The use of FTIR-spectrometry for flux measurements

Hella van Asperen, Thorsten Warneke, Simone Sabbatini, Giacomo Nicolini, Dario Papale, Justus Notholt

JRA1: WP13.2

The evaluation of having FTIR-measurements on ICOS ecosystem sites

InGOS Project Meeting
14-16 October 2014

University of Bremen

Outline

1) Introduction

2) Set up field experiment

3) Experiments: results

4) Practical considerations use FTIR

5) Possible future projects

The use of FTIR-spectrometry to measure GHG

Why use FTIR-spectrometry?

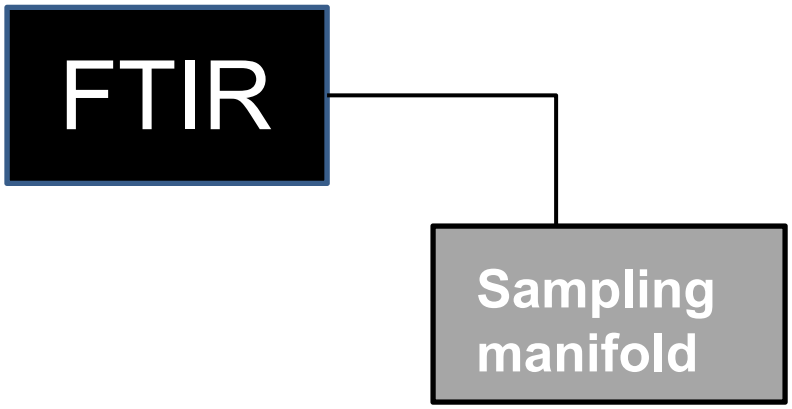
- Measure different (greenhouse) gases simultaneously

  CO_2, CH_4, N_2O, CO, $^{13}CO_2$

- High precision
- Relatively mobile, measurements automated by software
- **Possible to connect to different (flux) measurement techniques at the same time**

Species	Precision (1σ, 10 min)
CO_2	0.02 ppbv
$^{13}CO_2$	0.04 ‰
CH_4	0.02 ppbv
CO	0.02 ppbv
N_2O	0.06 ppbv

Set up field experiment

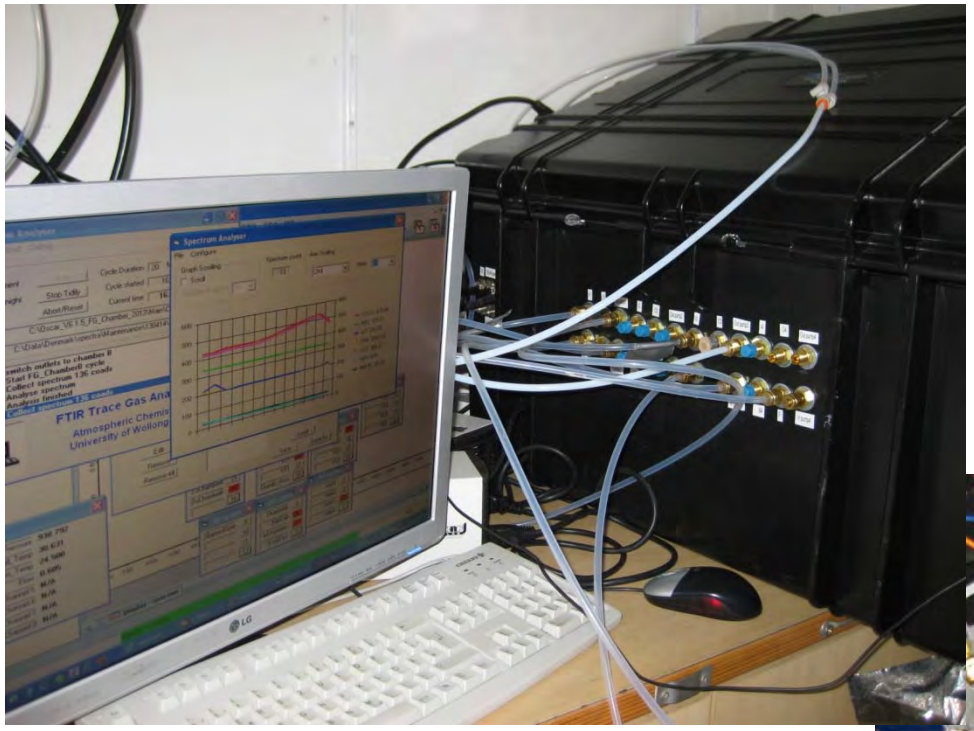


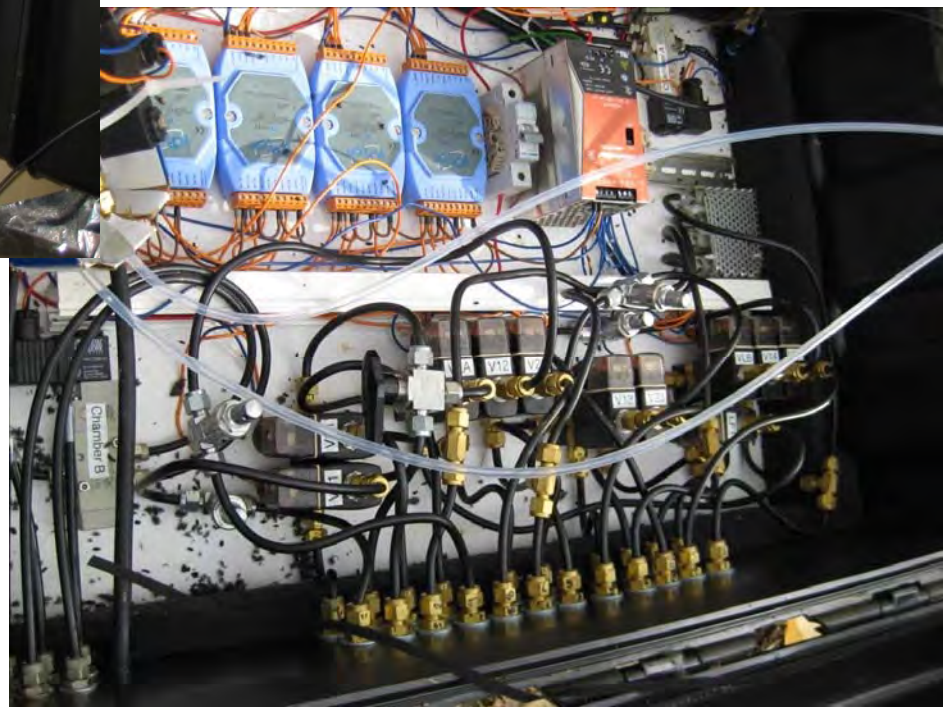
FTIR:

- How to connect to different flux measurement techniques??

Sampling manifold

Sample manifold box





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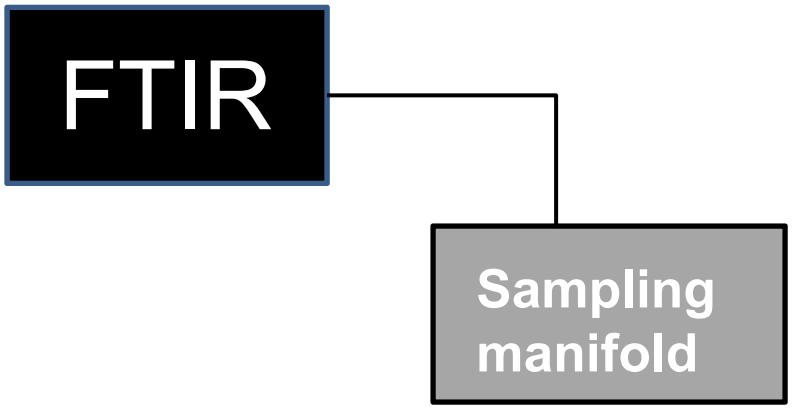

FTIR:

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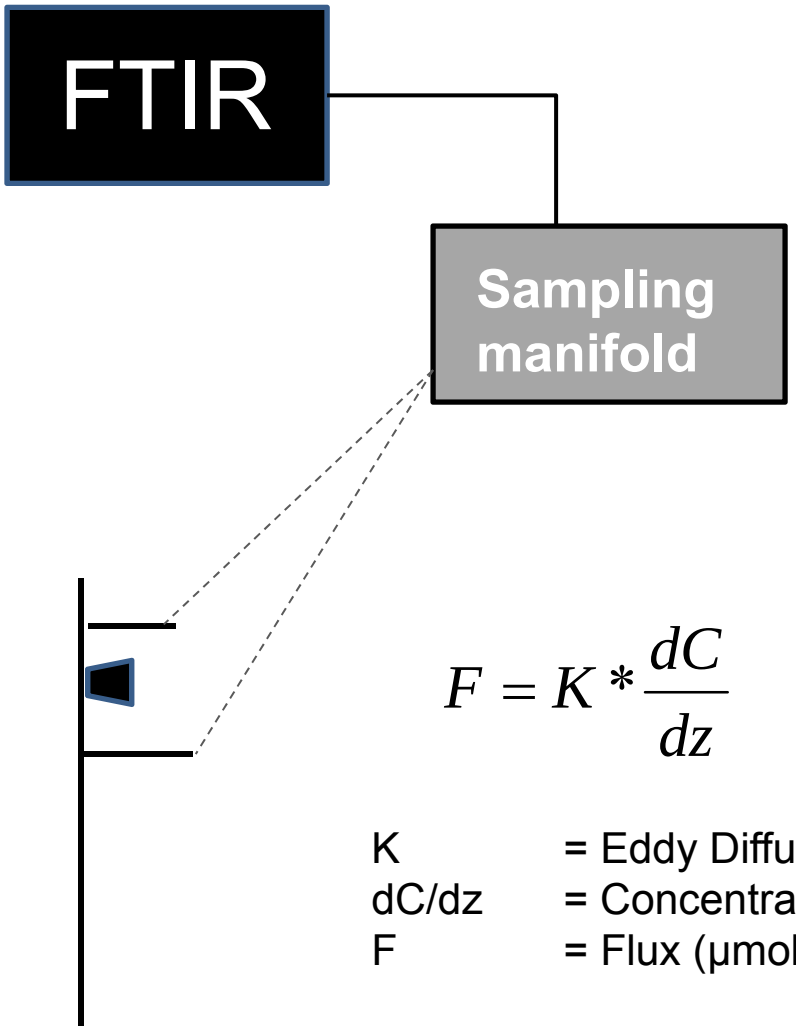


FTIR:

