Herausforderungen bei der Messung von N_2O, CH_4 und CO_2 Bodengasflüssen

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IMK-IFU: Atmosphärische Umweltforschung
KIT
Karlsruhe Institute of Technology

- Messmethoden
- Probenahme
- Qualitätskontrolle

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Messmethoden

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- Chambers
  - the simplest and most common approach
- Eddy covariance
  - applicable to large landscapes with uniform surface sources
- Flux-gradient methods
  - as for eddy covariance, applicable to large landscapes with uniform surface sources
- Mass balance techniques
  - suitable for small bounded areas and heterogeneous surface sources
- Eddy accumulation
  - a fast response system for large uniform landscapes
- Open path lasers / FTIR
  - suitable for point, line and small area sources
- Backward Lagrangian stochastic dispersion
  - suitable for small to medium size landscapes and point and areal sources

Chamber techniques

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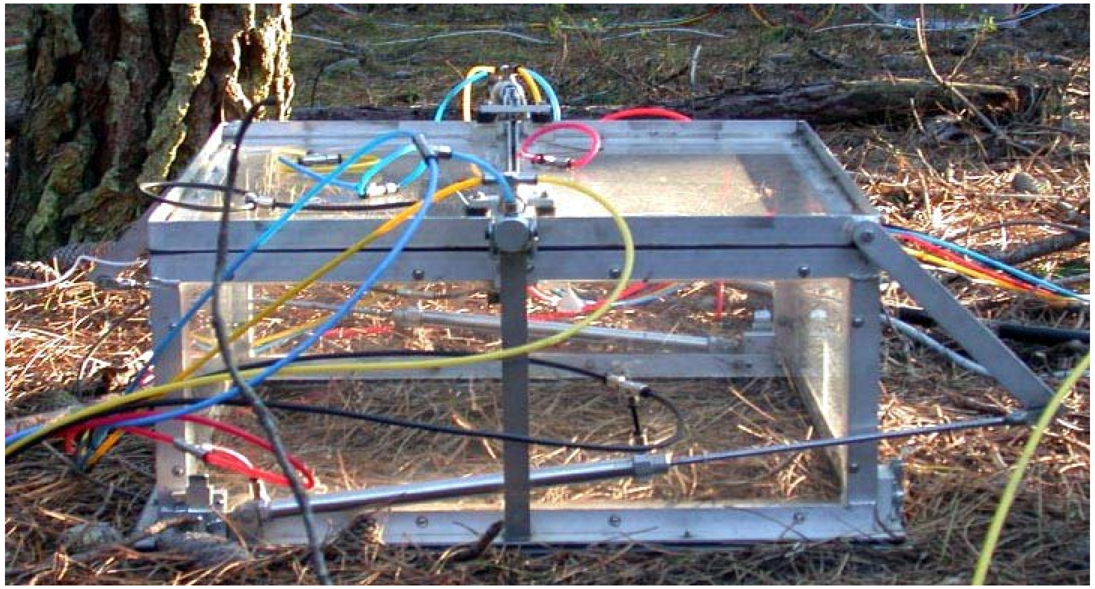
The most common approach for measuring trace gas emissions from soils

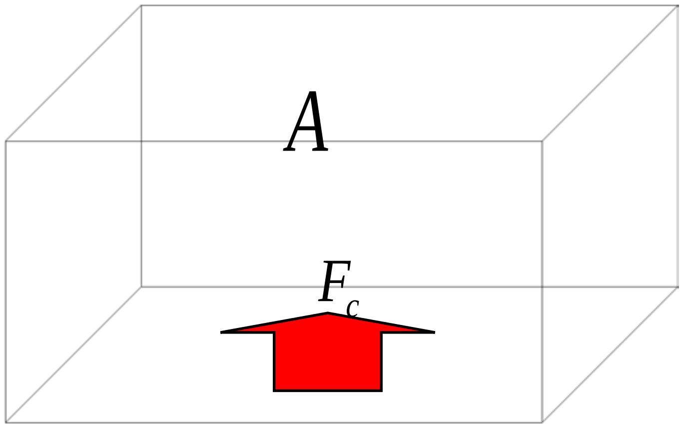
- Two types:
  - Closed chambers
  - Dynamic chambers

- Two operation modes
  - Manual
  - Automatic

Static chamber

- Gas-tight enclosure of a soil-plant system or e.g. plant part
- Follow the increase/ decrease in concentration of a gaseous compound with time (e.g. N_2O, CO_2, CH_4)
- Kinetics of increase/ decrease is used to calculate the flux





$$F_c = \frac{V}{A}\frac{\partial C_c}{\partial t}$$

Static chamber

Advantages:

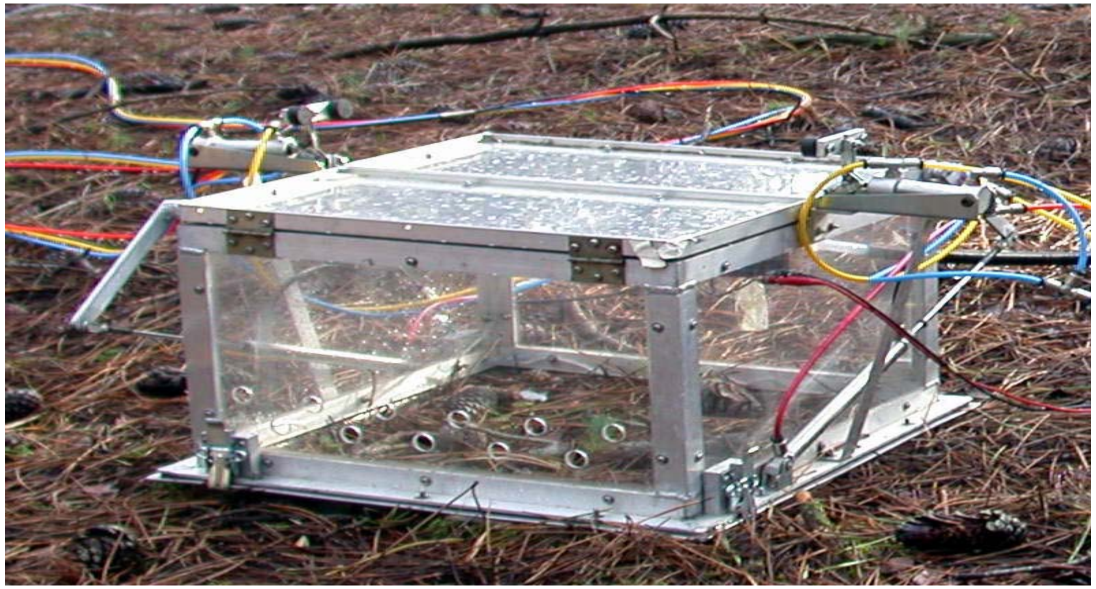
- Low-tech, cheap
- Easy to apply, no power supply, no gas analyzer online
- High sensitivity
- Typically applied for non-reactive substances such as N_2O, CH_4 or CO_2

