Novel ways to look at N_2O emissions (using an FTIR analyser)

1. ^{15}N labelling in soil chamber experiments
2. Tracer measurements in the nocturnal boundary layer

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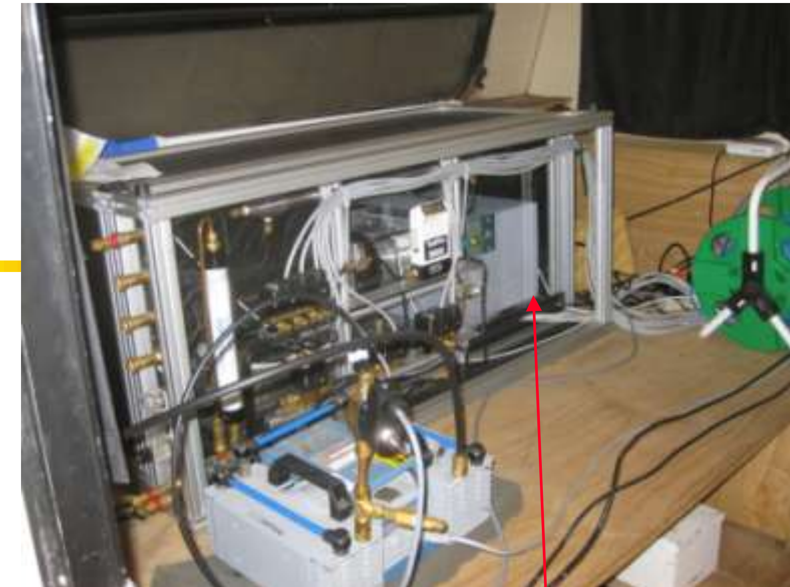
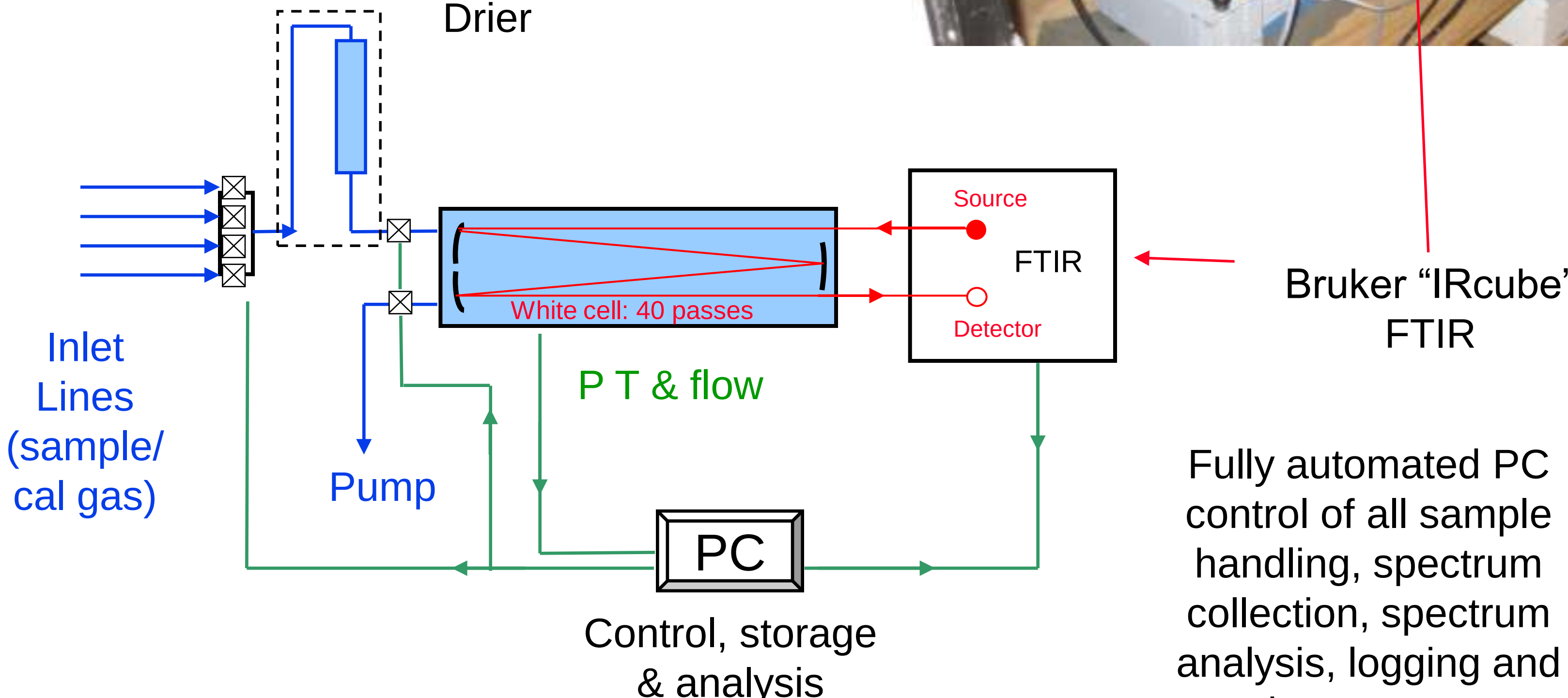
The UoW FTIR trace gas analyser*