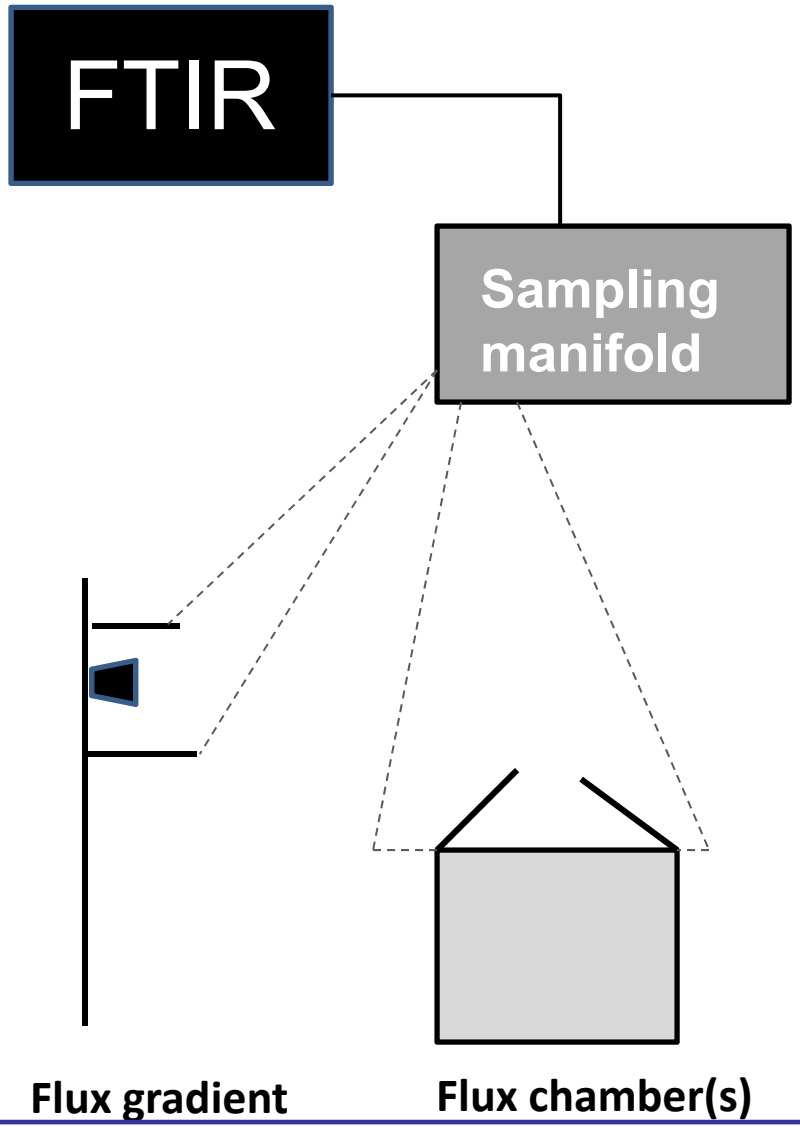
- Flux gradient system
  - Use of sampling bags
  - Sonic anenometer
  - Preferably EC-measurements
- Concentration measurements
  - Automated measurements with 12 inlets

$$F = K * \frac{dC}{dz}$$

K = Eddy Diffusivity factor
dC/dz = Concentration gradient
F = Flux (µmol m^{-2} s^{-1})

Flux gradient

Set up field experiment



FTIR:

- Flux gradient system
- Concentration measurements

- Flux chamber(s)

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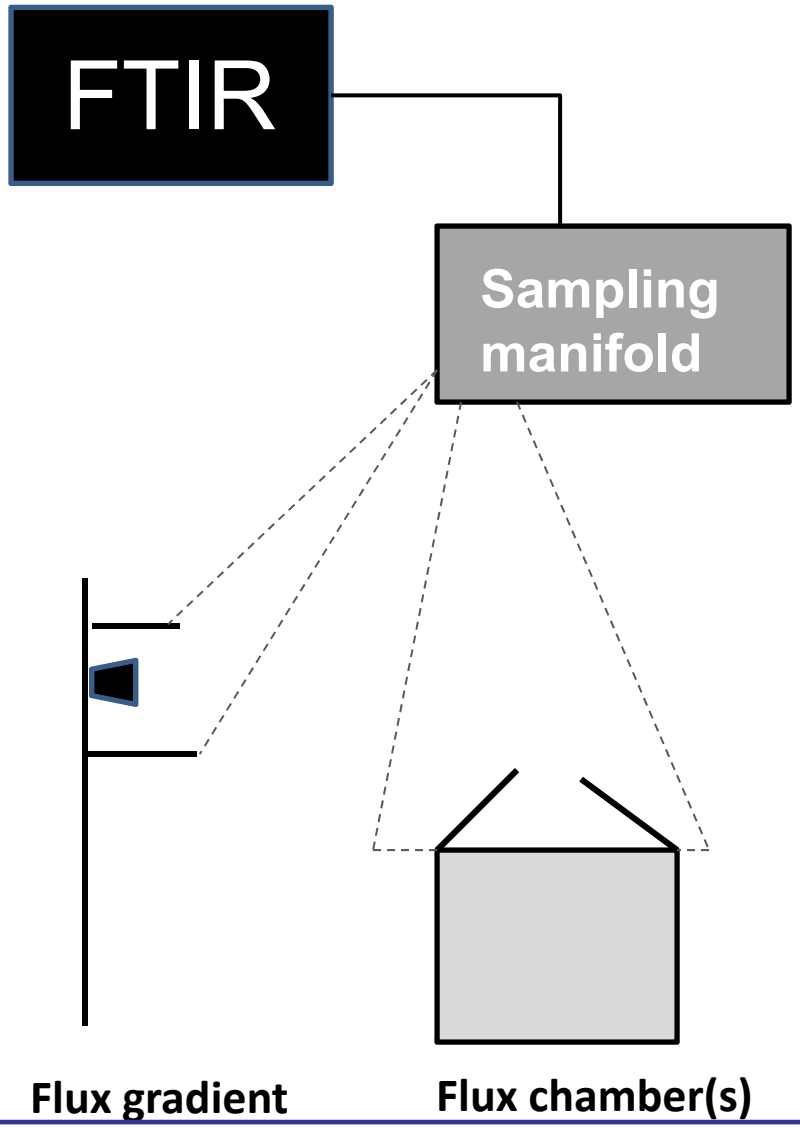


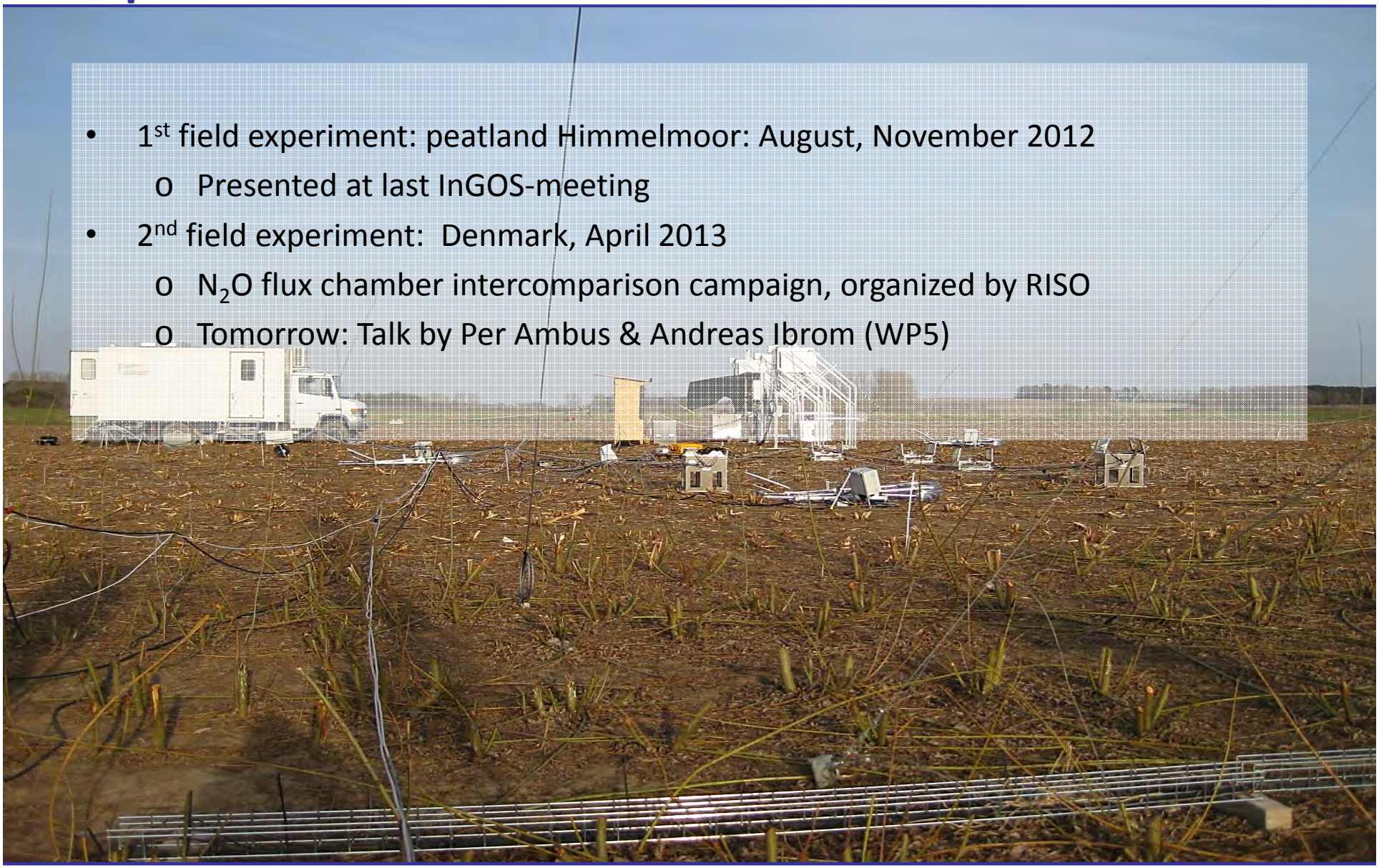
FTIR:

- Flux gradient system
- Concentration measurements
- Flux chamber(s)
- Environmental variables

Experiments

- 1st field experiment: peatland Himmelmoor: August, November 2012
  - Presented at last InGOS-meeting

Experiments



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  - Tomorrow: Talk by Per Ambus & Andreas Ibrom (WP5)

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Cooperation with UNITUS, University of Tuscia, Viterbo, Italy

- 3rd field experiment: Italy , August 2013
  - 'grassland experiment'

- 4th field experiment: Italy, September 2013
  - EC-storage component: Example of multiple concentration measurements
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Grassland experiment: results

Long data set of different concentrations and fluxes….

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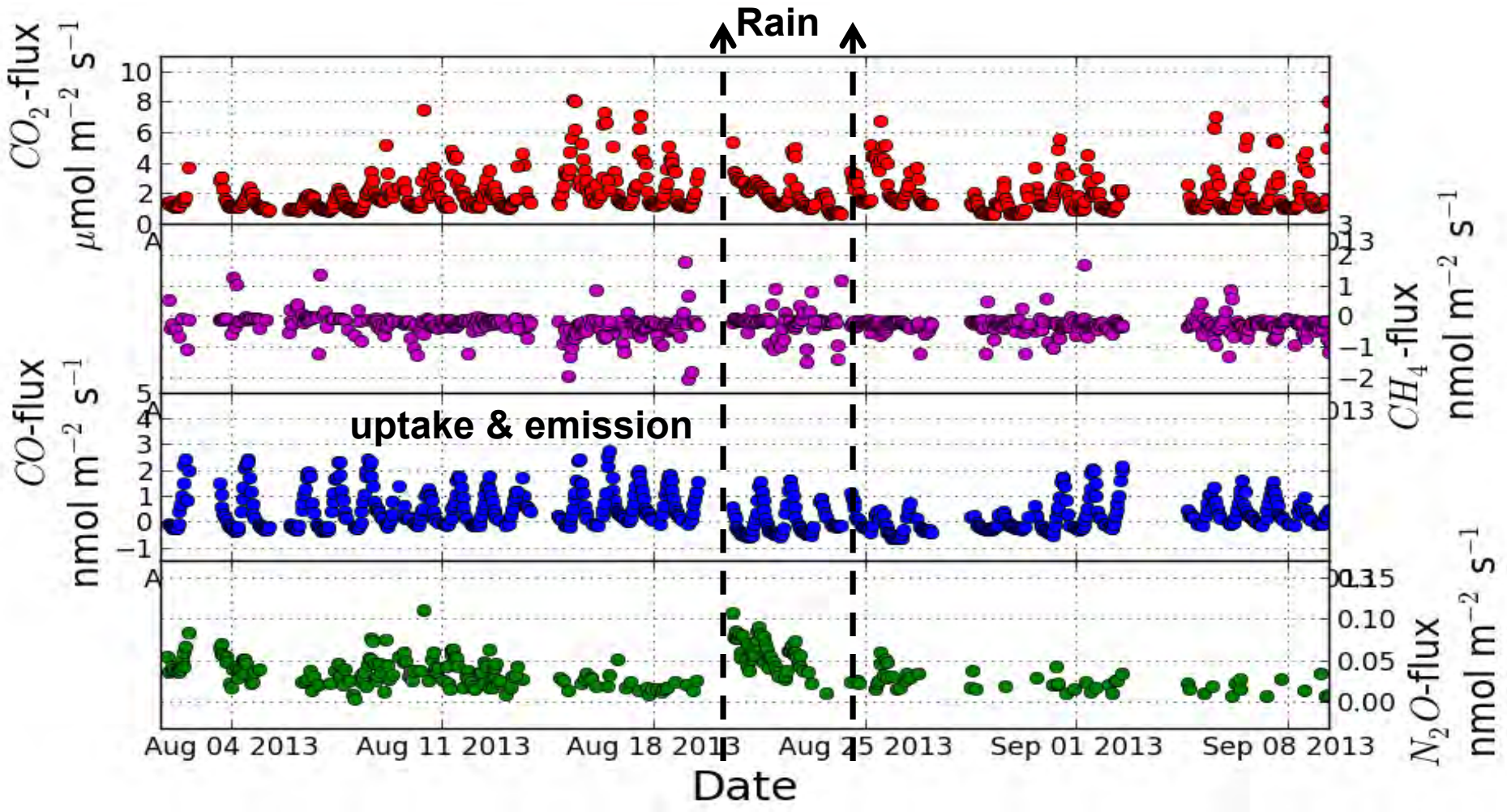

