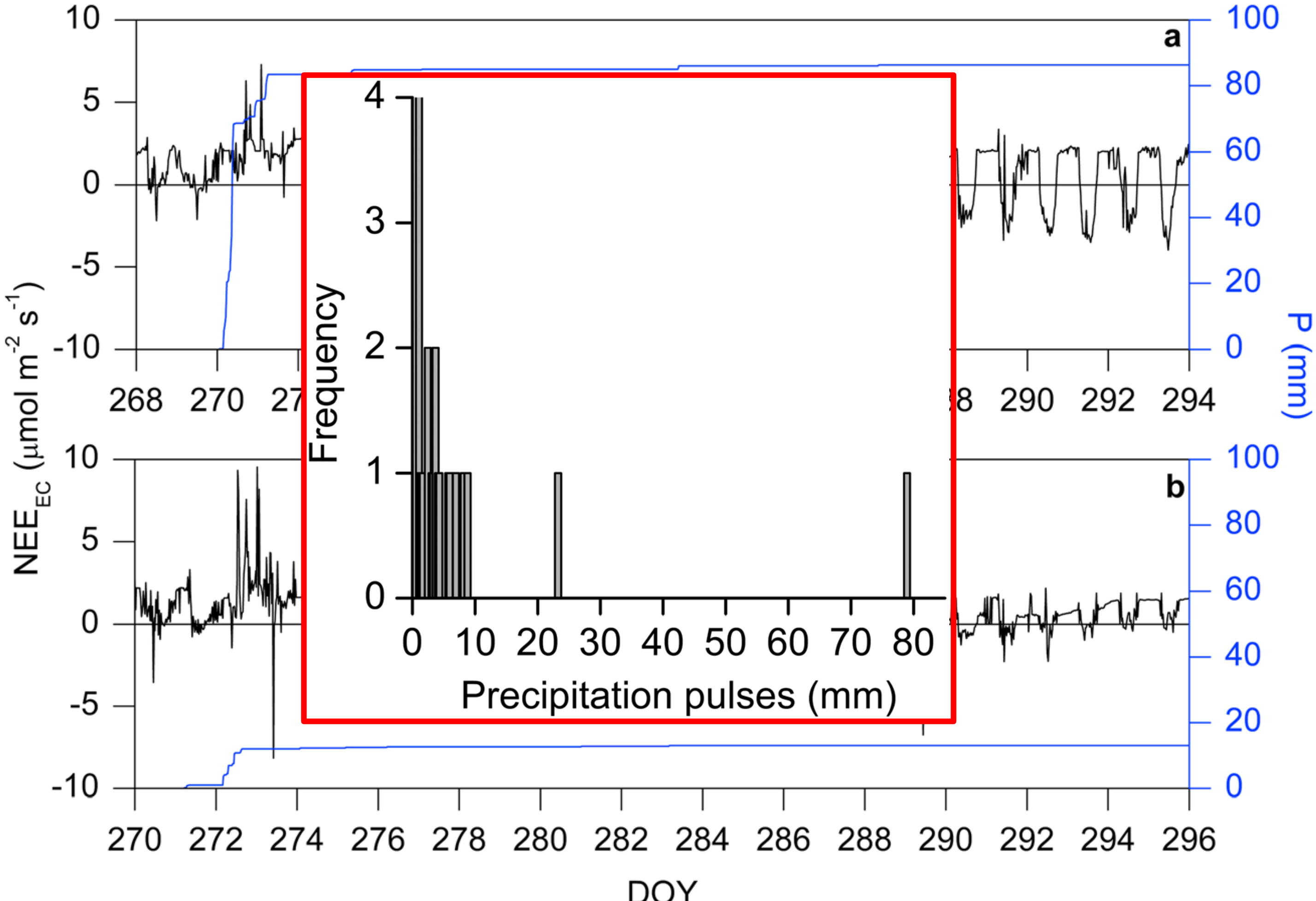
Study case

Rain pulses provoked 9 - 58% total dry