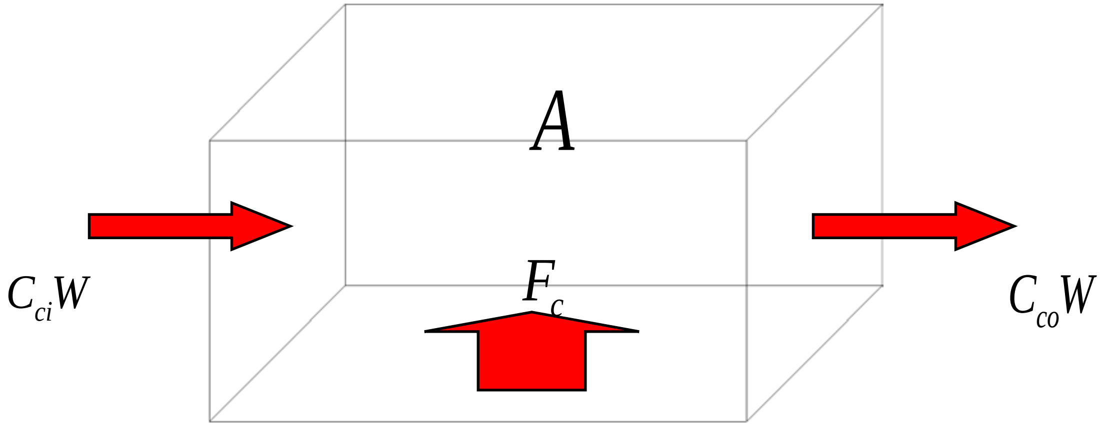
Disadvantages:

- Alteration of environmental conditions (e.g. temperature, moisture, soil gas concentration profile)
- Biosphere-Atmosphere exchange is a balance of consumption-production processes, this equilibrium may be changed (e.g. for CH_4, NO)

Dynamic chamber

- Gas-flow through a chamber enclosuring a soil-plant system or e.g. plant part
- Measurement of the compound concentration at the inlet and at the outlet (e.g. CO_2, NO or NO_2)
- Fluxes are calculated from concentration differences and air mass flow





$$F_c = \frac{W}{A}\left(C_{co} - C_{ci}\right)$$

Dynamic chamber

Advantages:

- Reduced disturbance of environmental conditions, especially of gas concentrations
- Easy to apply
- Medium to high sensitivity depending on the detector

Disadvantages:

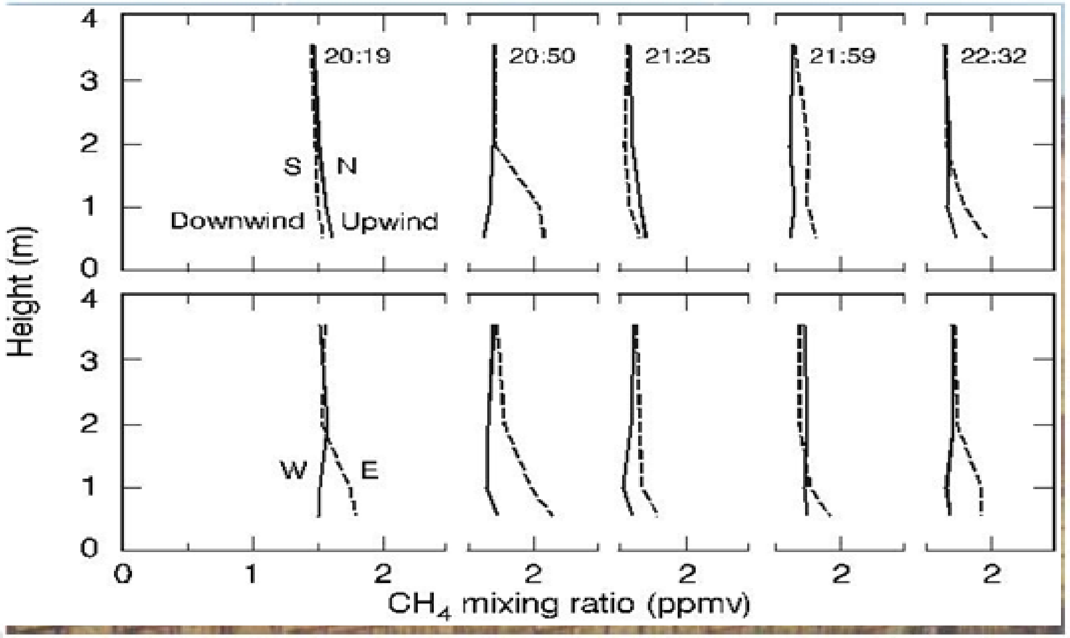
- High exchange rates are applied (pumps and thus power is needed)
- Still environmental conditions are biased

A closed path EC system

(Courtesy Campbell Scientific Australia)

T. Denmead, *CSIRO Land and Water*

Mass balance for closed systems

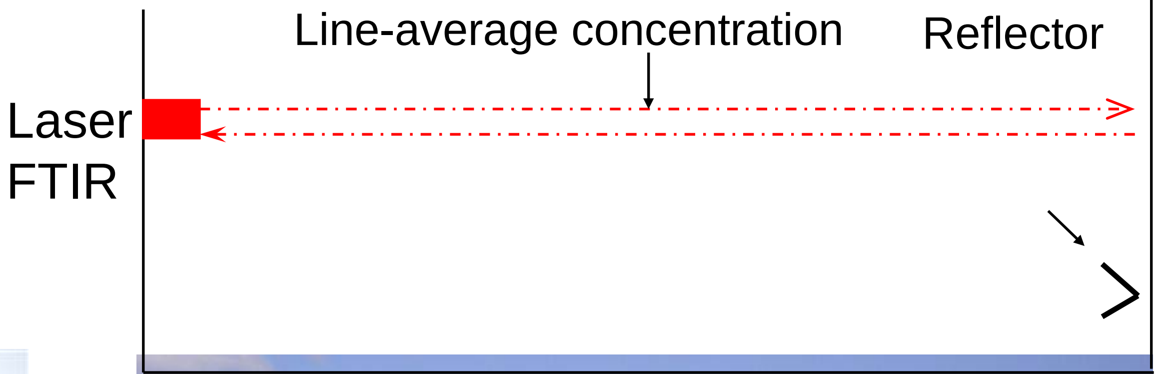


- Measuring CH_4 production with a closed mass balance method
- Animals enclosed in a plot 24m x 24m
- 4 sampling tubes on each boundary, at heights of 0.5, 1, 2 and 3.5m
- Top sampling arm high enough to be above the plume from the test area
- Air drawn continuously into the 16 sampling tubes
- The 16 airstreams pass in turn through a CH_4 gas analyser
- Anemometers measure *u(z)*