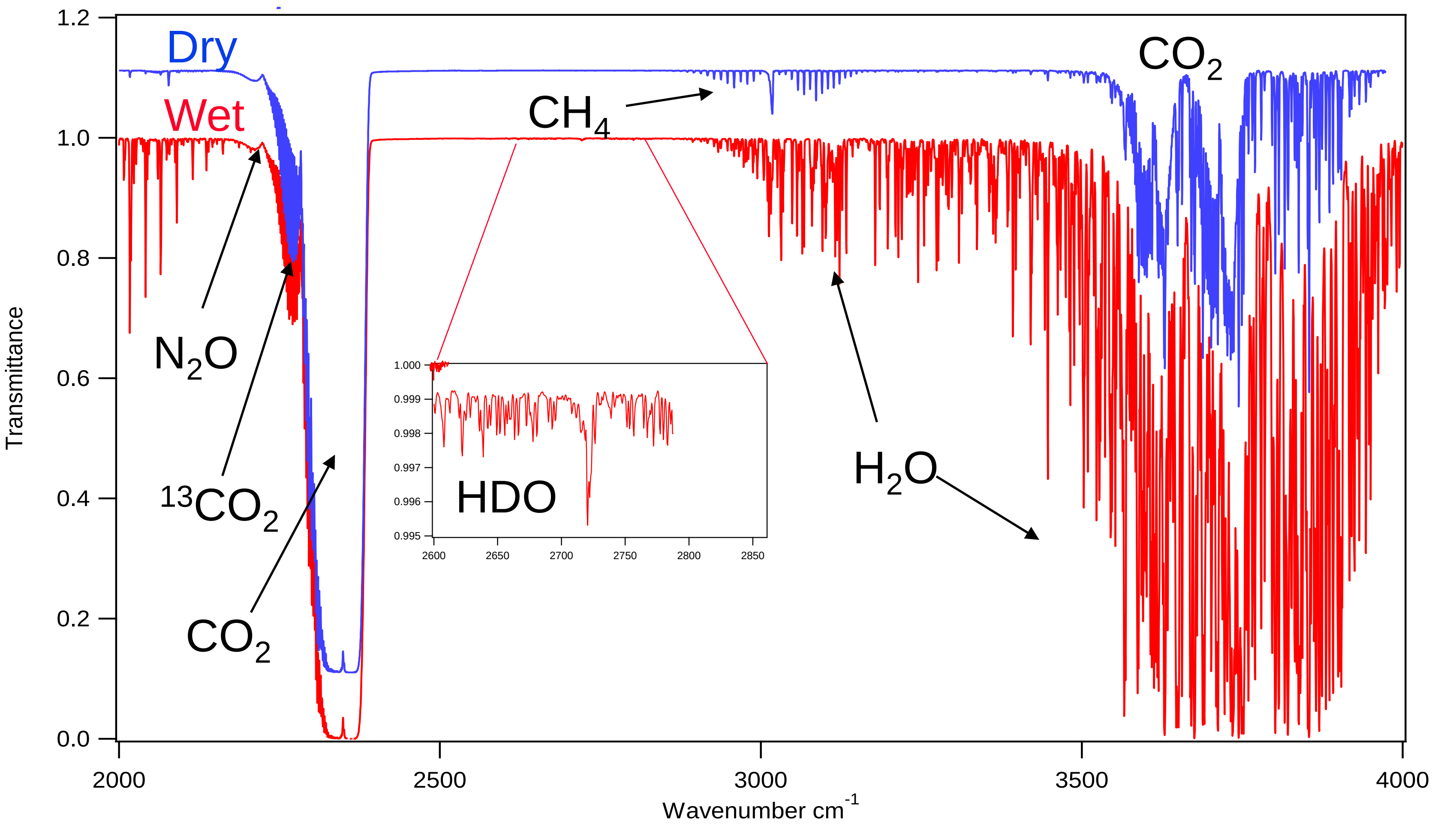




Fully automated PC control of all sample handling, spectrum collection, spectrum analysis, logging and data storage