Grassland experiment: results

Focus on:

1) Photodegradation
2) Comparison Flux Gradient & Eddy Covariance measurements
3) del$^{13}CO_2$ measurements

Grassland experiment

1) photodegradation

Grassland experiment: motivation

- Photodegradation: *the direct breakdown of organic matter by sunlight produces* CO_2, CH_4, CO

- Important in arid regions

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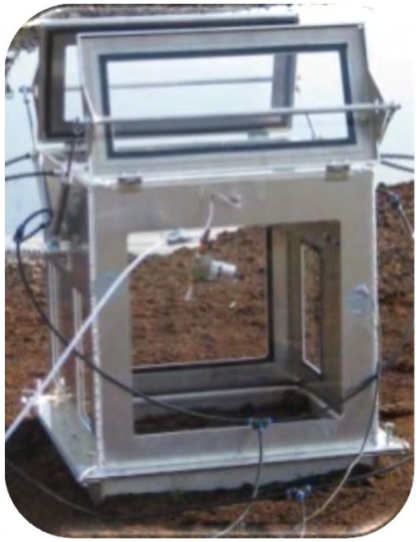

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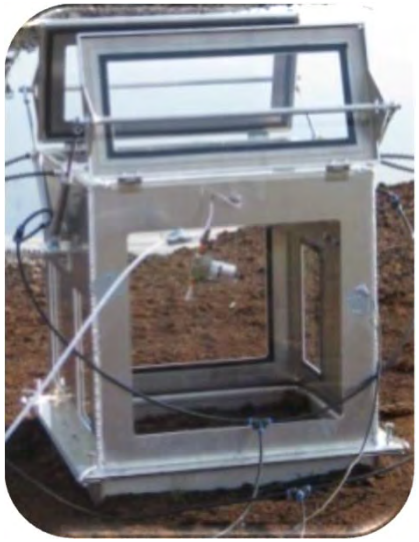


Difference between chambers?

- Not for CO_2
- Possibly for CO

Environment not suitable?

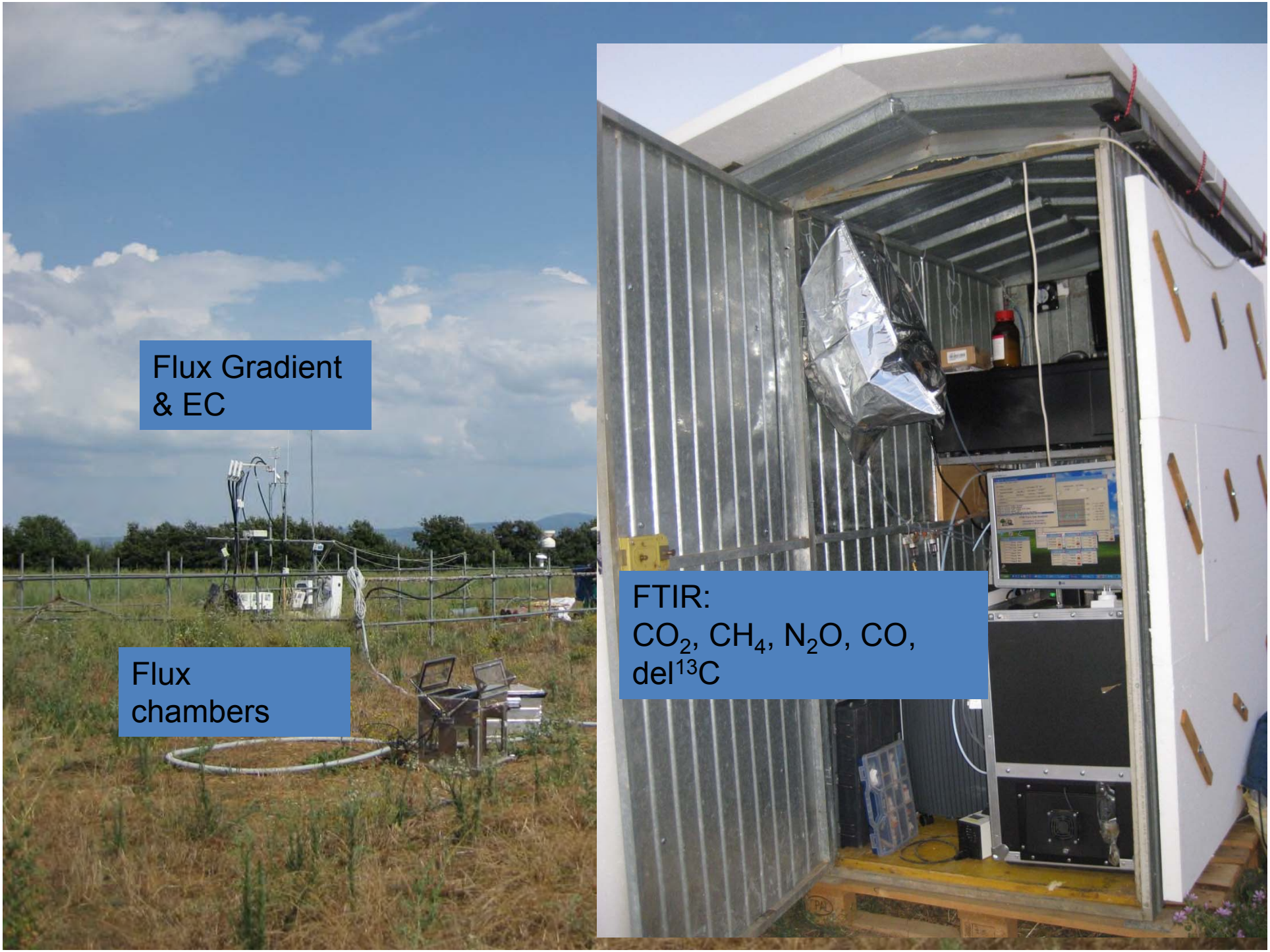
Grassland experiment: location

- Cooperation with UNITUS, University of Tuscia, Viterbo, Italy

  Dry grassland (Rocca4)

Advantages:

- photodegradation significant
- comparison EC/FG and chambers
  - *Similar footprint*


Flux Gradient & EC
Flux chambers
FTIR:
CO_2, CH_4, N_2O, CO, del^{13}C

Grassland experiment: photodegradation?

- Different footprint EC/flux gradient and flux chambers
  - *not suitable to determine photodegradation*

- Comparison between chambers

Grassland experiment: photodegradation?

- Different footprint EC/flux gradient and flux chambers
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- Comparison between chambers
  - No difference for CO_2
  - Problem with biotic flux

Grassland experiment: photodegradation CO?

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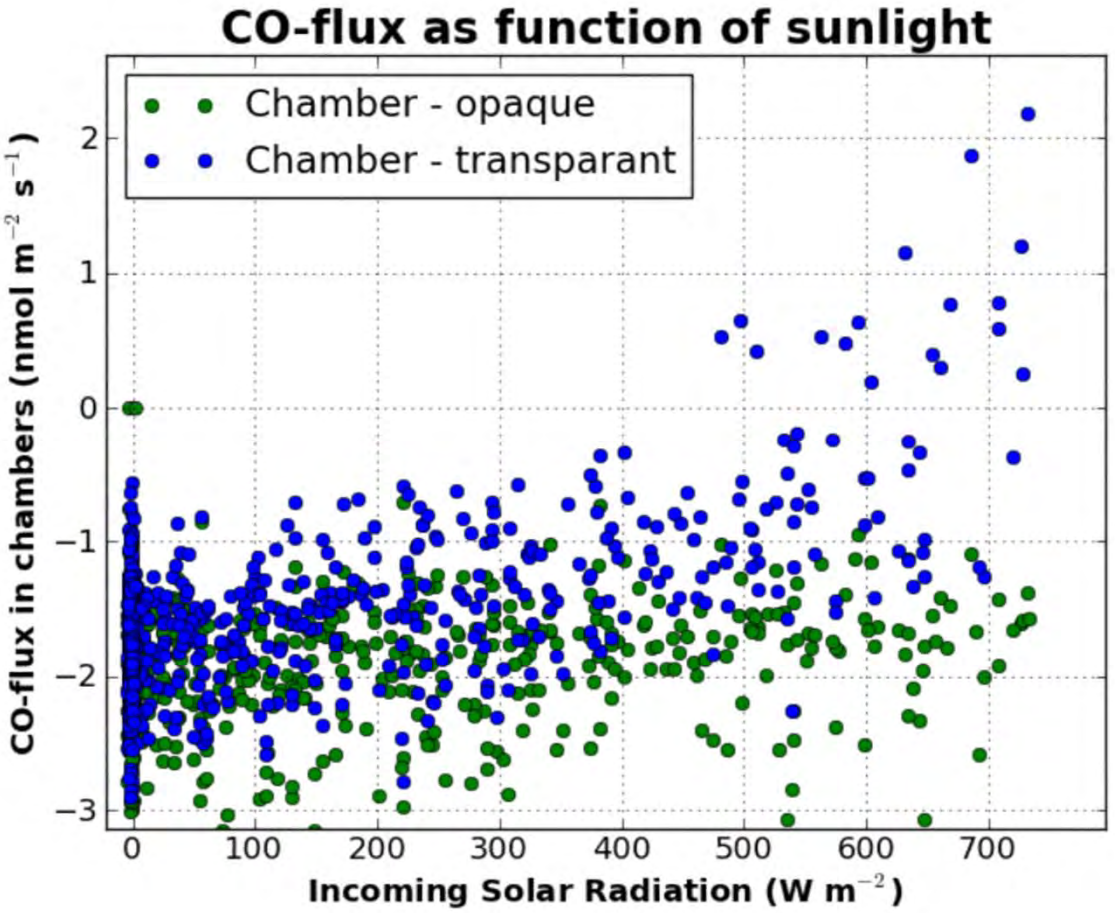
What we saw in Himmelmoor (Germany)……