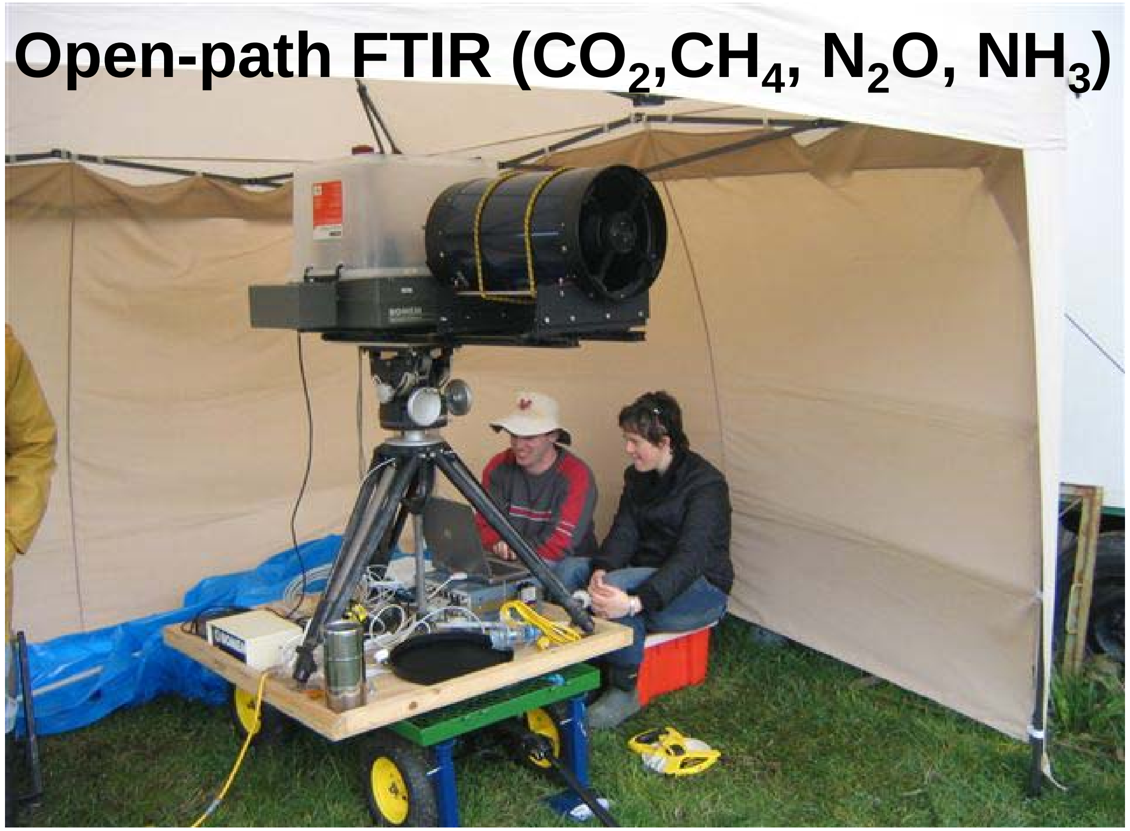
T. Denmead, *CSIRO Land and Water*

Open-path lasers and FTIR

Instruments measure line-averaged concentrations up to 1km, FTIR less



Open-path FTIR (CO_2,CH_4, N_2O, NH_3)

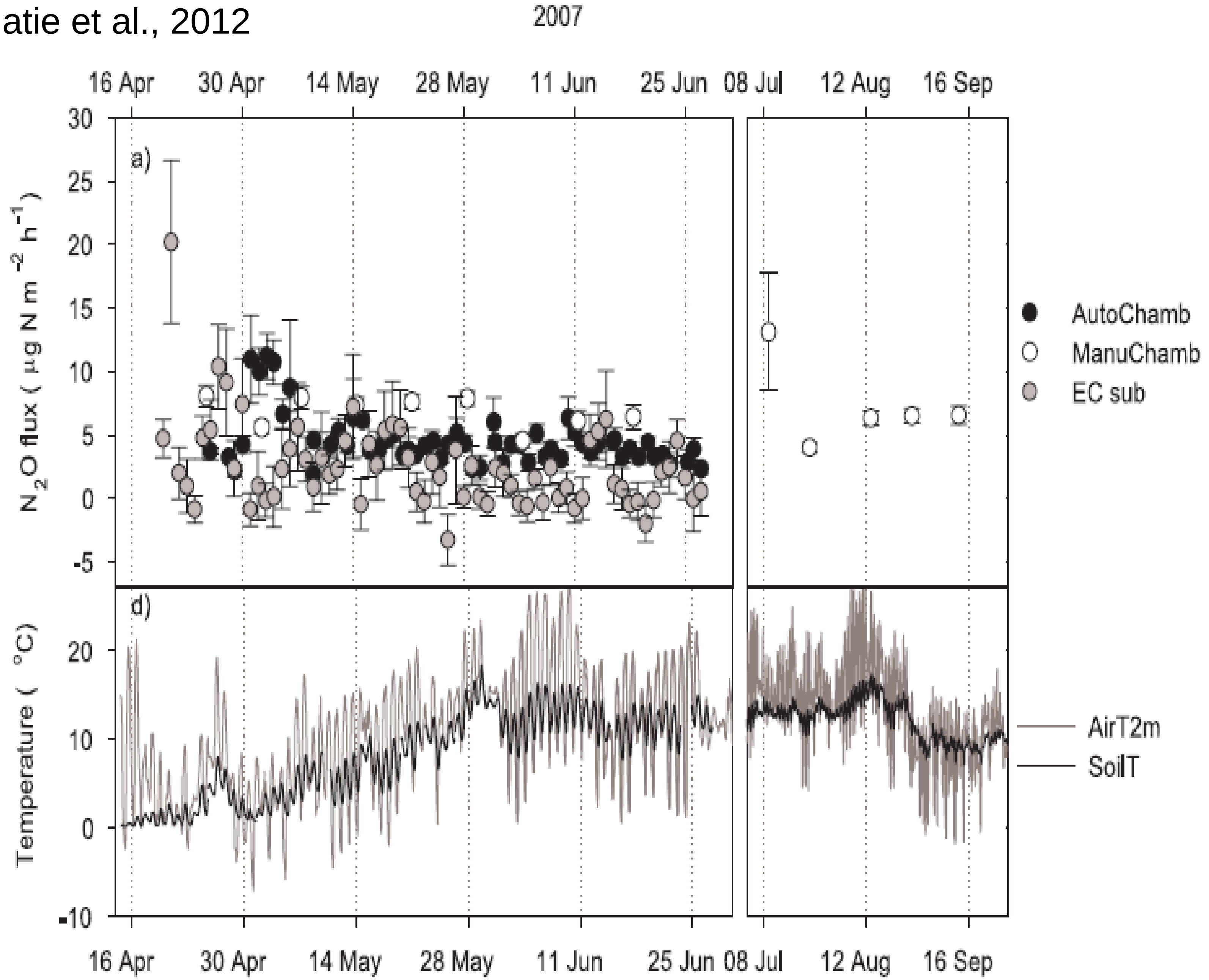


Open-path laser (CO_2, CH_4, NH_3)