*Now commercially available as Spectronus, Ecotech P/L

Mid-infrared spectrum of clean air



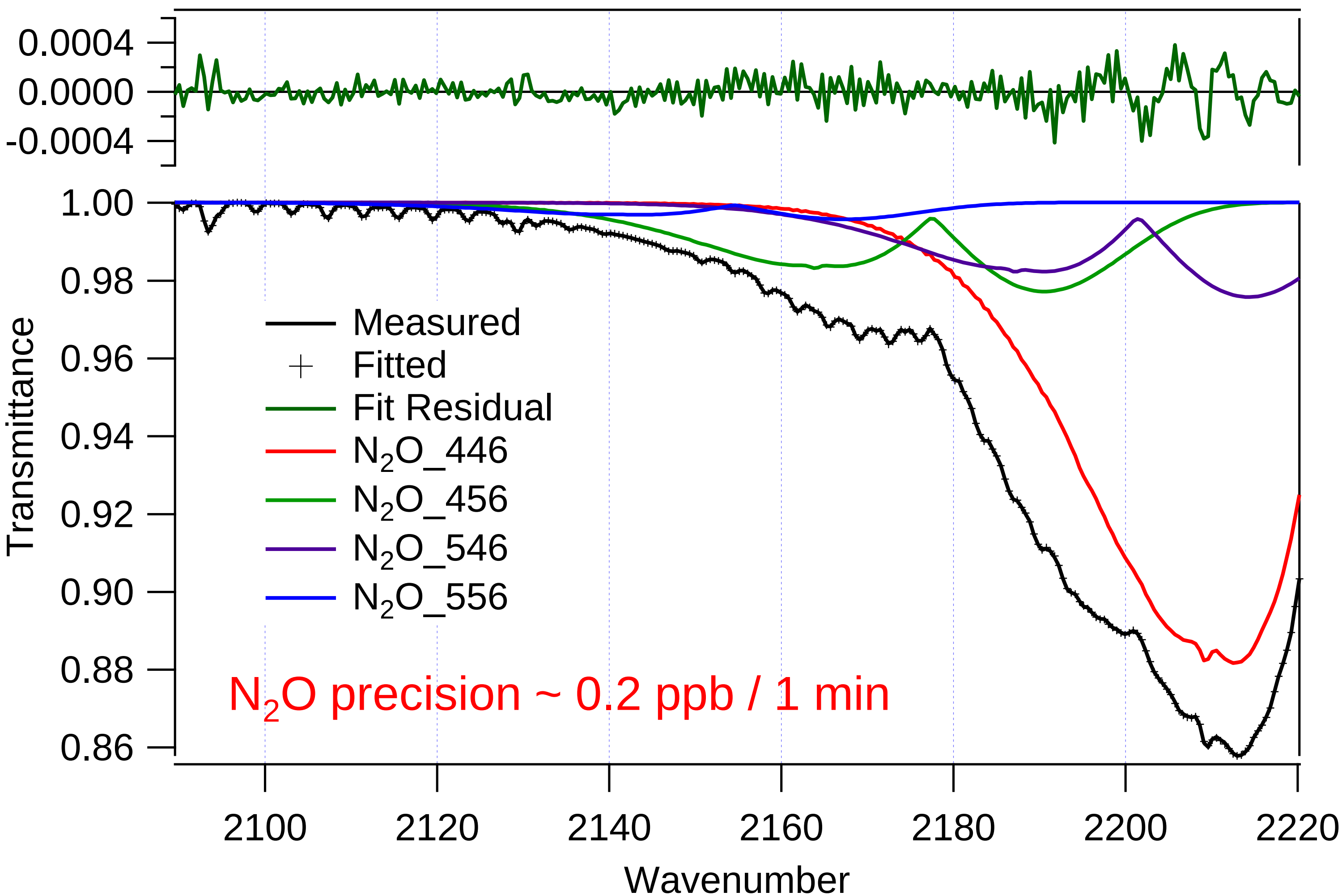
1. ^{15}N labelling in soil chamber experiments