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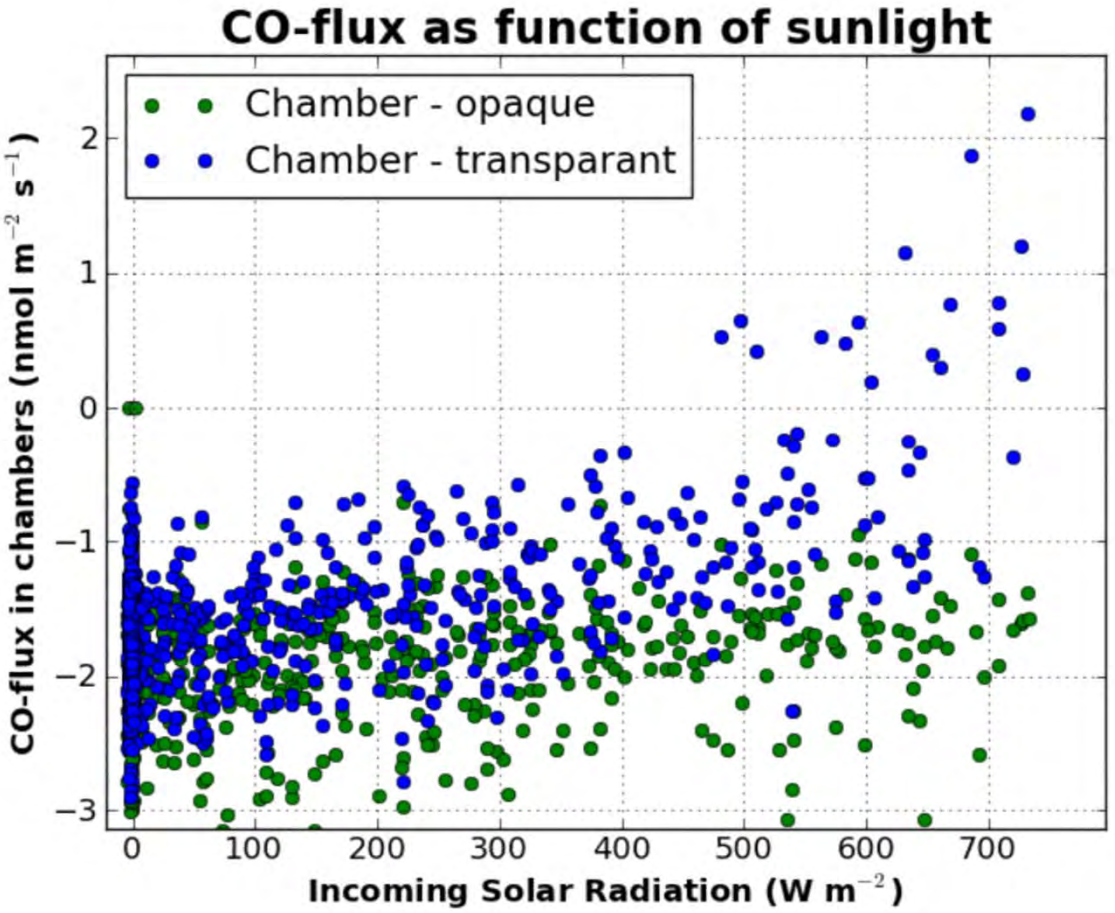


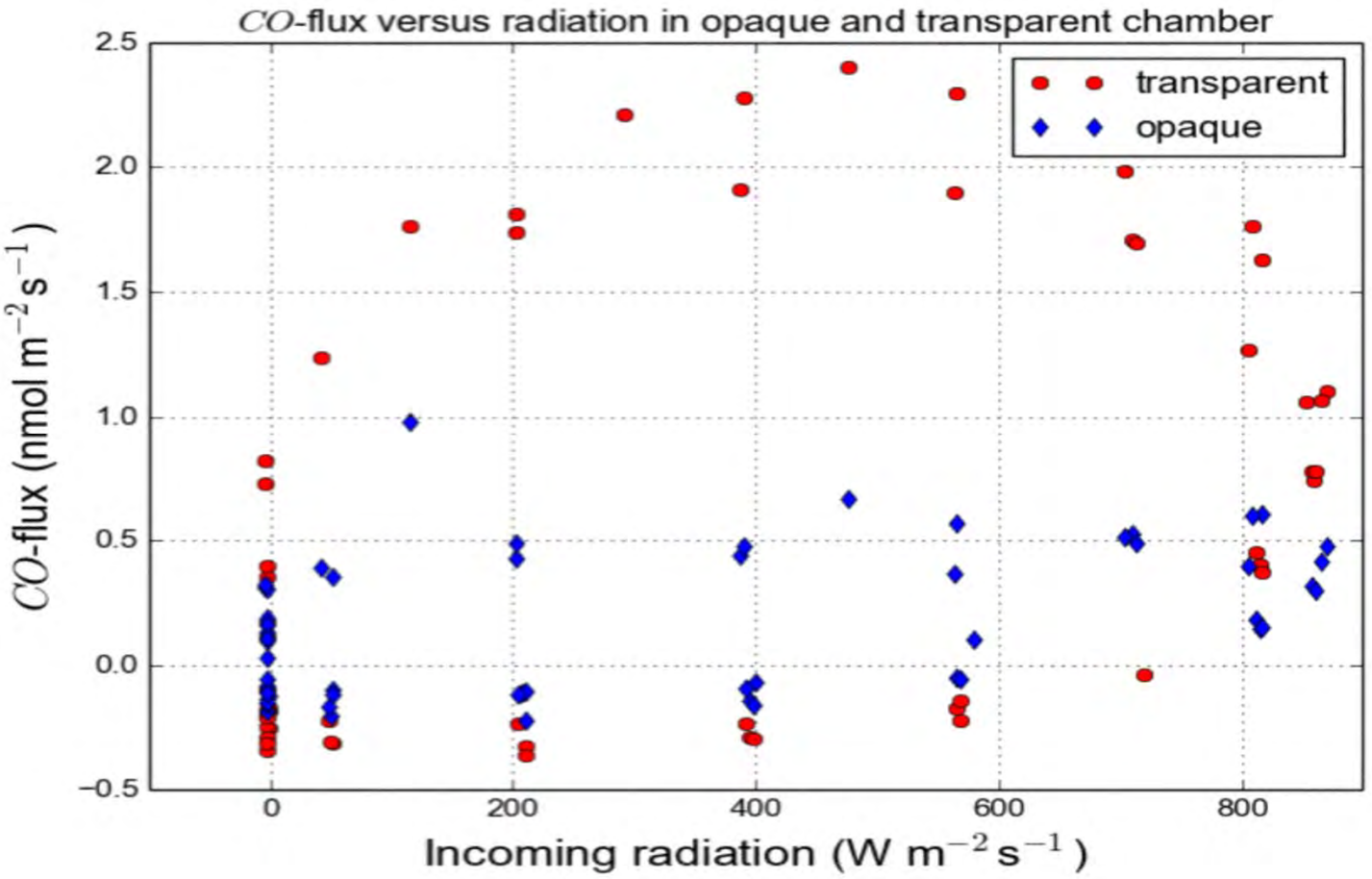
← Emission: abiotic

←Uptake: biogical

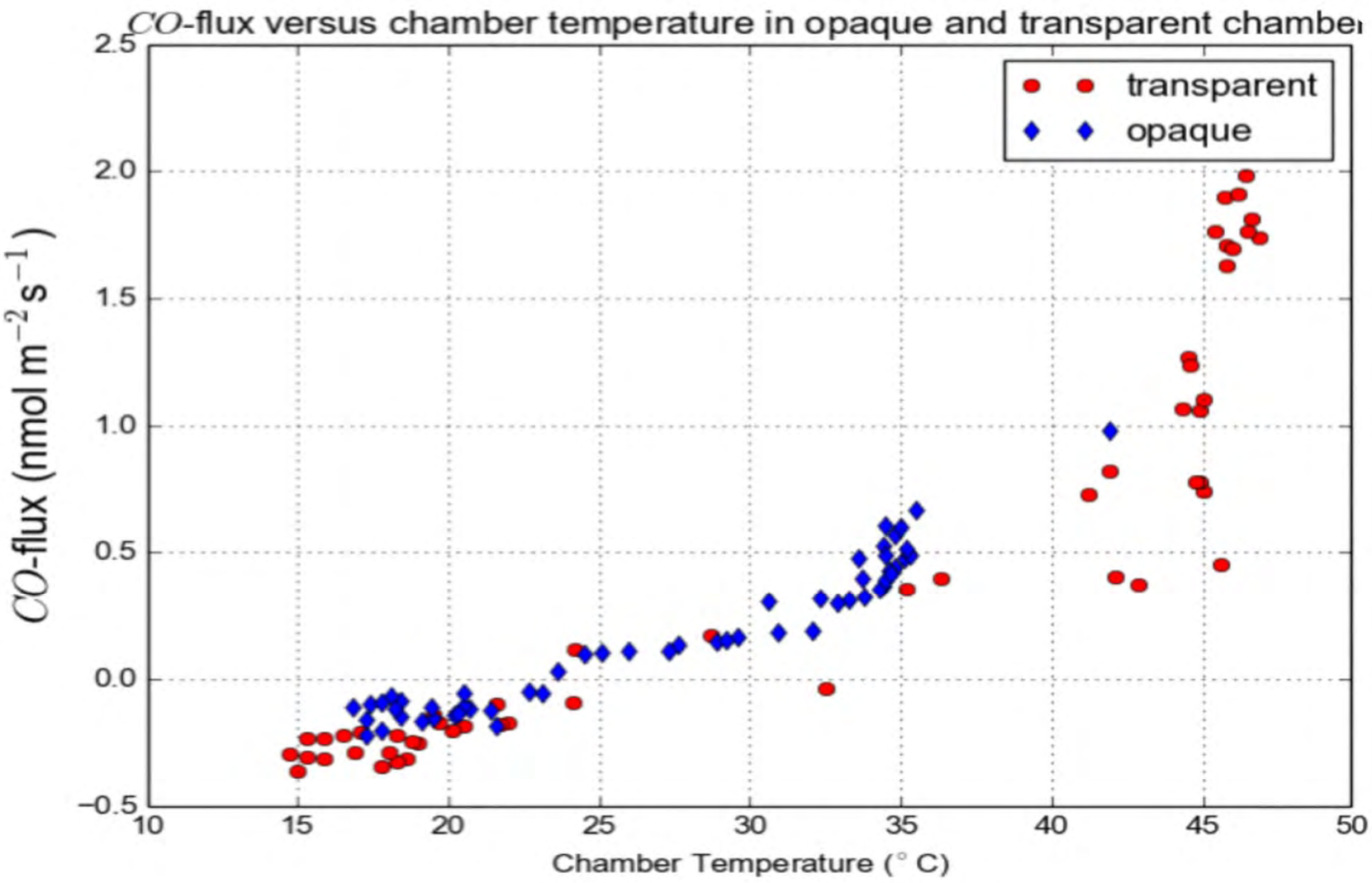
Grassland experiment: photodegradation CO?

What we see in Italy……

other abiotic process? → thermal degradation



Grassland experiment: thermal degradation CO?