T. Denmead, *CSIRO Land and Water*

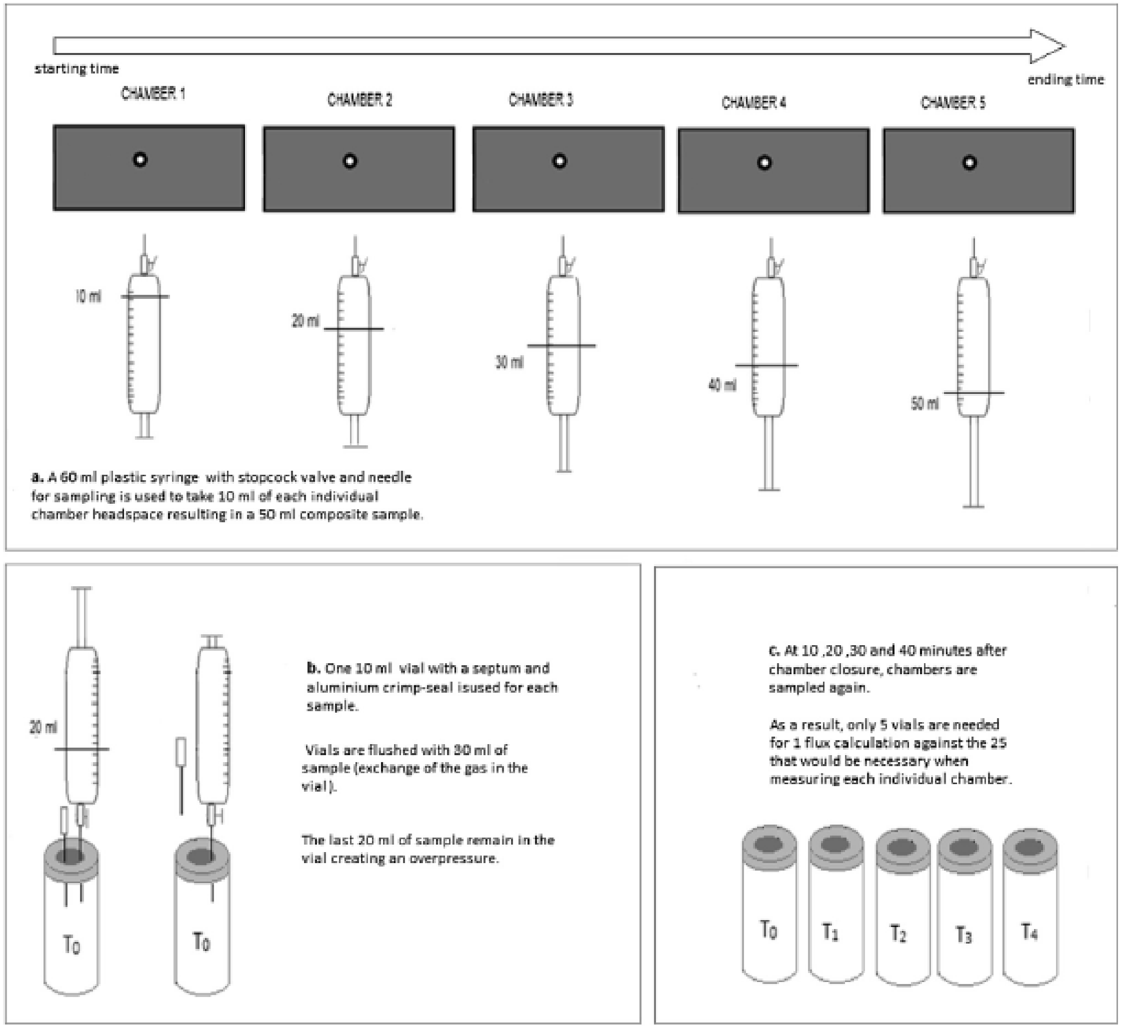
Chambers vs. micromet

Pihlatie et al., 2012



Gas Sample Pooling

to overcome spatial heterogeneity of soil GHG emissions



Arias-Navaro et al., 2013