Outline

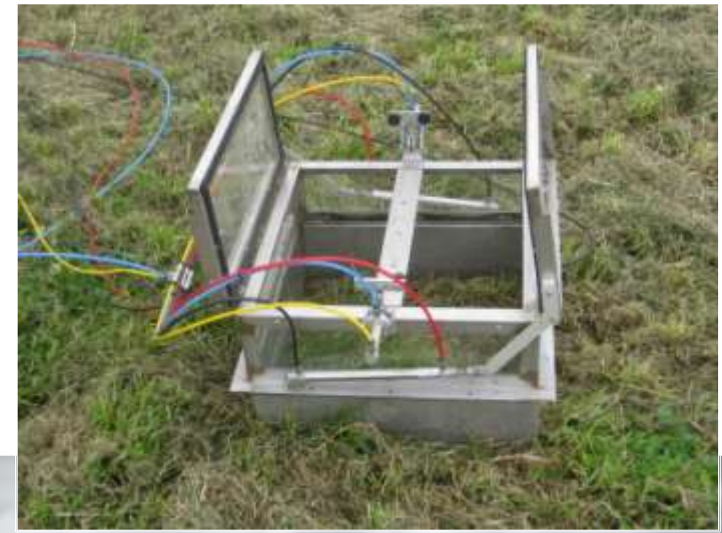
- Combine the FTIR analyser with automated chambers
  - Continuous measurements of CO_2, N_2O, all ^{15}N-N_2O isotopologues, CH_4, CO
- Add ^{15}N as nitrate or urea to soil
  - Partition emitted $^{15}N_2O$ into soil N pool and added ^{15}N
- Use FTIR to measure emissions of
  - $^{14}N^{14}NO$ - 446
  - $^{14}N^{15}NO$ - 456
  - $^{15}N^{14}NO$ - 546
  - $^{15}N^{15}NO$ - 556
- Measure ^{15}N in soil/root/shoot/microbial components (IRMS)
- Attempt a N mass balance for the added ^{15}N