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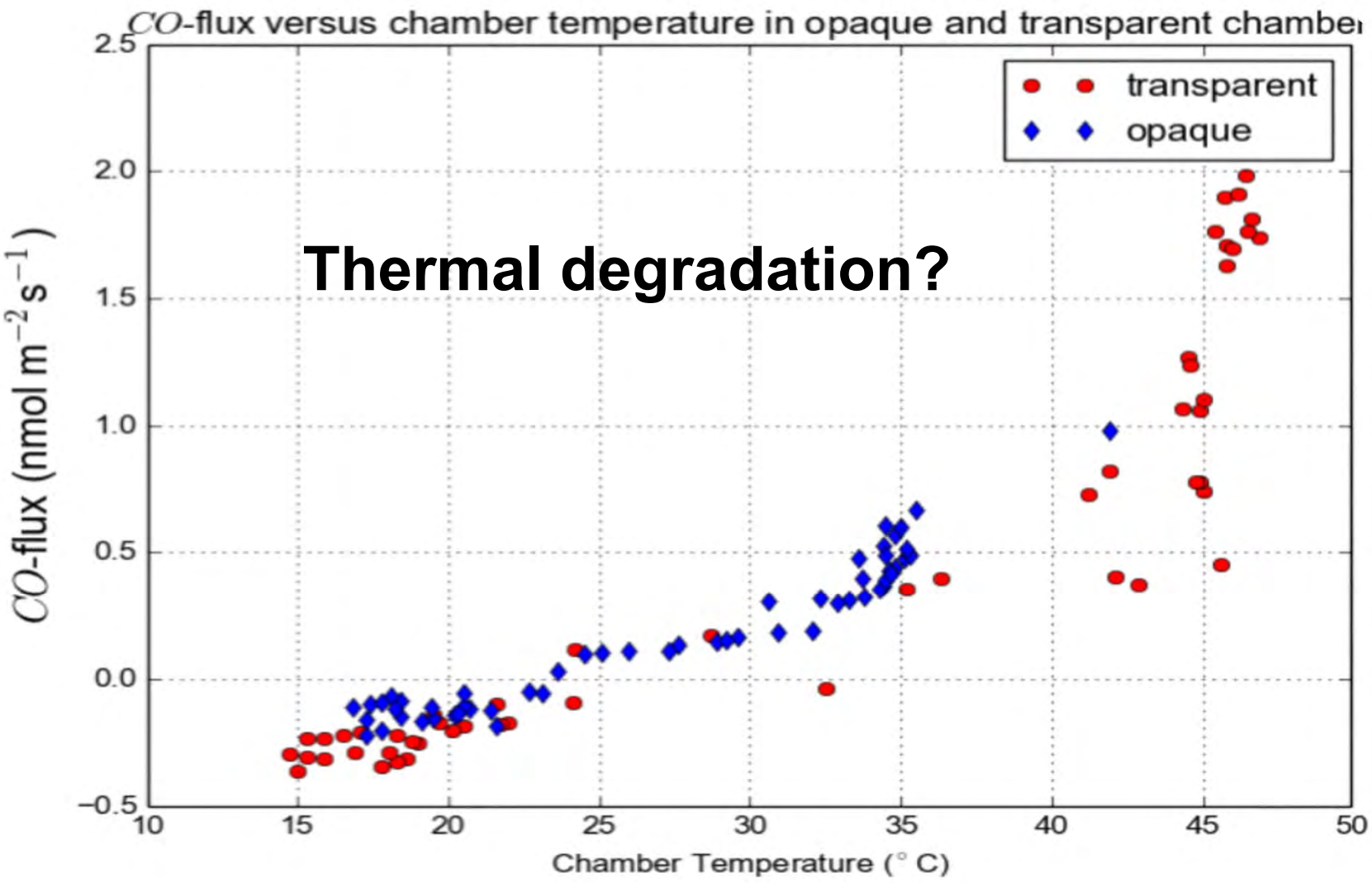
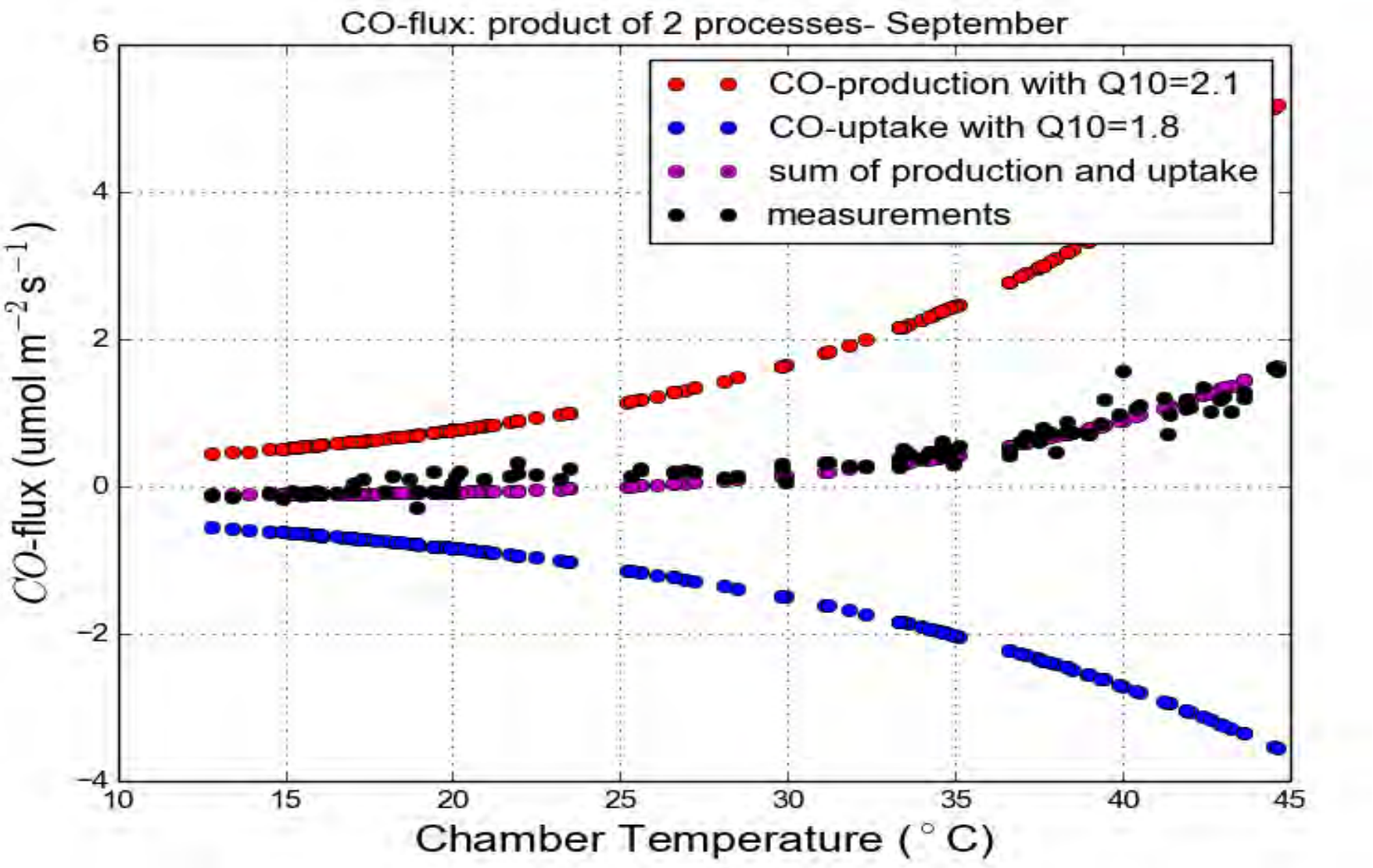


Grassland experiment: netto flux CO



Grassland experiment: photodegradation CO?

Abiotic fluxes CO_2→ we dont observe them

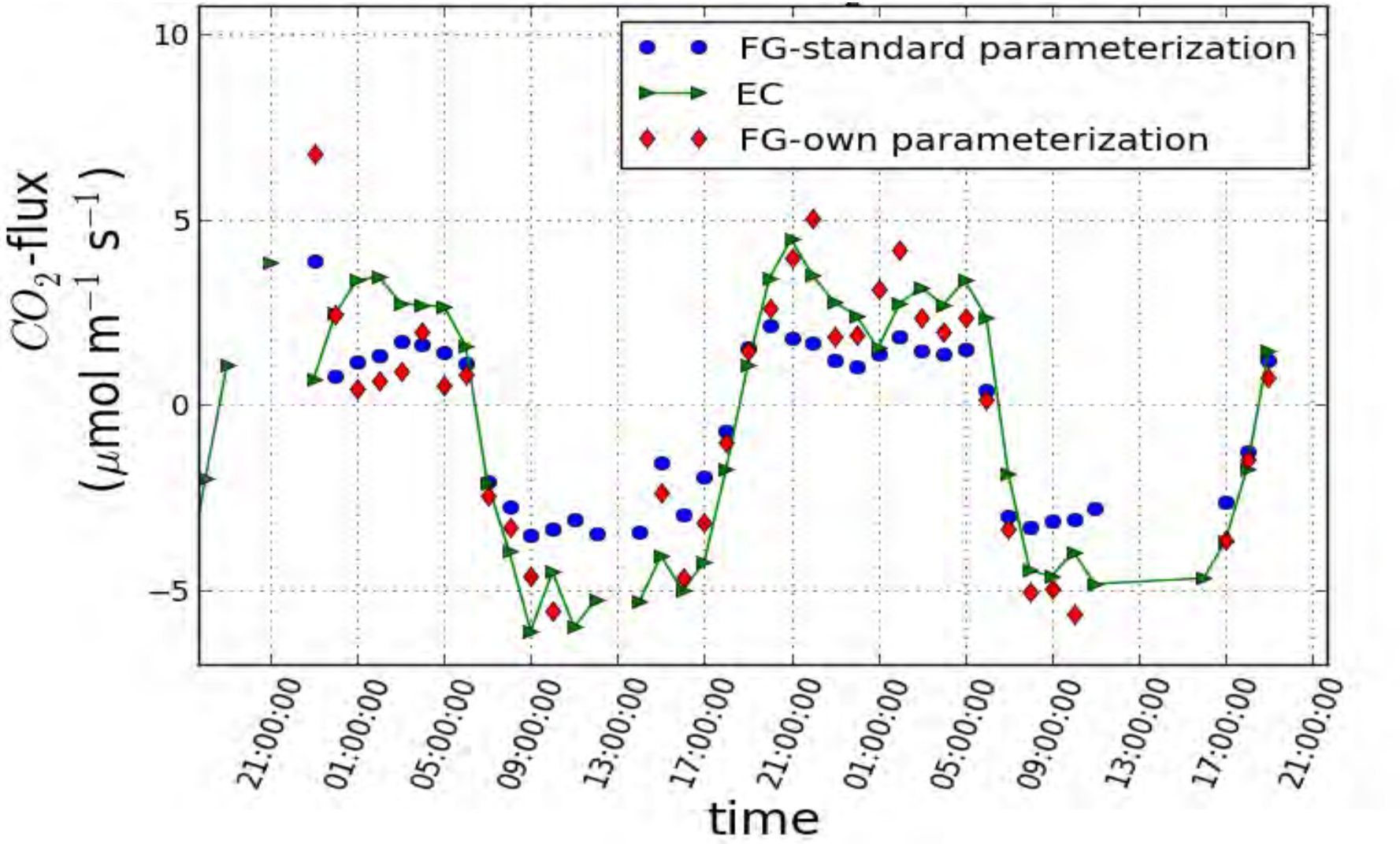
fluxes CO→ sum of biological uptake and abiotic emission

Abiotic flux →Thermal of photodegradation?