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Forschungszentrum Karlsruhe
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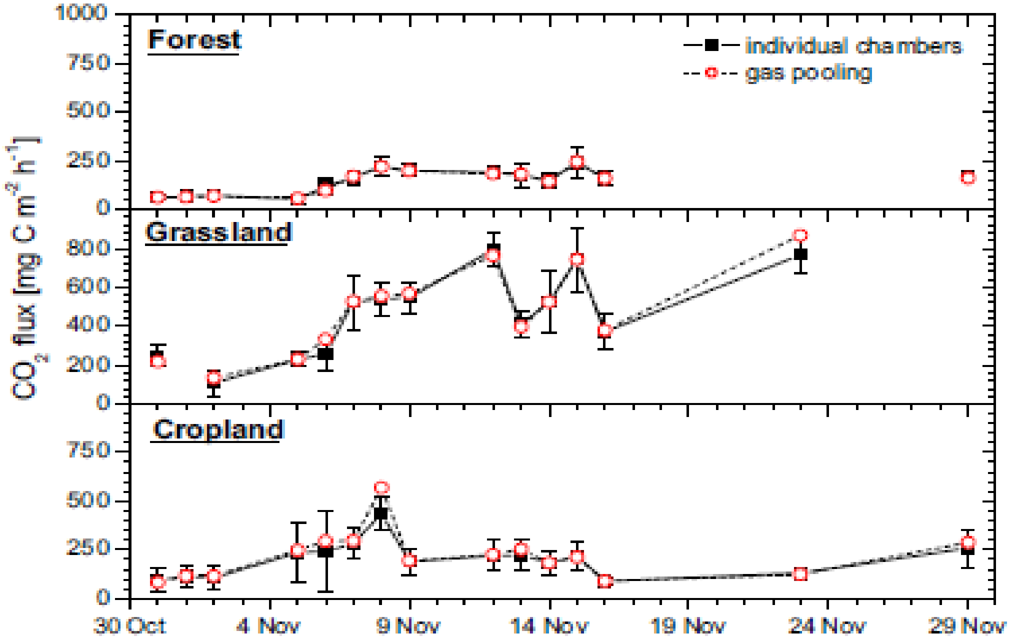
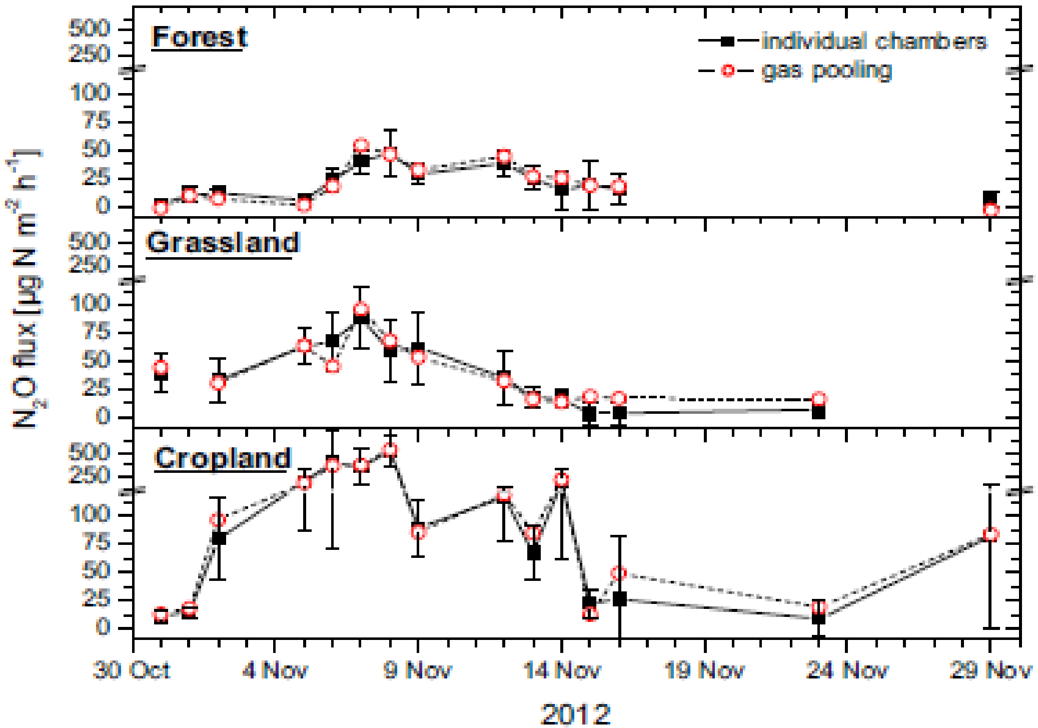
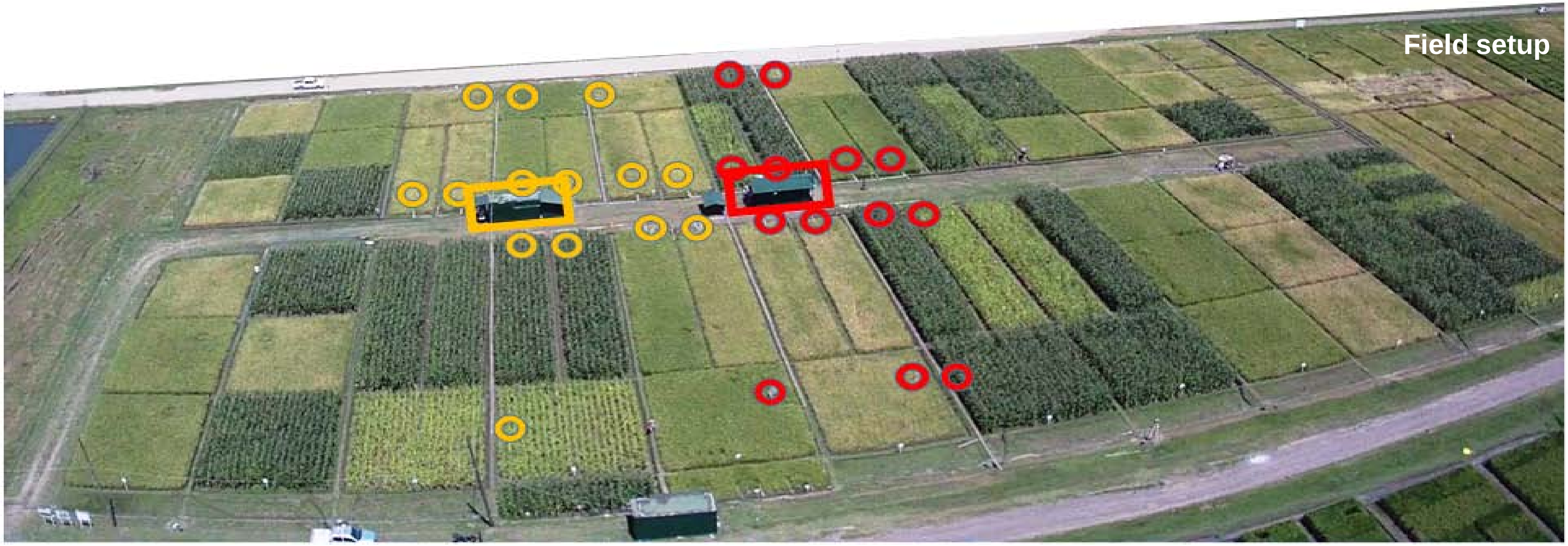
Gas Sample Pooling