season C emission



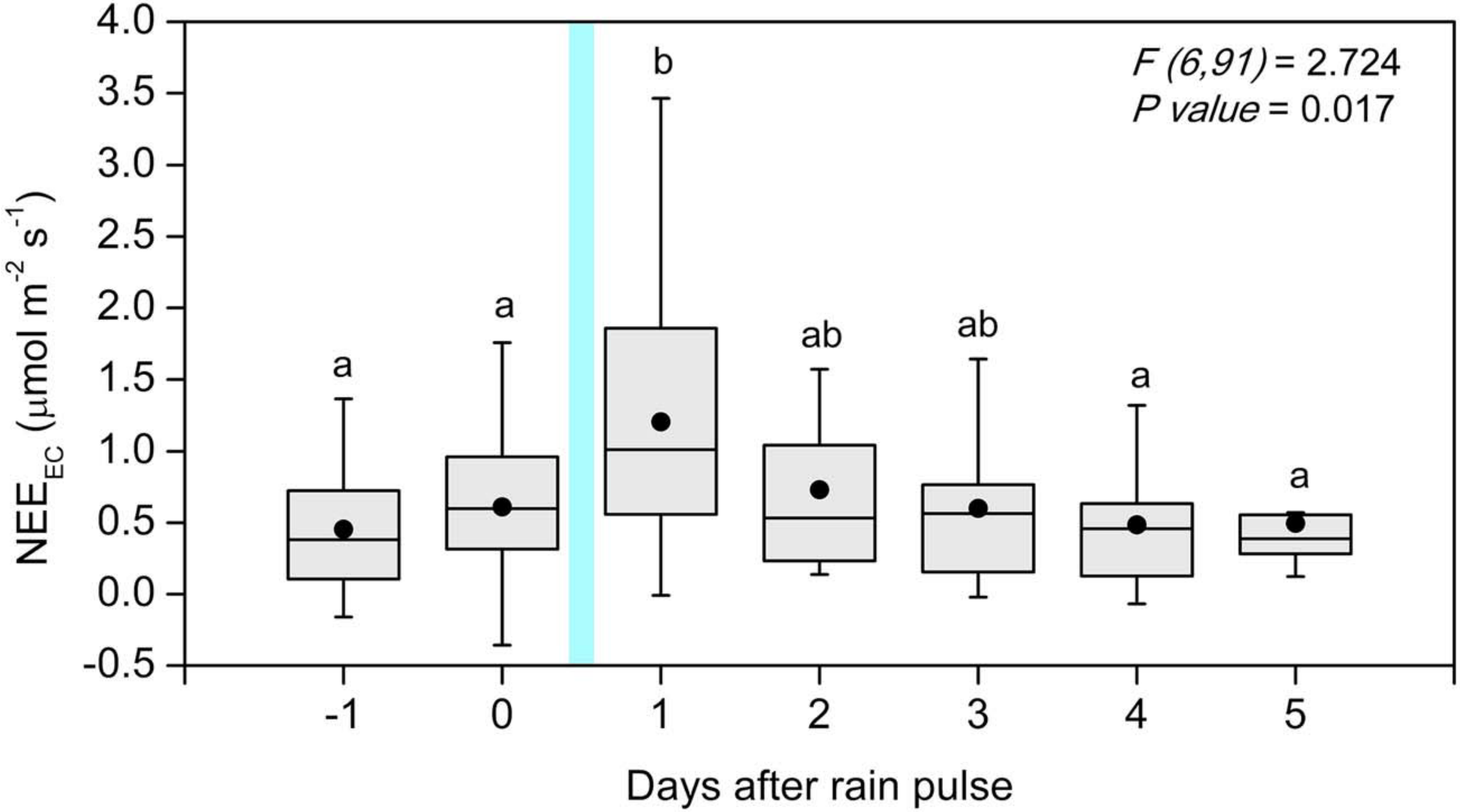
Study case

Rain pulses provoked 9 - 58% total dry season C emission

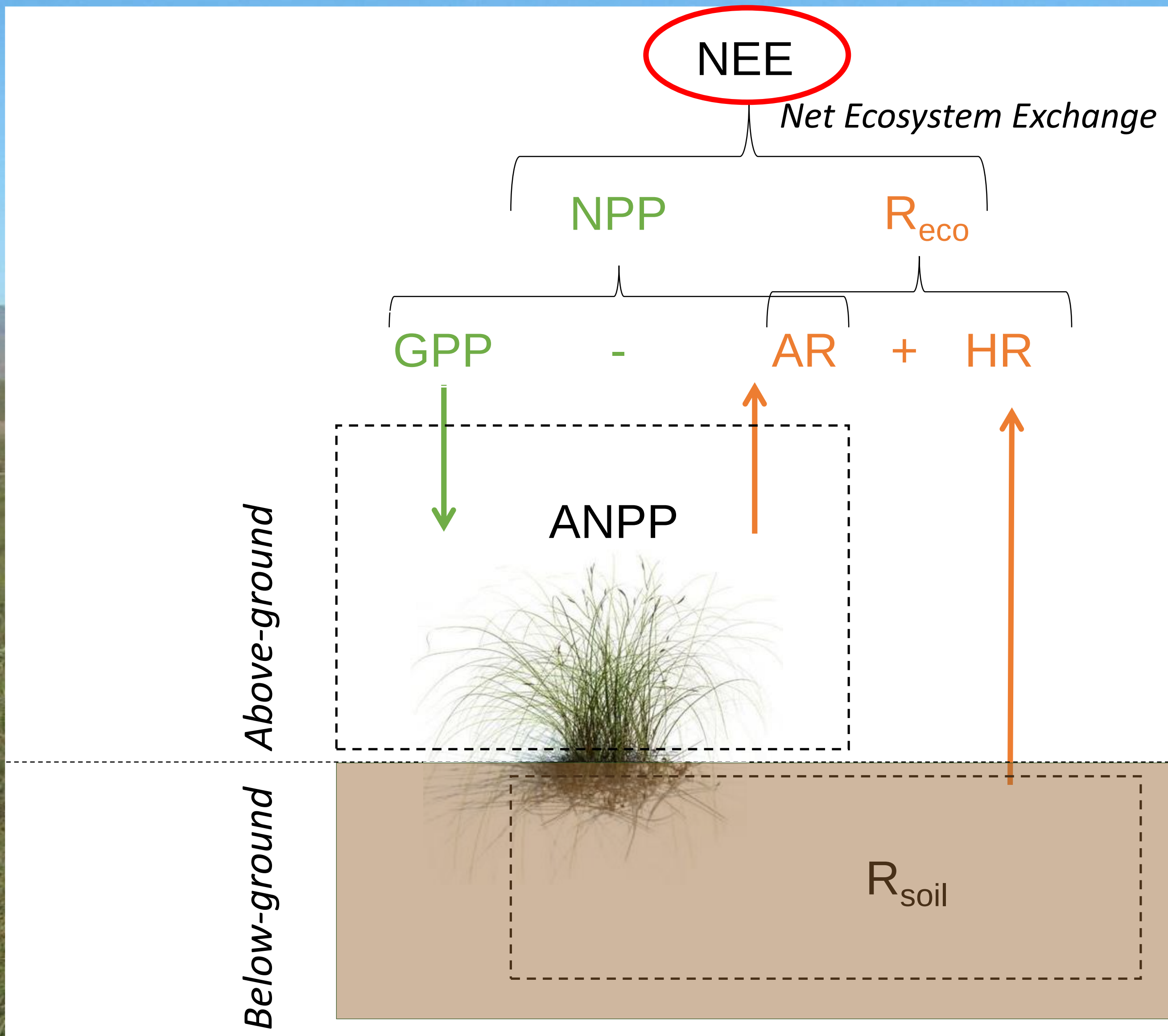


Study case