most likely thermal degradation

2) Comparison Flux Gradient & Eddy Covariance measurements

Grassland experiment: EC versus Flux Gradient



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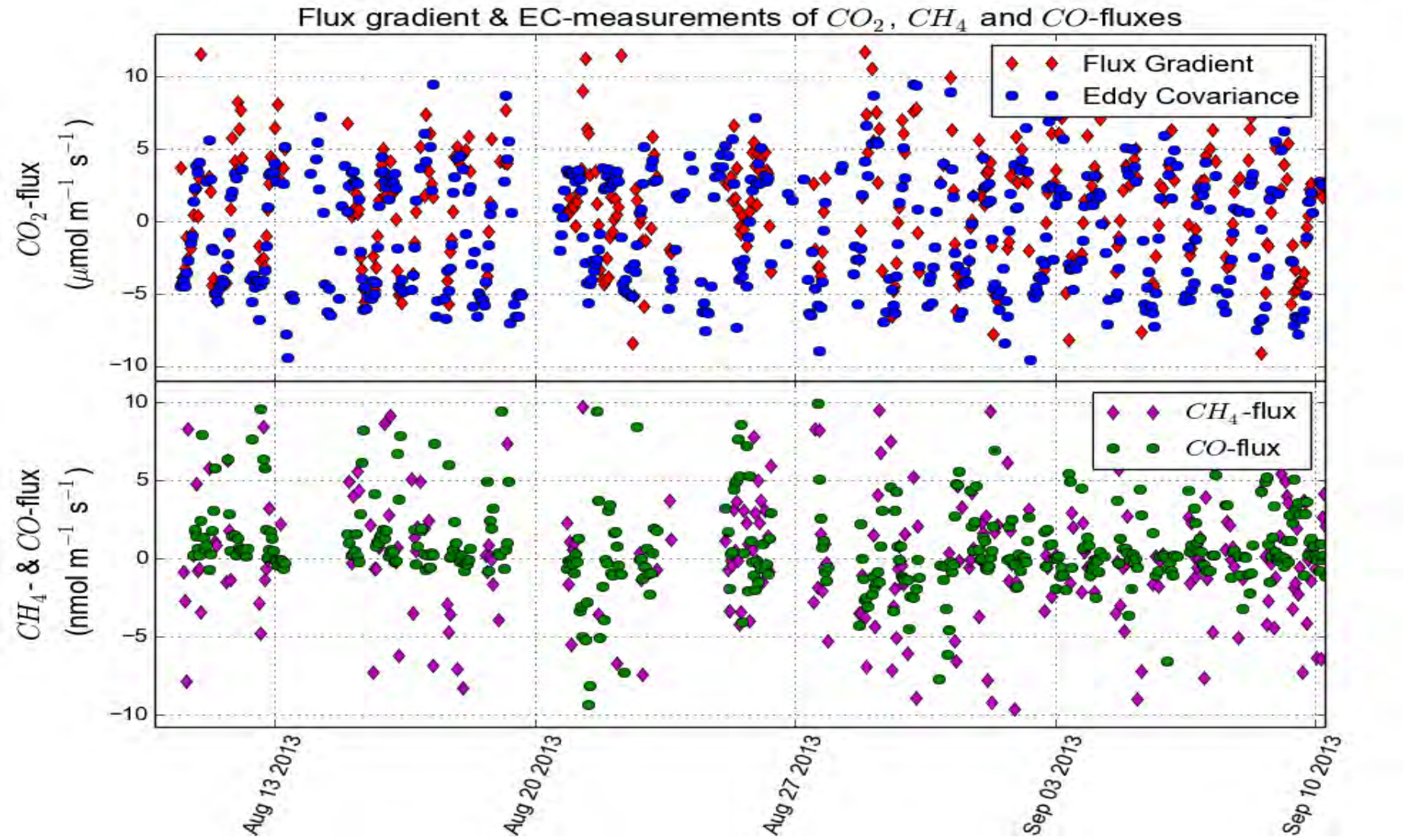
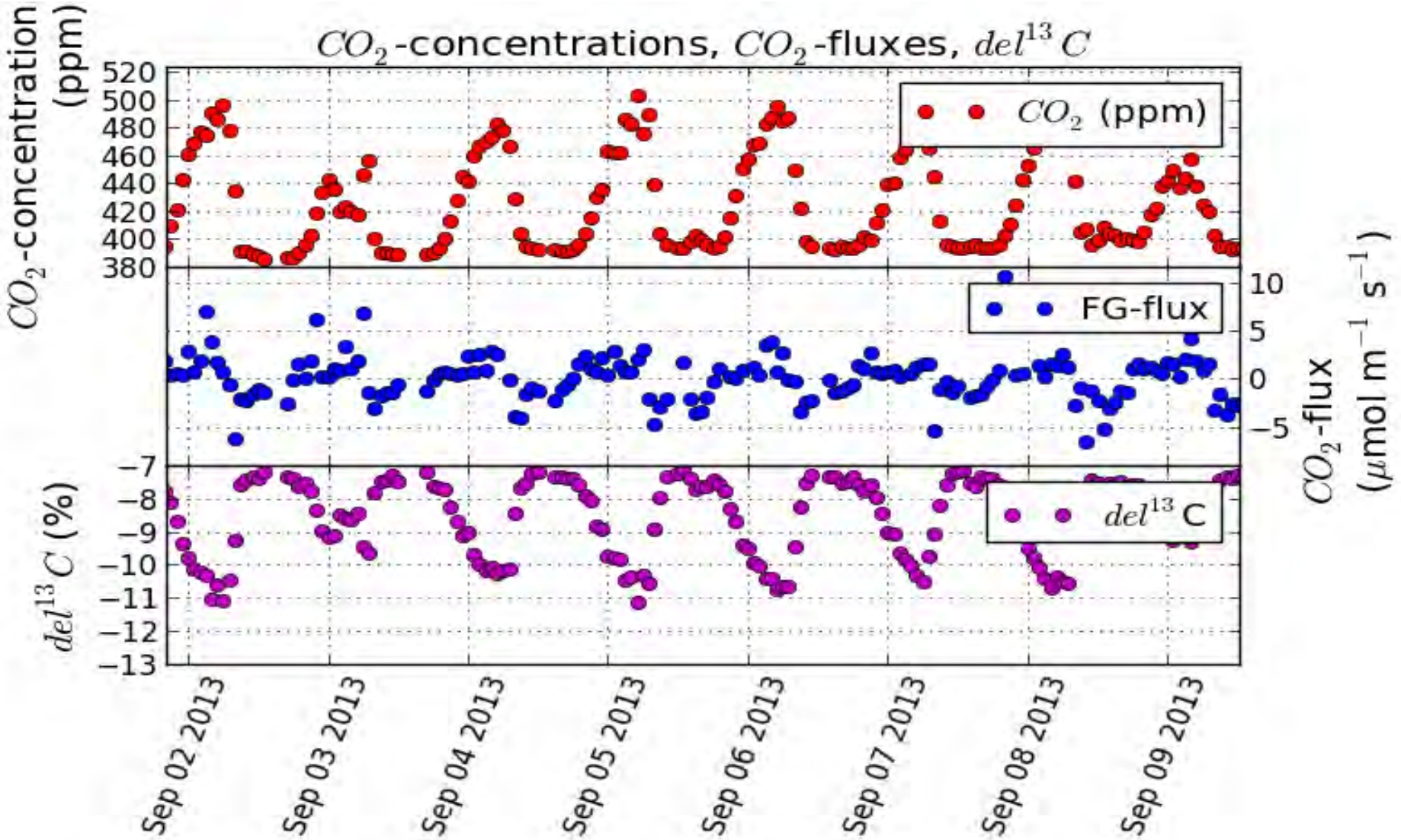


Grassland experiment

3) del$^{13}CO_2$ measurements

Grassland experiment: Atmosperic del$^{13}CO_2$



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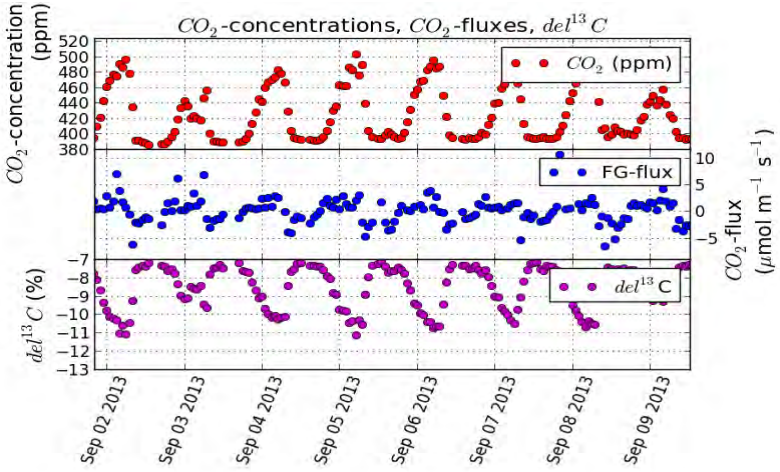
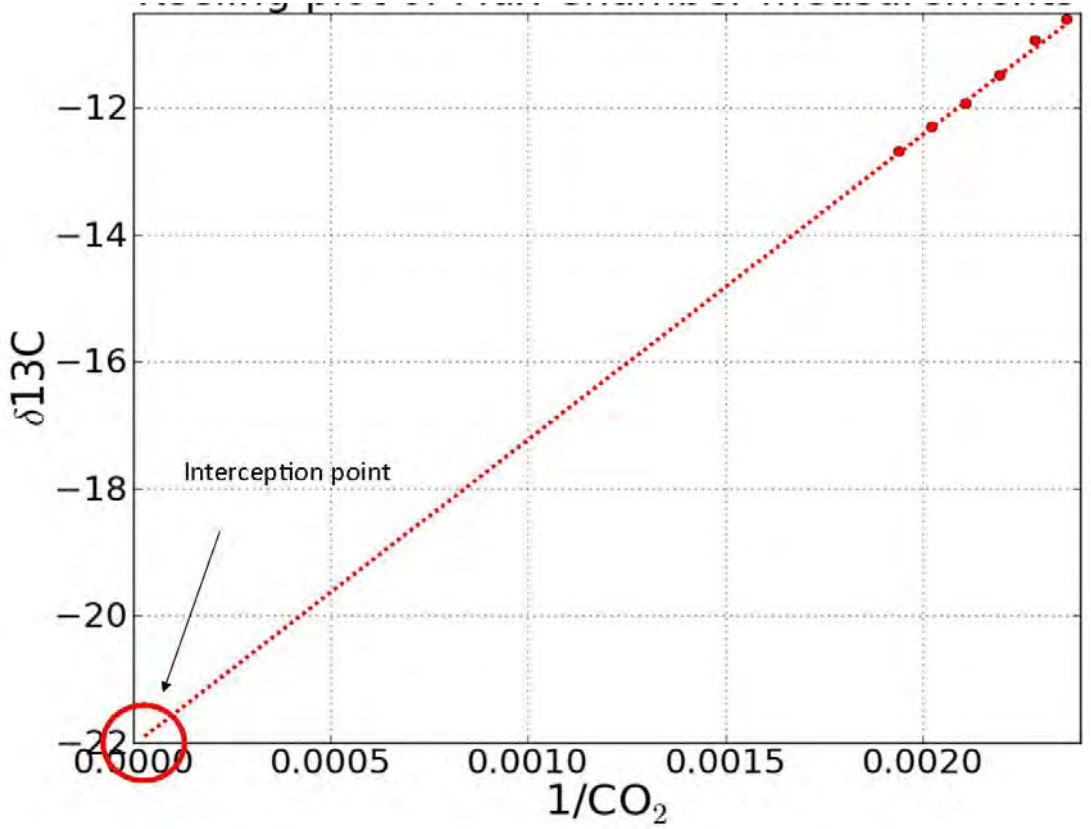
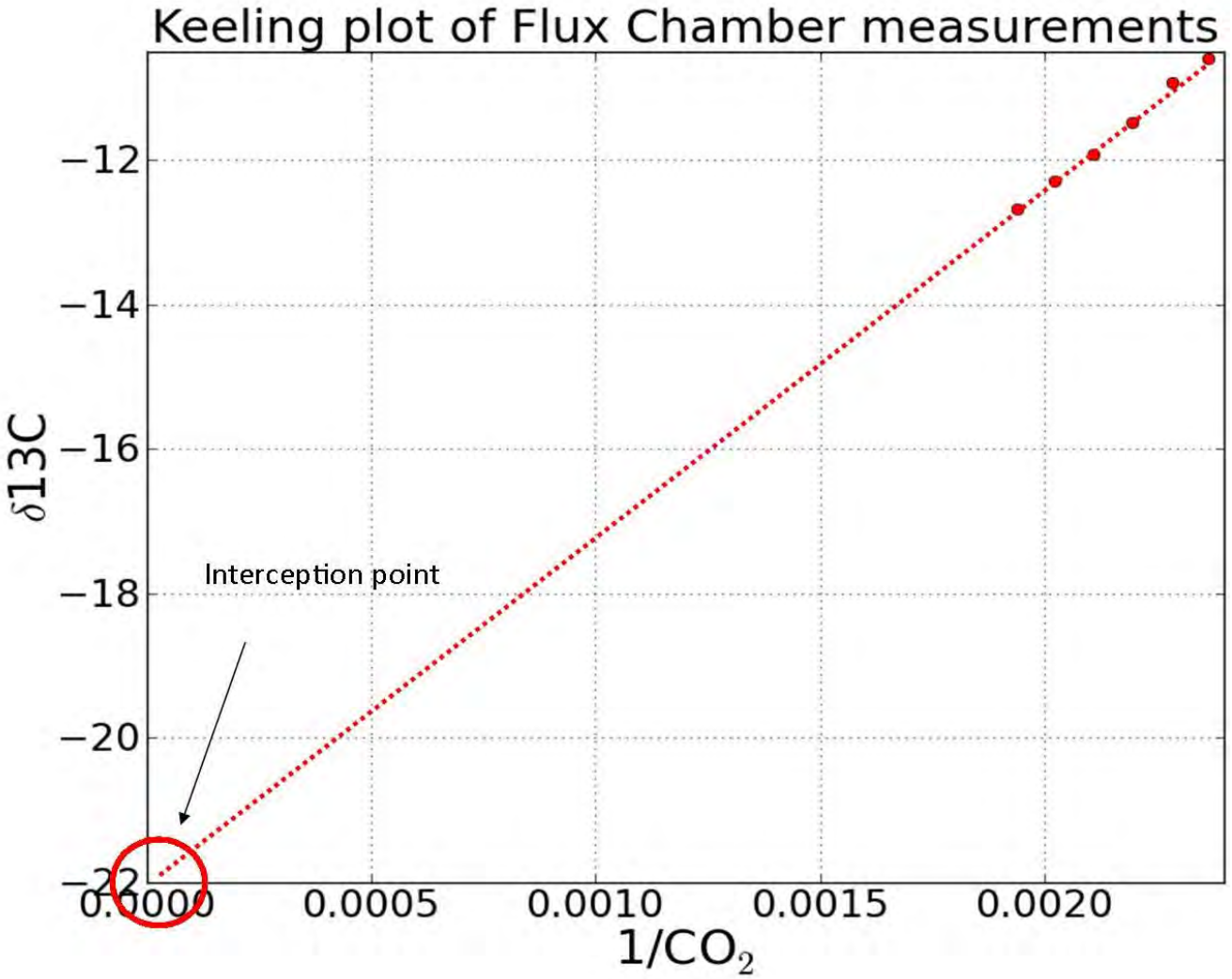