Arias-Navaro et al., 2013

ICON GHG emissions from diversifying rice cropping systems



Chamber positions Row and Interrow

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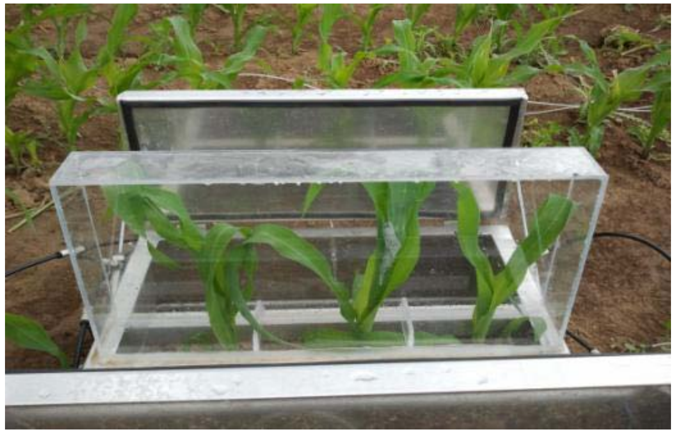

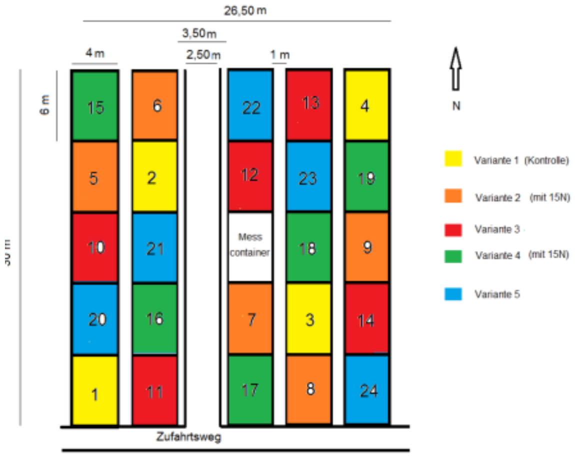

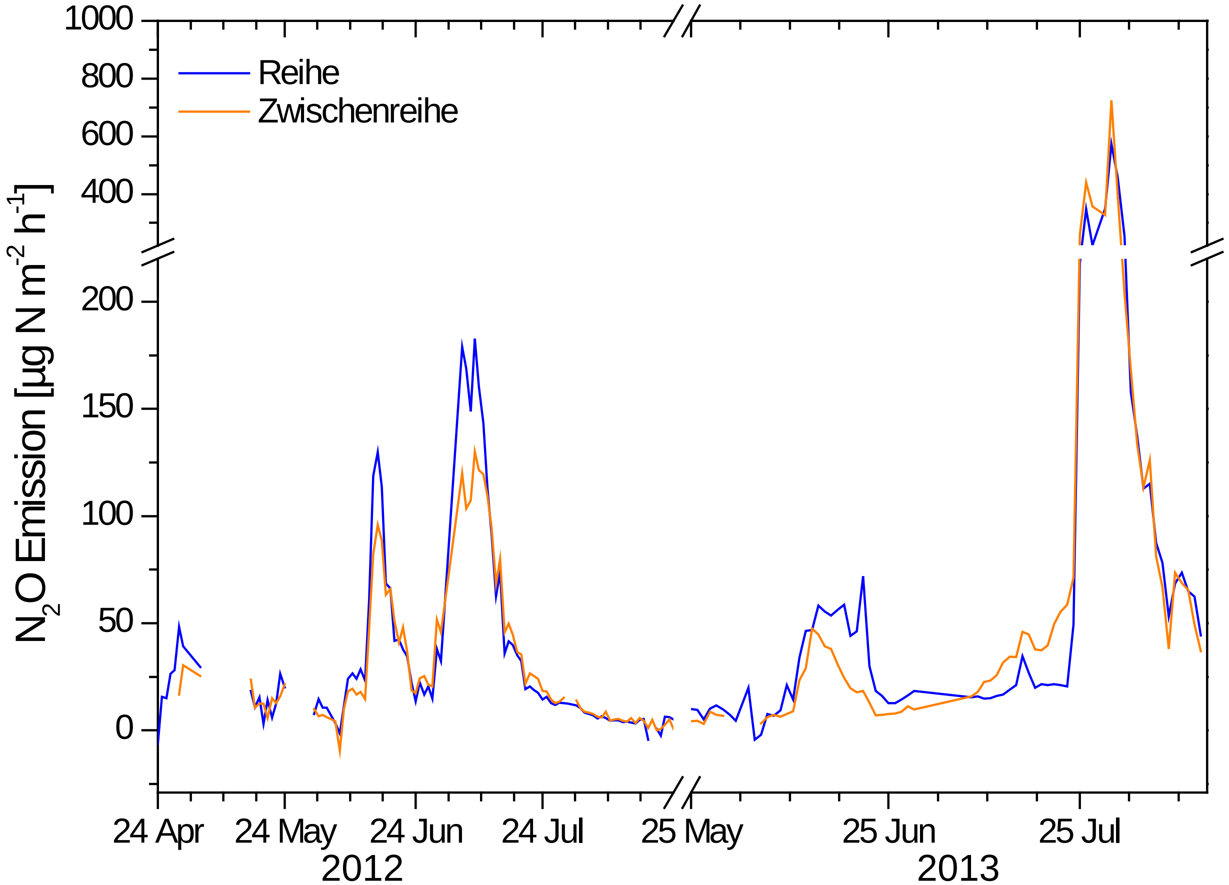

GHG exchange of grassland ecosystems along a climate sequence in the TERENO pre-Alps Observatory

Graswang (860m)	Rottenbuch (750m)	Fendt (600m)



Automated GHG measuring system

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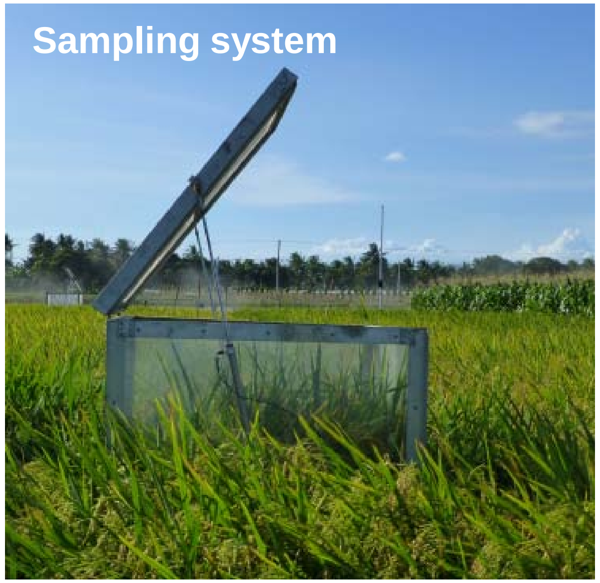
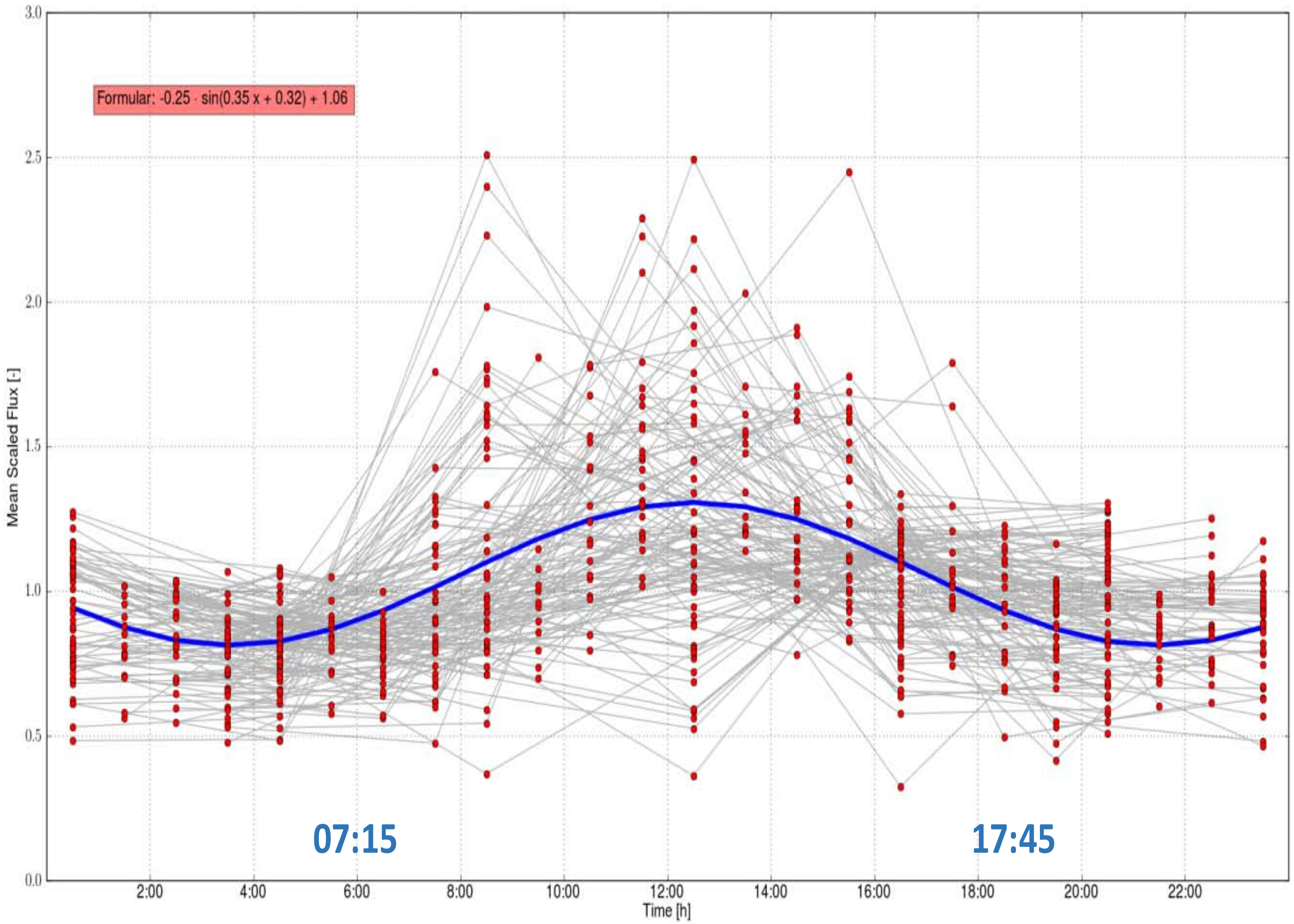
dirunal flux patterns

Diurnal patterns of CH_4 emissions





Sampling time / frequency matters

Annual flux deviation sampling time

Chamber	Annual emission (continuous measurements) (±s.e., kg N ha^{-1} yr^{-1})	Sampling time (LST)	Percent deviation (%)
1	3.2±0.2	08:00	7.5
		12:00	22.2
		16:00	11.9
2	2.0±0.1	09:00	5.3
		13:00	18.7
		17:00	13.2
3	2.4±0.2	06:00	−8.1
		10:00	8.6
		14:00	27.8
4	2.7±0.2	07:00	−12.2
		11:00	22.2
		15:00	34.3