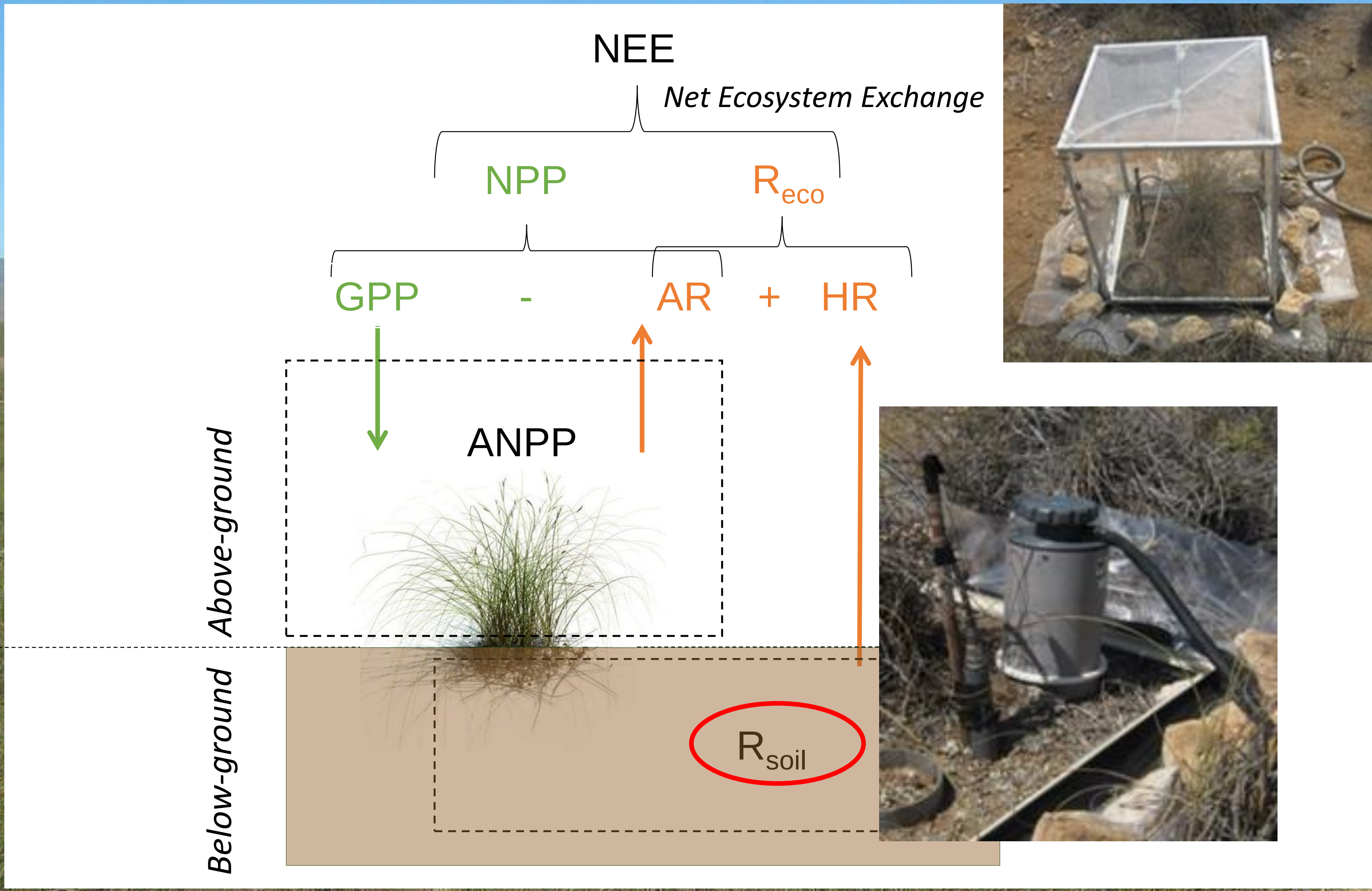
Rain pulses provoked 9 - 58% total dry season C emission