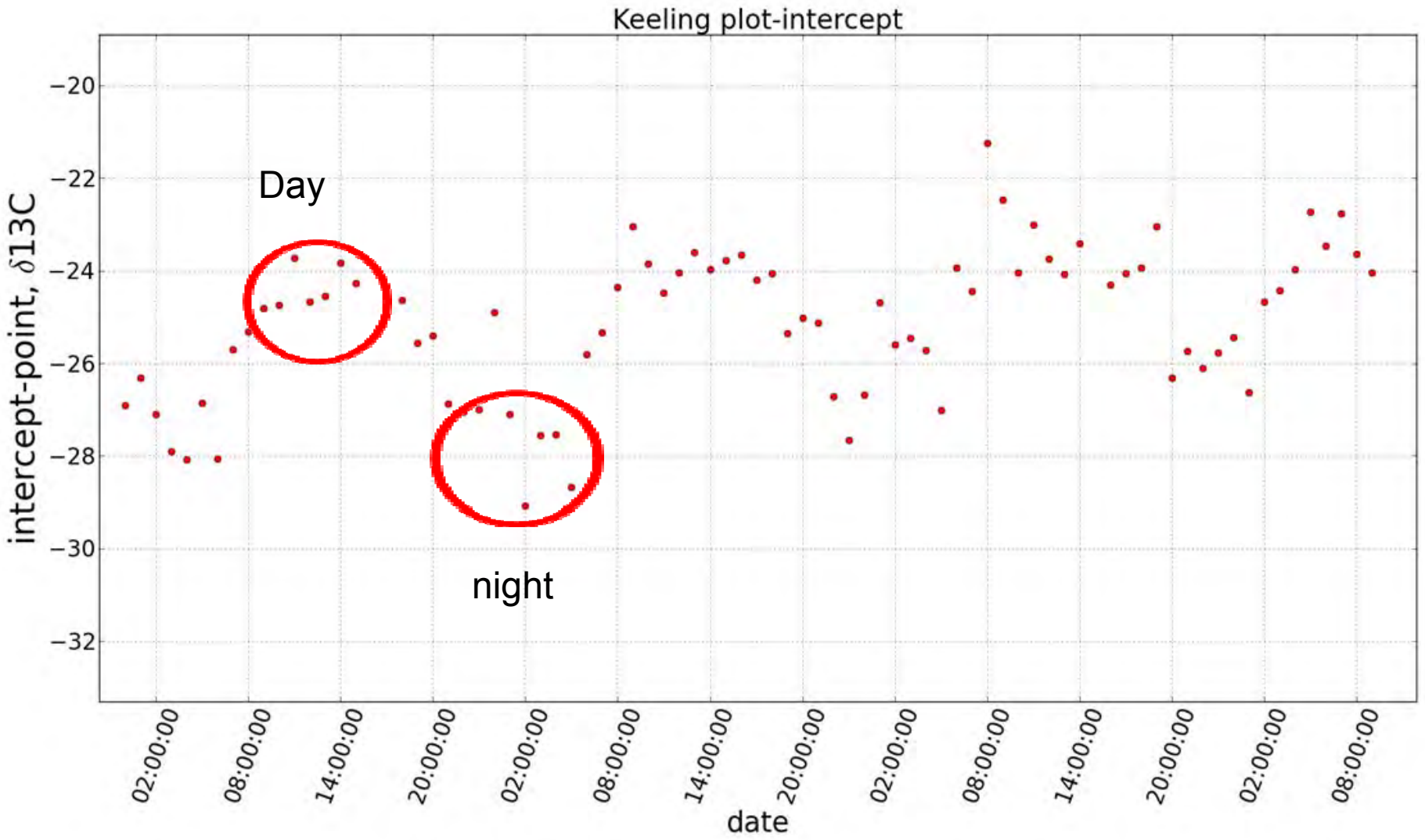
Nighttime boundary layer build up→
Keeling plot



Grassland experiment: Respiratory del$^{13}CO_2$



Grassland experiment: Chamber del$^{13}CO_2$



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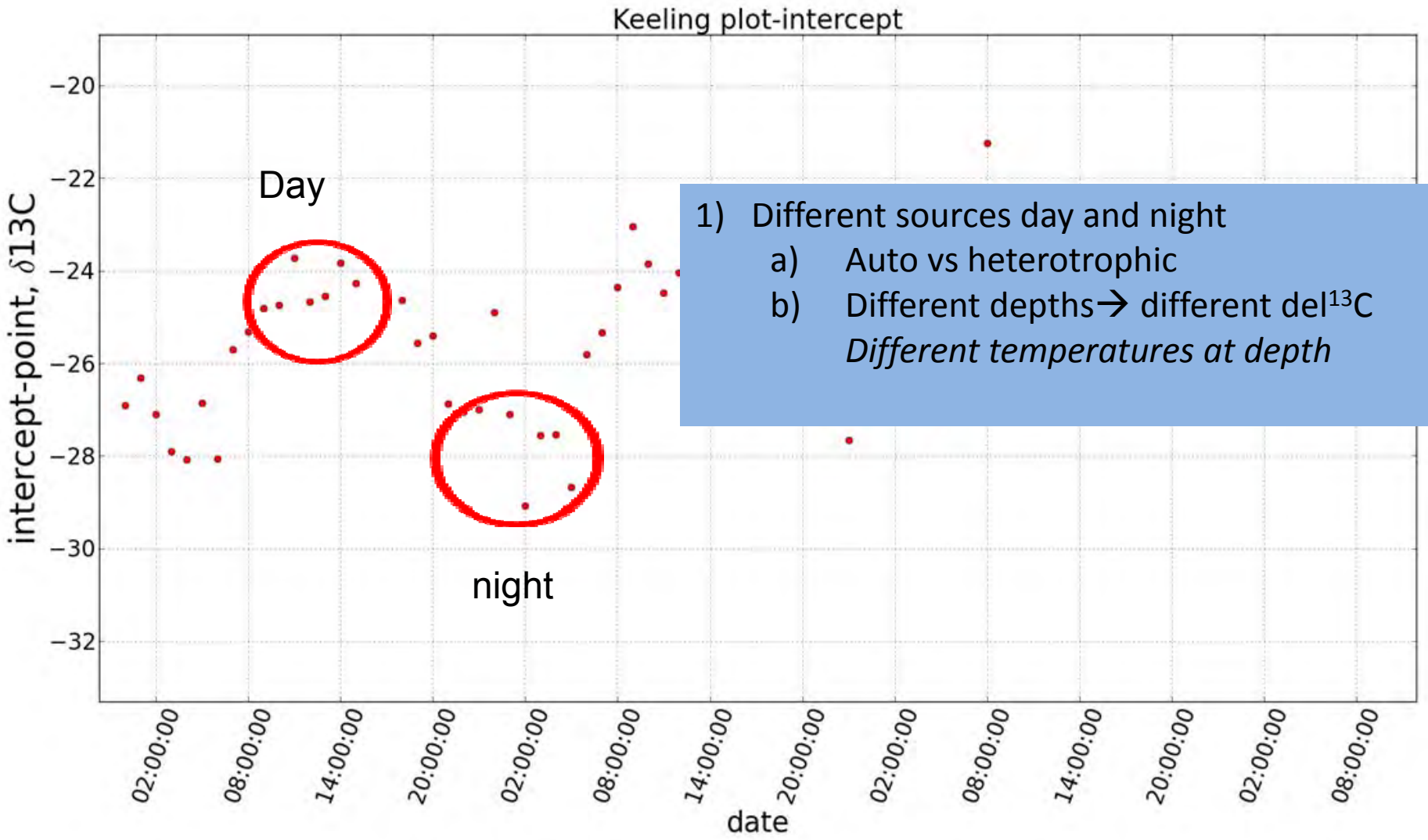
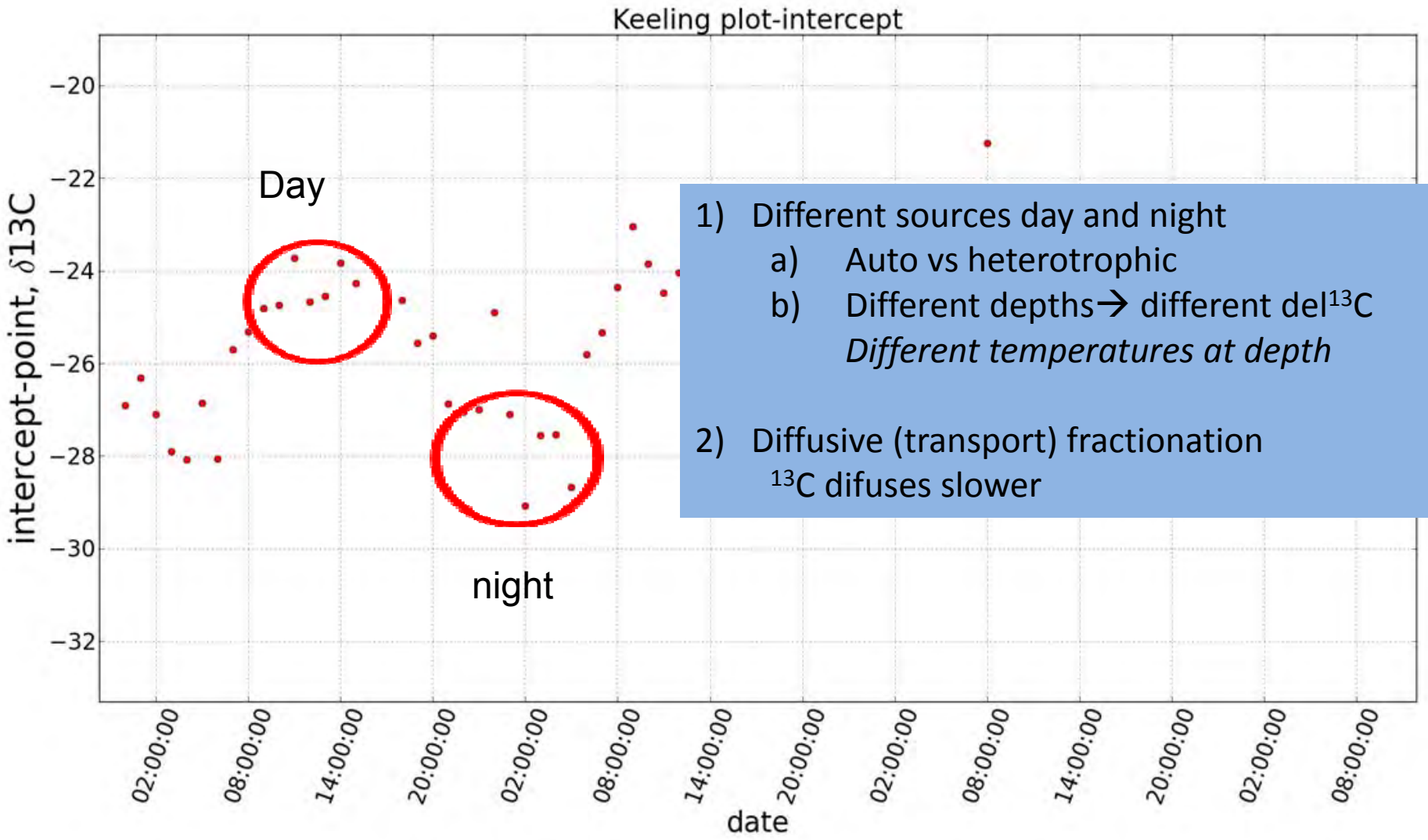