LST: Local standard time

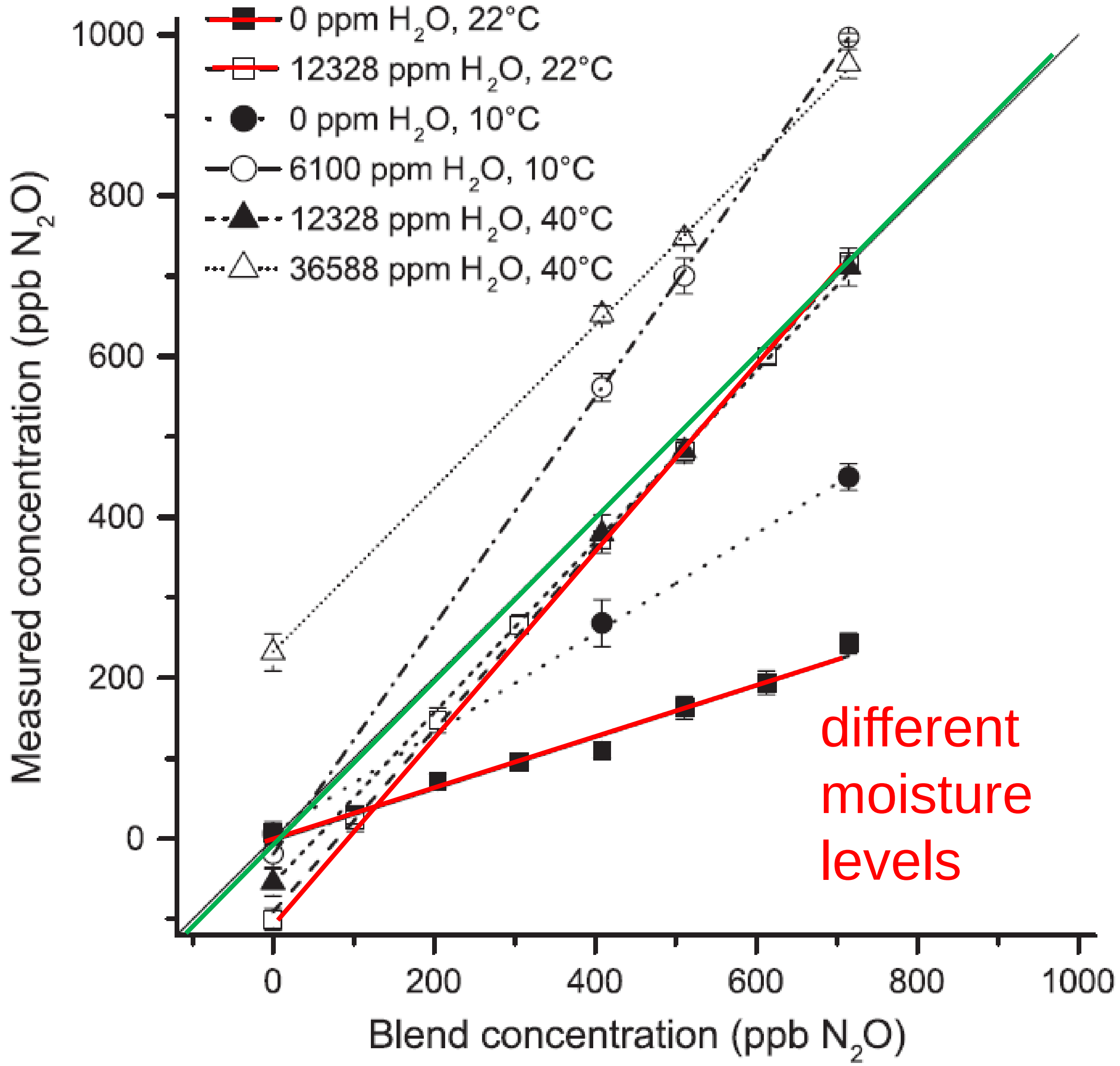
Annual flux deviation sampling frequency

Sampling interval (days)	Deviation range (%)
1	3.3–7.3
2	3.8–6.6
3	−1.8–16.9
4	−3.3–16.4
5	1.2–11.7
6	−4.9–20.0
7	−10.7–21.3
8	−5.3–12.9
9	−9.3–17.8
10	−9.5–25.3
20	−15.5–44.2
30	−31.1–70.5

Liu et al., 2010

Analytical Instruments

- Gas Chromatography
- Infrared-Spectroscopy
- Photoacoustic Spectroscopy



Rosenstock et al., 2013

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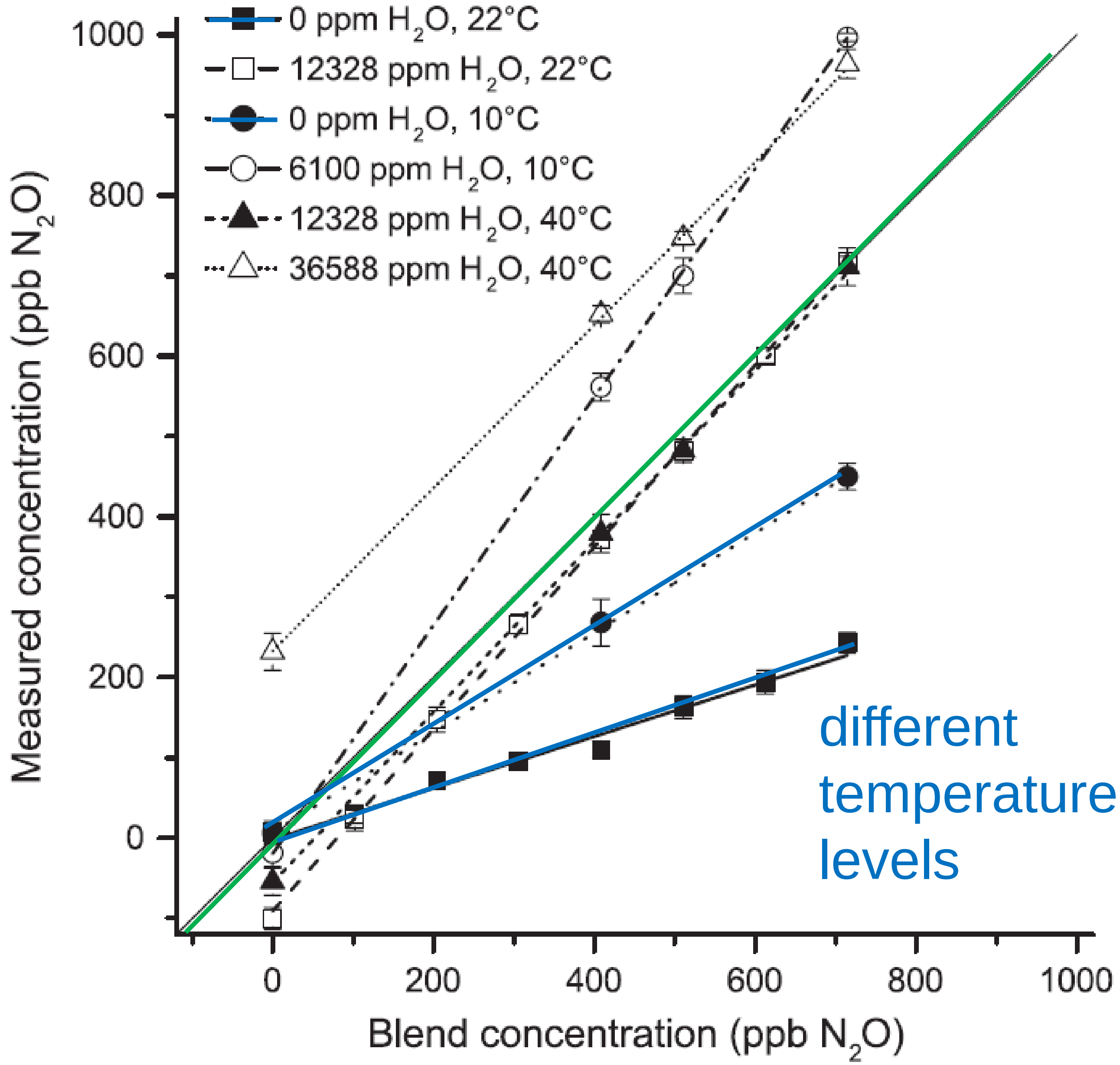