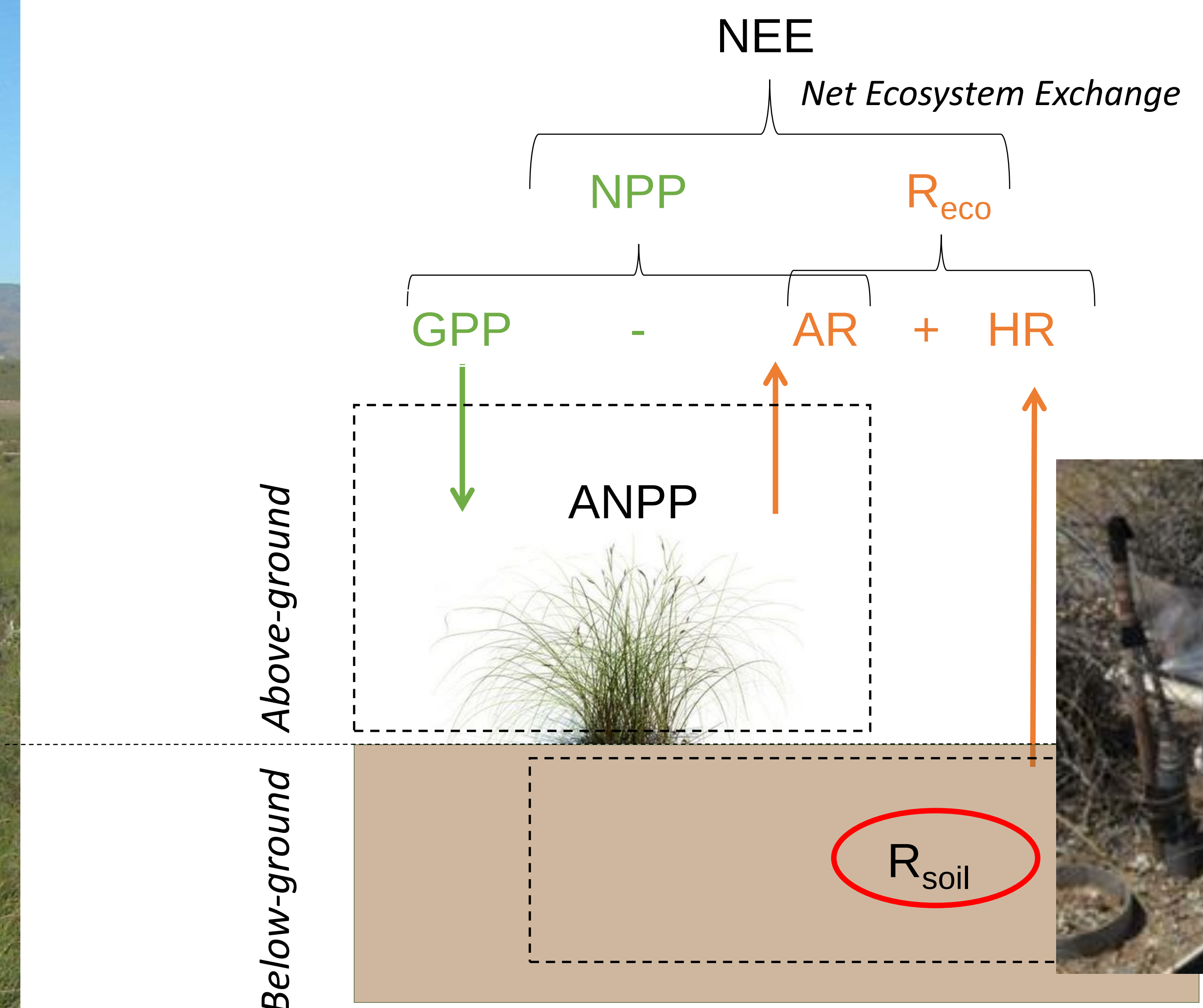
Study case


NEE
Net Ecosystem Exchange
NPP
R_{eco}
GPP - AR + HR
ANPP
Above-ground
Below-ground
R_{soil}