1) Different sources day and night
   a) Auto vs heterotrophic
   b) Different depths→ different del^{13}C
      Different temperatures at depth

Grassland experiment: Respiratory del$^{13}CO_2$



1) Different sources day and night
   a) Auto vs heterotrophic
   b) Different depths→ different del^{13}C
      Different temperatures at depth

2) Diffusive (transport) fractionation
   ^{13}C difuses slower

Practical considerations

The use of FTIR-spectrometry for flux measurements:

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The use of FTIR-spectrometry for flux measurements:

- Flux gradient system
  - Type of sampling lines (Tefflon/stainless steel)
    - CO production in/by Tefflon lines
    - Constant flow or stainless steel
  - Type of pumps
  - Location of inlet

    Comparison to EC-measurements adds value

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- Flux chamber
  - Transparent/non transparent
  - Temperature measurement in chamber

- Frequent calibration measurements

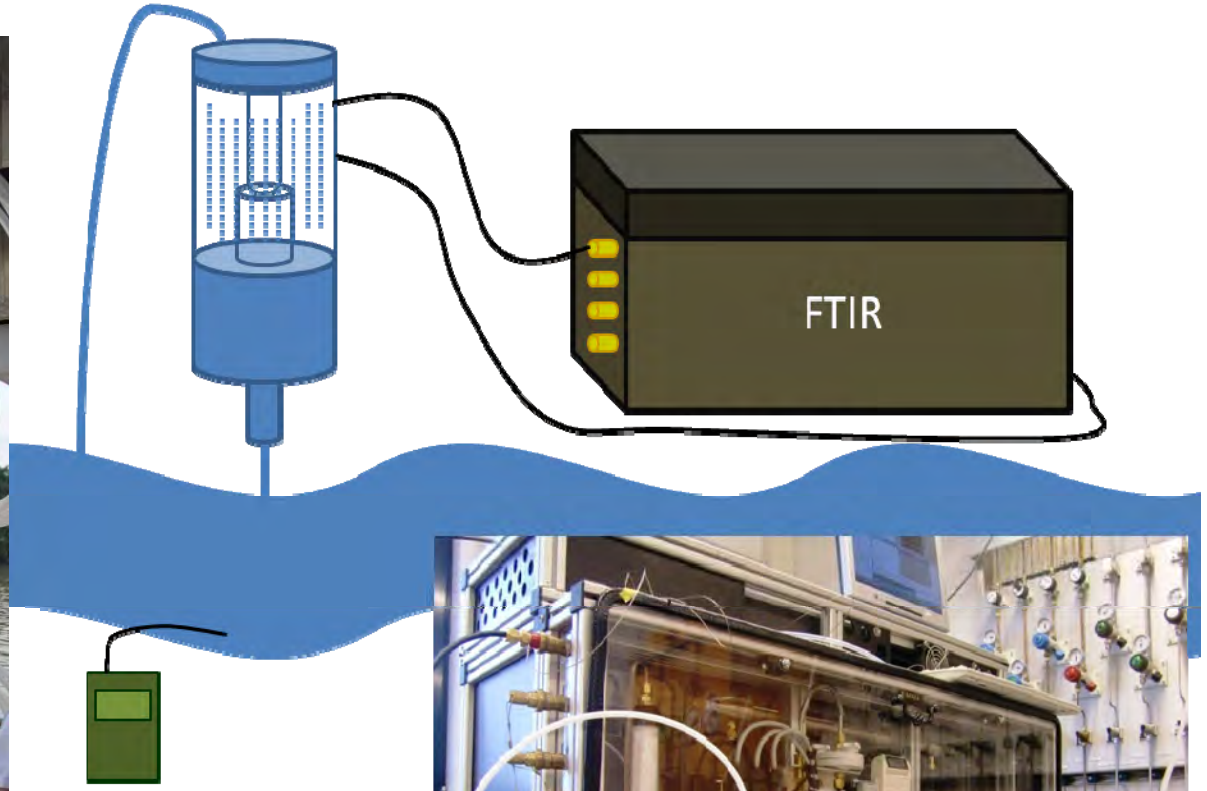
Possible future projects with FTIR

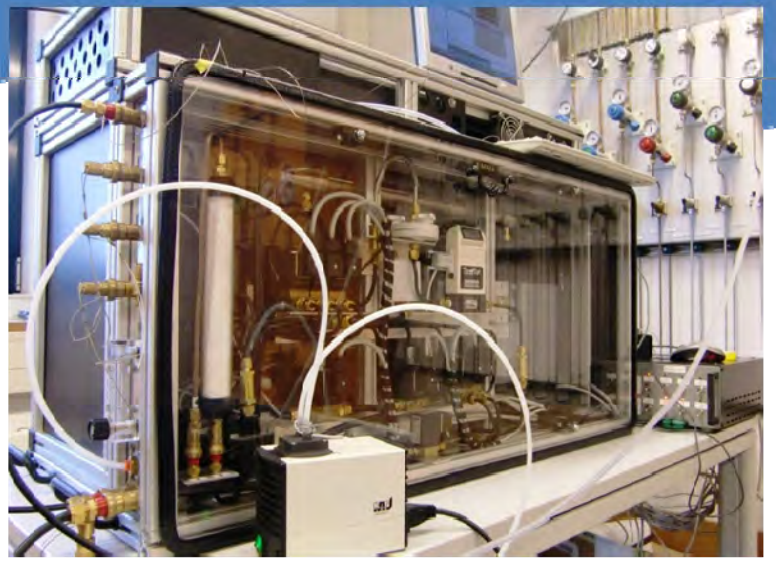
Using FTIR to measure GHG emissions and concentrations in inland waters

Inland water GHG emissions and concentrations are relatively unknown

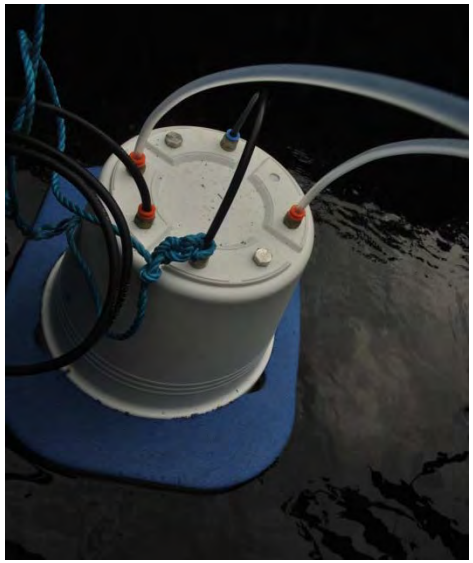
Using FTIR to measure at fracking sites

GHG (fluxes) in water





GHG (fluxes) in water



Poster this afternoon:

Measurements of dissolved greenhouse gases in rivers and estuaries using Fourier Transform Infrared (FTIR) spectrometry

Denise Müller, Thorsten Warneke

To summarize

FTIR-spectrometry for flux measurement:

- Combination of flux chamber, flux gradient and concentrations measurements simultaneously was succesfull
- For flux gradient measurements, alongside EC measurements are preferred
- for flux chamber measurements, design (for temperature) should be considered

With FTIR, possible study subjects:

- Photo or thermal degradation
- Eddy covariance versus flux gradient
- (Respiratory) del$^{13}CO_2$-measurements

Thank you & Questions

Special thanks to everyone from the University of Tuscia who supported me during my stay in Italy.

Fieldsite Himmelmoor

Literature on CO-uptake in soils

CO-uptake vs. CO-emission

Uptake:	Oxidation by soil bacteria or enzymes
Emission:	Chemical decomposition & photodegradation

Conrad & Seiler (1985): CO uptake =~1umol m^{-2} h^{-1}

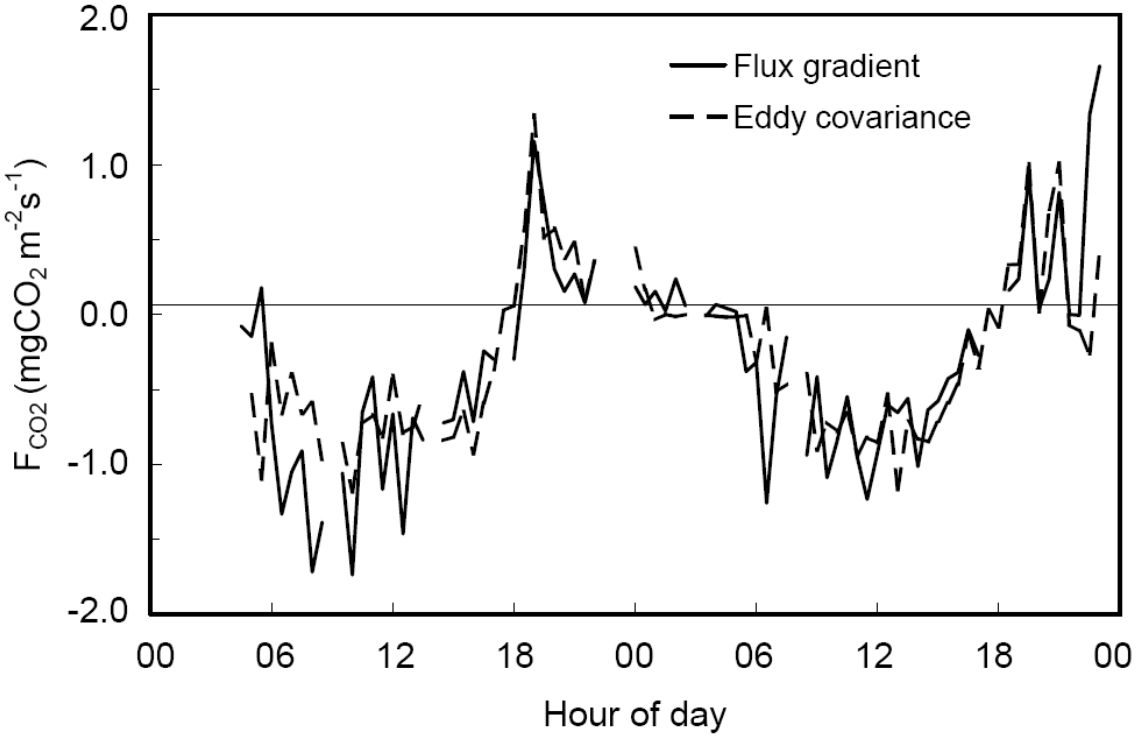
Yonemura (2000): CO uptake =~1.5 umol m^{-2} h^{-1}

Himmelmoor: 4 nmol per m^2 s = 14.4 umol m^2 h^{-1}

Dependent on temperature & organic matter

Extra slide 1

Extra slide 2: Flux gradient versus Eddy Covariance



Example of diurnal variation of CO_2 flux measured by the EC-technique and the Flux Gradient technique. From Griffith (2002).

Extra slide 3: Fieldwork Himmelmoor