Rosenstock et al., 2013

Major issues with chamber methodologies

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Effects on soil environmental conditions

Soil temperature

► can be minimized (<2 ◦C) using insulated chambers with reflective covers and short deployments

Soil moisture

► low profile collars nearly flushing with the soil surface can minimize micro-climate issues

► collars should be relocated if soil moisture differs from that in adjacent soil

Root activity

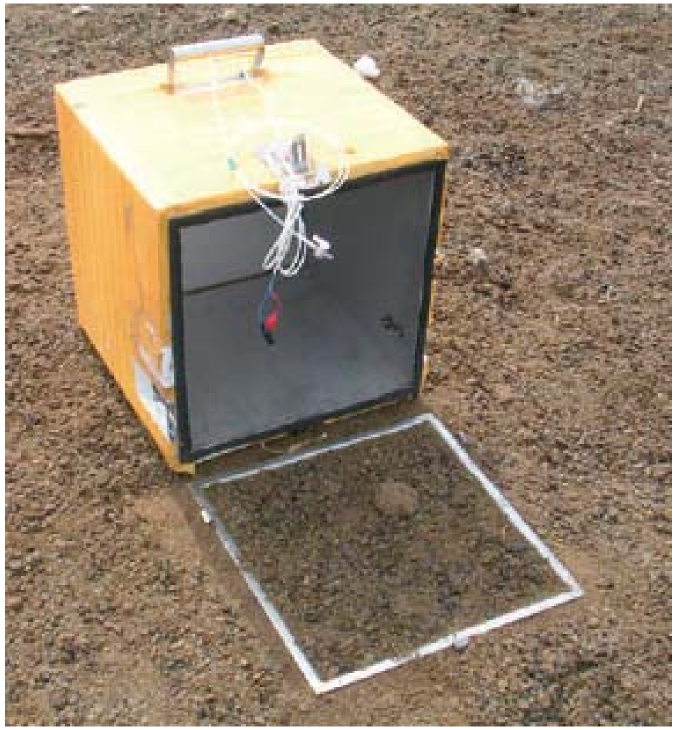
► delay between collar insertion and start of measurements

► hours to weeks/ months depending on insertion depth

Soil disturbance

► use of collars instead of push-in chambers

► insertion depth ≥0.4 cm/min of deployment



Rochette, 2011; De Klein 2012; Butterbach-Bahl et al., 2011

Major issues with chamber methodologies

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Effects on soil-chamber gas transfer

Pressure fluctuations

► properly designed venting tube transmitting changes in barometric pressure to the chamber headspace while minimizing leakage and contamination

Turbulence regime

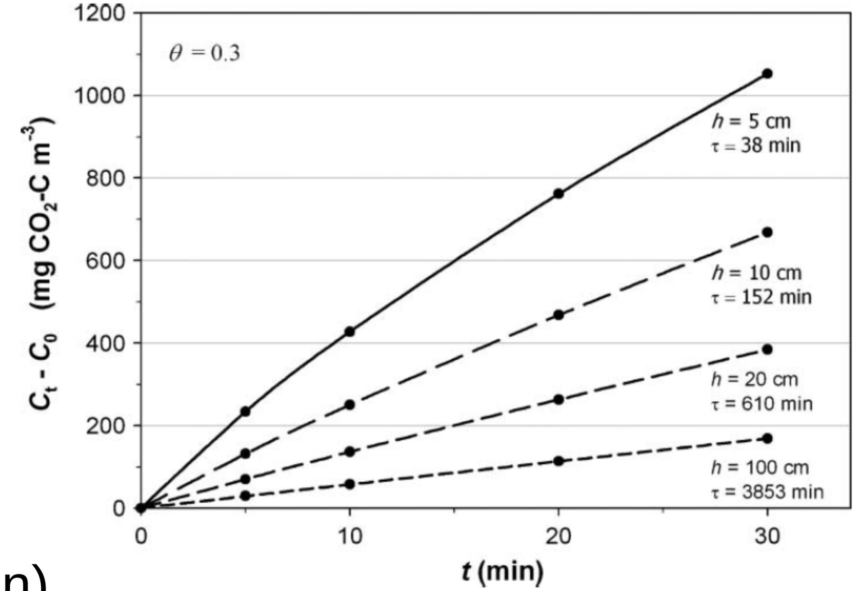
►use of fans seems to be of advantage at least in large chambers

Soil-chamber-atmosphere vertical gas concentration gradient

► use of non-linear models, often less biased than linear models, but may display higher sensitivity to measurement error

► several calculation methods are proposed (LR, HMR, Q) which differ in degree of complexity, all aim to estimate pre-deployment emissions by calculating ∂C/∂t at deployment time = 0

► bias can be minimized by adjustment of chamber height (>10 cm, better 20 - 40 cm) and deployment time (<30 min) in relation to expected fluxes



Rochette, 2011; De Klein 2012; Butterbach-Bahl et al., 2011

Major issues with chamber methodologies

Leakage and contamination

Gas tight chamber collar connection

Flux calculation

► temperature and pressure corrected (take measurements)

► based on ≥ 4 measurements (including t_0 sample)

Air sample handling and storage

► pressurizing samples into pre-evacuated vials (10-20 ml)
► minimize duration of sample storage (<5 days)

Measurements

► use sufficient samples with calibration standards

► test linearity of ECD hat high concentrations

► avoid bias with CO_2 e.g. by bypass, ascarite columns, CO_2 in carrier gas

Rochette, 2011; De Klein 2012; Butterbach-Bahl et al., 2011

Protocol/ Guidelines

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Nitrous Oxide Chamber Methodology Guidelines

December 2012
Edited by Cecile de Klein and Mike Harvey
Version 1

GLOBAL RESEARCH ALLIANCE
ON AGRICULTURAL GREENHOUSE GASES

Nitrous Oxide Chamber Methodology Guidelines

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Nitrous Oxide Chamber Methodology Guidelines
Cecile de Klein & Mike Harvey (Eds)

KIT – die Kooperation von
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Tereno Fendt site