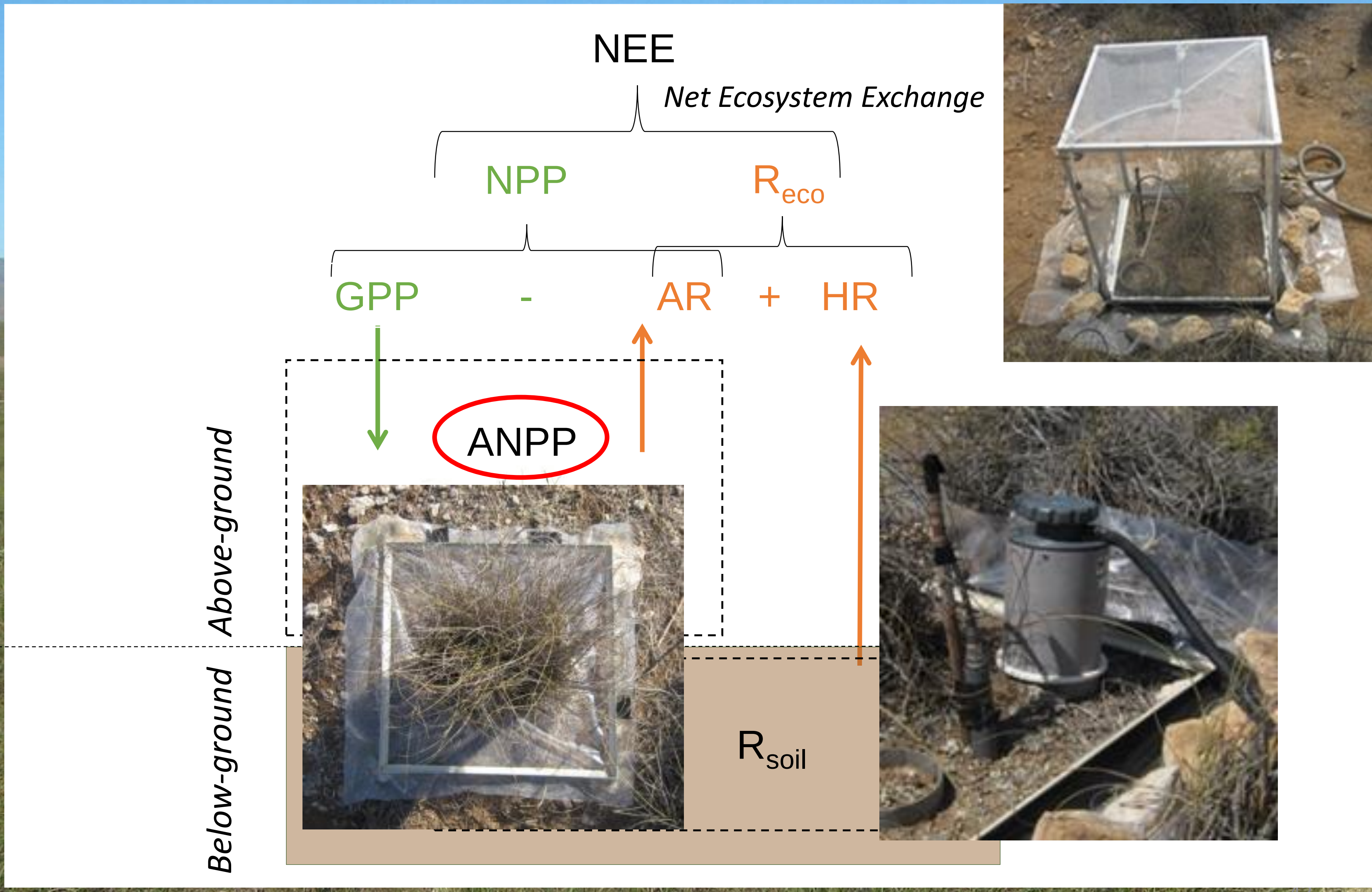
Study case


NEE
Net Ecosystem Exchange
NPP
R_{eco}
GPP - AR + HR
ANPP
Above-ground
Below-ground
R_{soil}

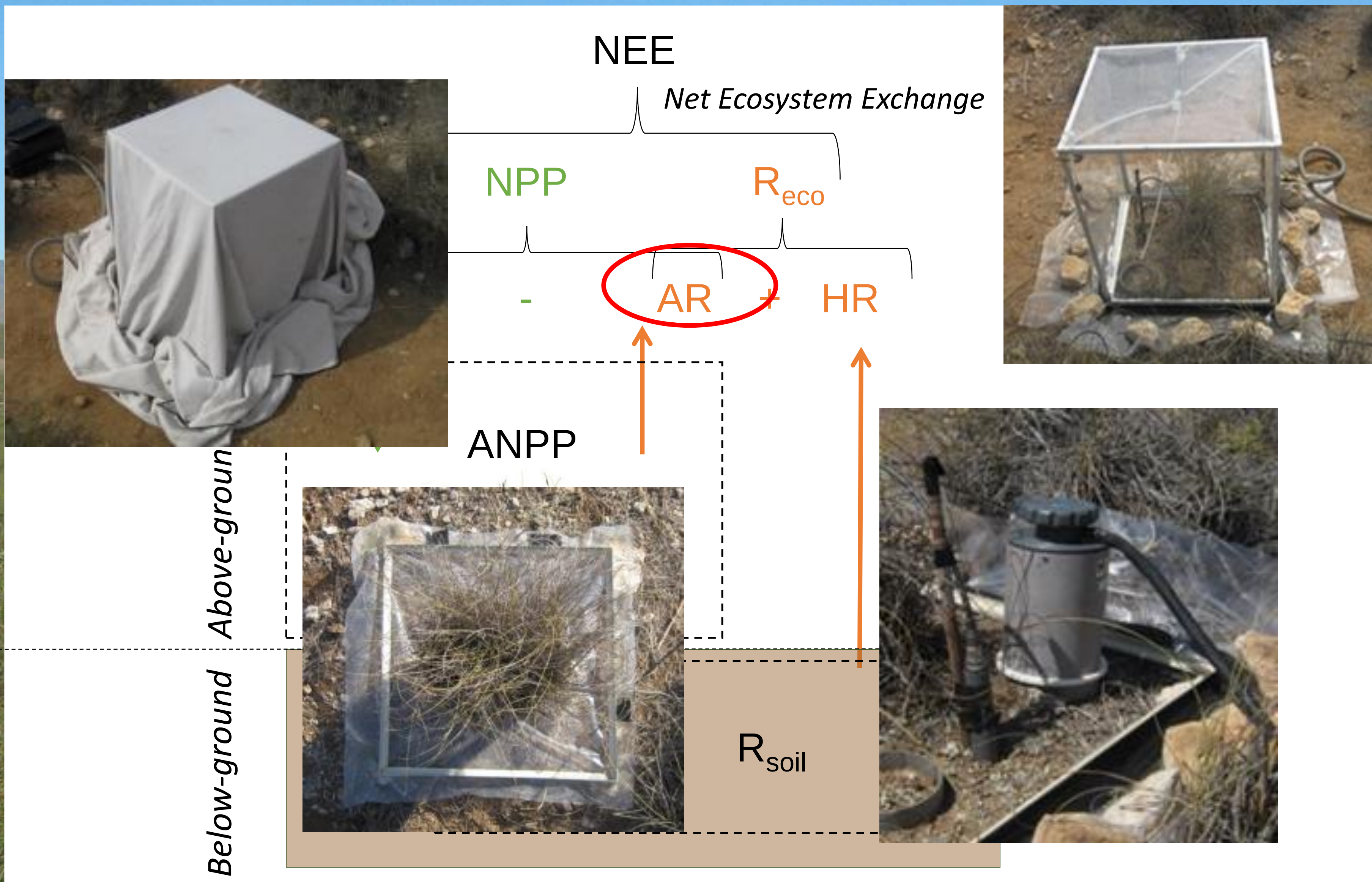
Study case


NEE
Net Ecosystem Exchange
NPP
R_{eco}
GPP - AR + HR
ANPP
Above-ground
Below-ground
R_{soil}

Study case

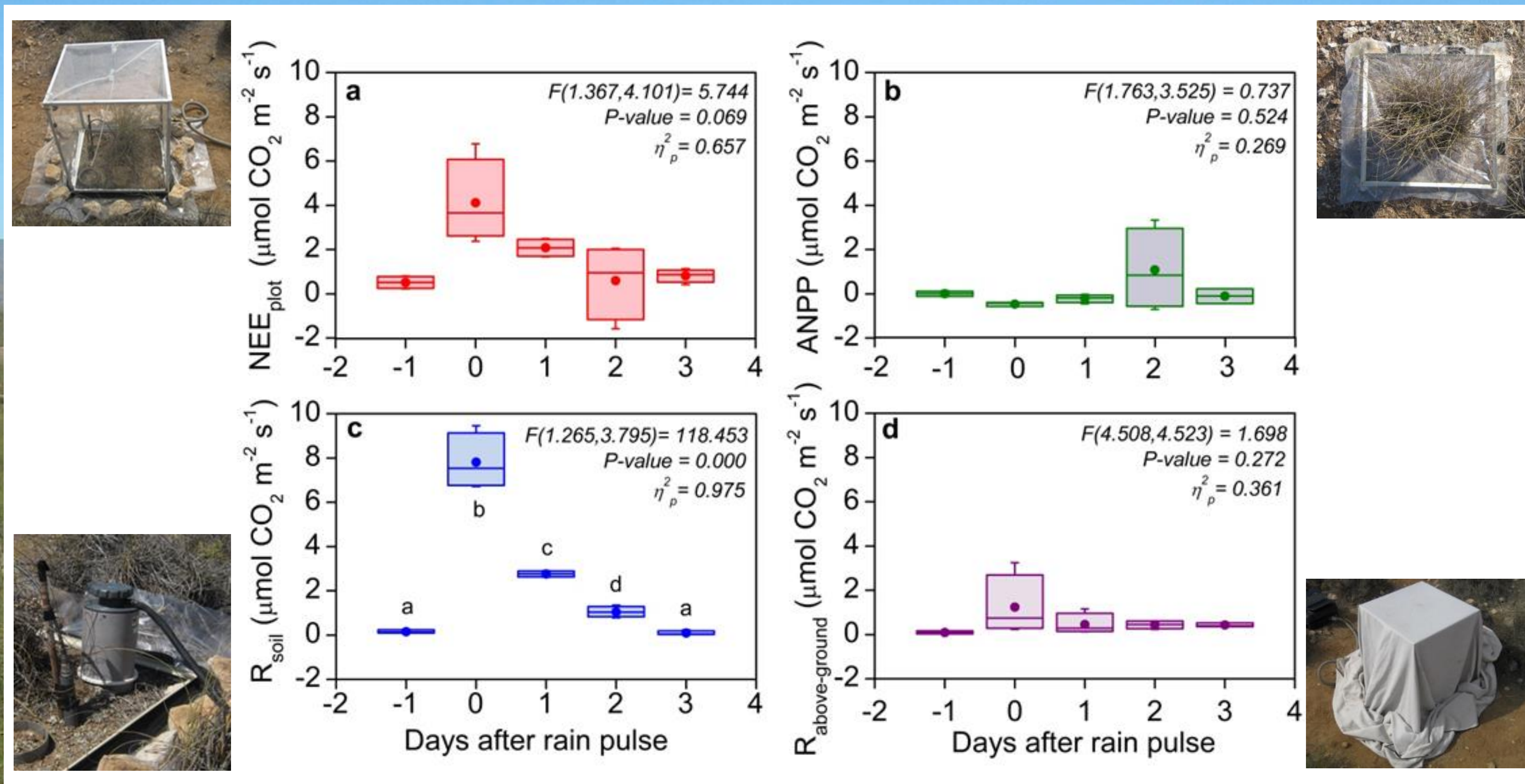

NEE
Net Ecosystem Exchange
NPP
R_{eco}
GPP - AR + HR
ANPP
Above-ground
Below-ground
R_{soil}

Study case



NEE
Net Ecosystem Exchange
NPP
Reco
-
AR
+
HR
ANPP
Above-groun
Below-ground
Rsoil

Study case


a
F(1.367,4.101)= 5.744
P-value = 0.069
η²p= 0.657
NEEplot (µmol CO2 m-2 s-1)
b
F(1.763,3.525) = 0.737
P-value = 0.524
η²p= 0.269
ANPP (µmol CO2 m-2 s-1)
c
F(1.265,3.795)= 118.453
P-value = 0.000
η²p= 0.975
a
b
c
d
a
Rsoil (µmol CO2 m-2 s-1)
Days after rain pulse
d
F(4.508,4.523) = 1.698
P-value = 0.272
η²p= 0.361
Rabove-ground (µmol CO2 m-2 s-1)
Days after rain pulse

Take-home messages

- Chamber technique is ideal to:
  - Measure GHG fluxes in many treatments
  - To understand underlying processes of net fluxes measured by EC systems
- There are two main types: static/closed vs dynamic chambers
- Influence on ambient conditions within the chamber must be quantified and minimized, if possible
- Take into account the temporal and spatial variability of the process you want to investigate before designing your experiment!

THANKS!

Q&A

Dr Ana Lopez Ballesteros
alopezba@tcd.ie