Fitted IR spectrum

N_2O isotopologues ~ 2200 cm^{-1}



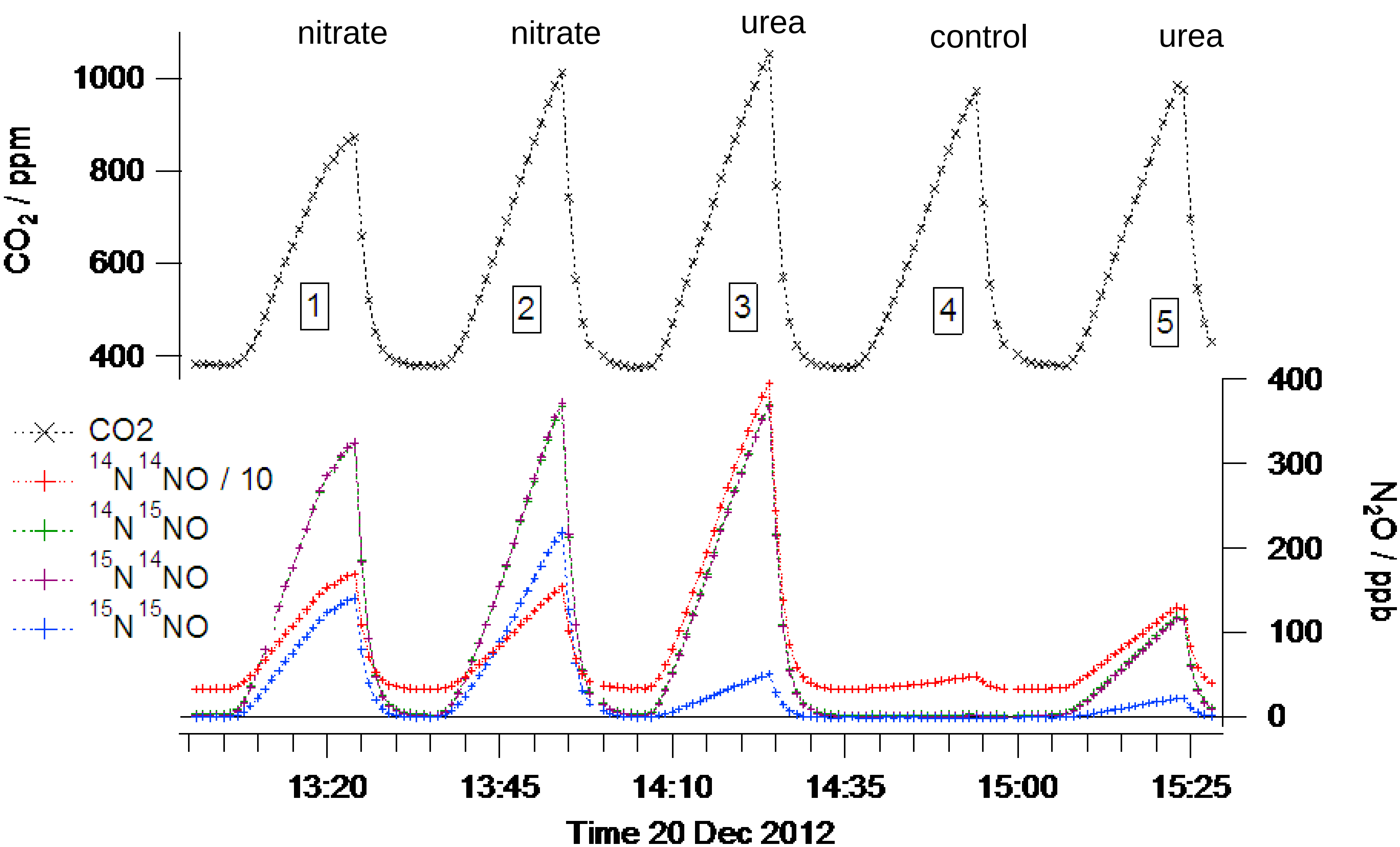
Site: Nowra, SE NSW



Measurement Protocol

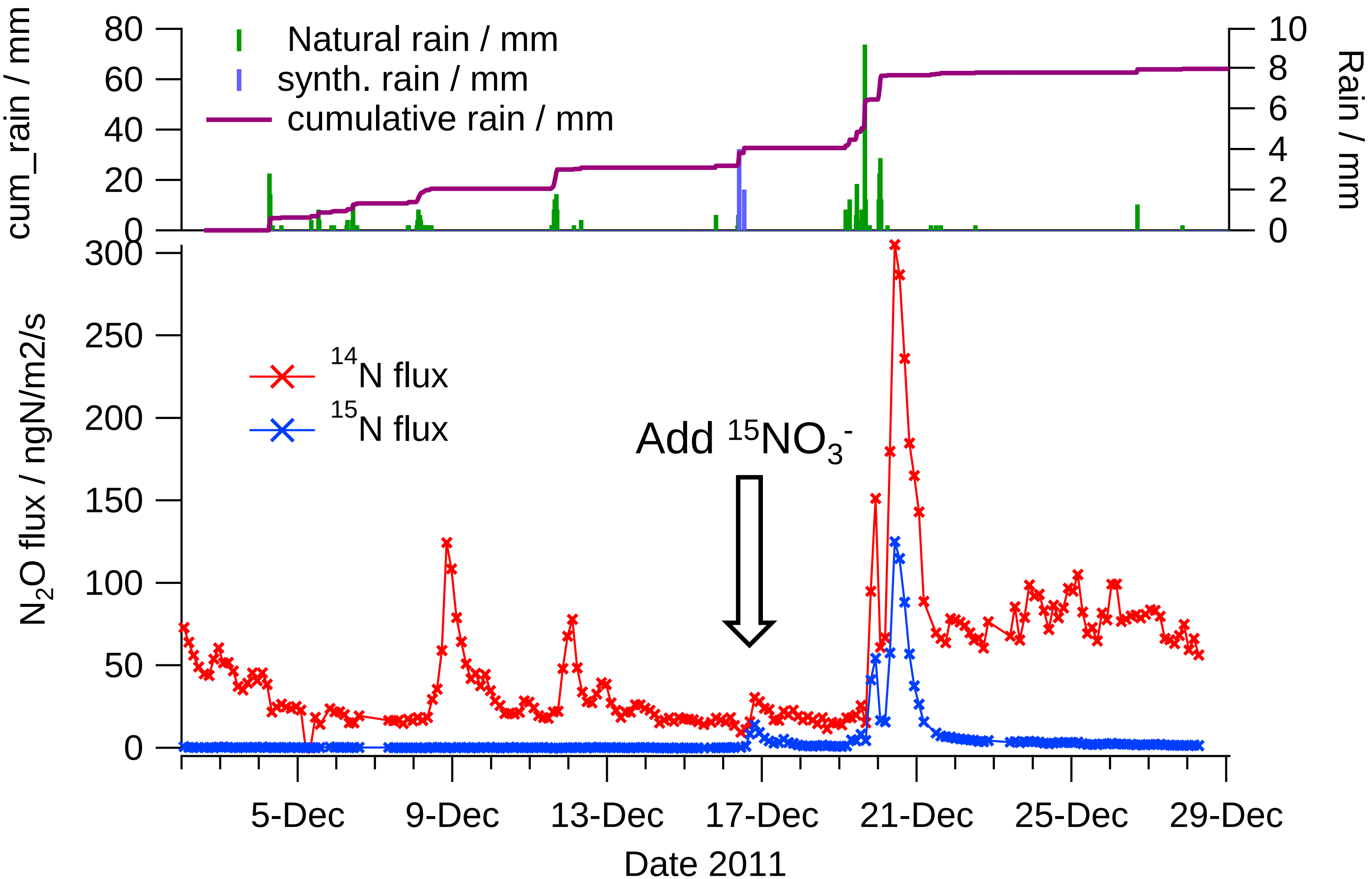
- Two 4-week trials
  - 2-28 Dec 2011
  - 2-30 Jan 2012
- 5 chambers: for each trial
  - 2 dosed with $K^{15}NO_3$ at ~800 or 400 mg^{15}N m^{-2}
  - 2 dosed with ^{15}urea at ~400 mg^{15}N m^{-2}
    - 4-8 kg ha^{-1}, ~ 10% of soil N pool
  - 1 control
  - Chambers moved between trials
- Each chamber sampled every 3 hours
  - 30 min per chamber
  - 6 min open, 18 min closed, 6 min open
  - 1 min per FTIR measurement of N_2O, isotopologues, CO_2, CO, CH_4
  - Gradient measurement on mast in 6th half hour period
  - Continuous over each 4 week period

Time series (1 cycle, 5 chambers)

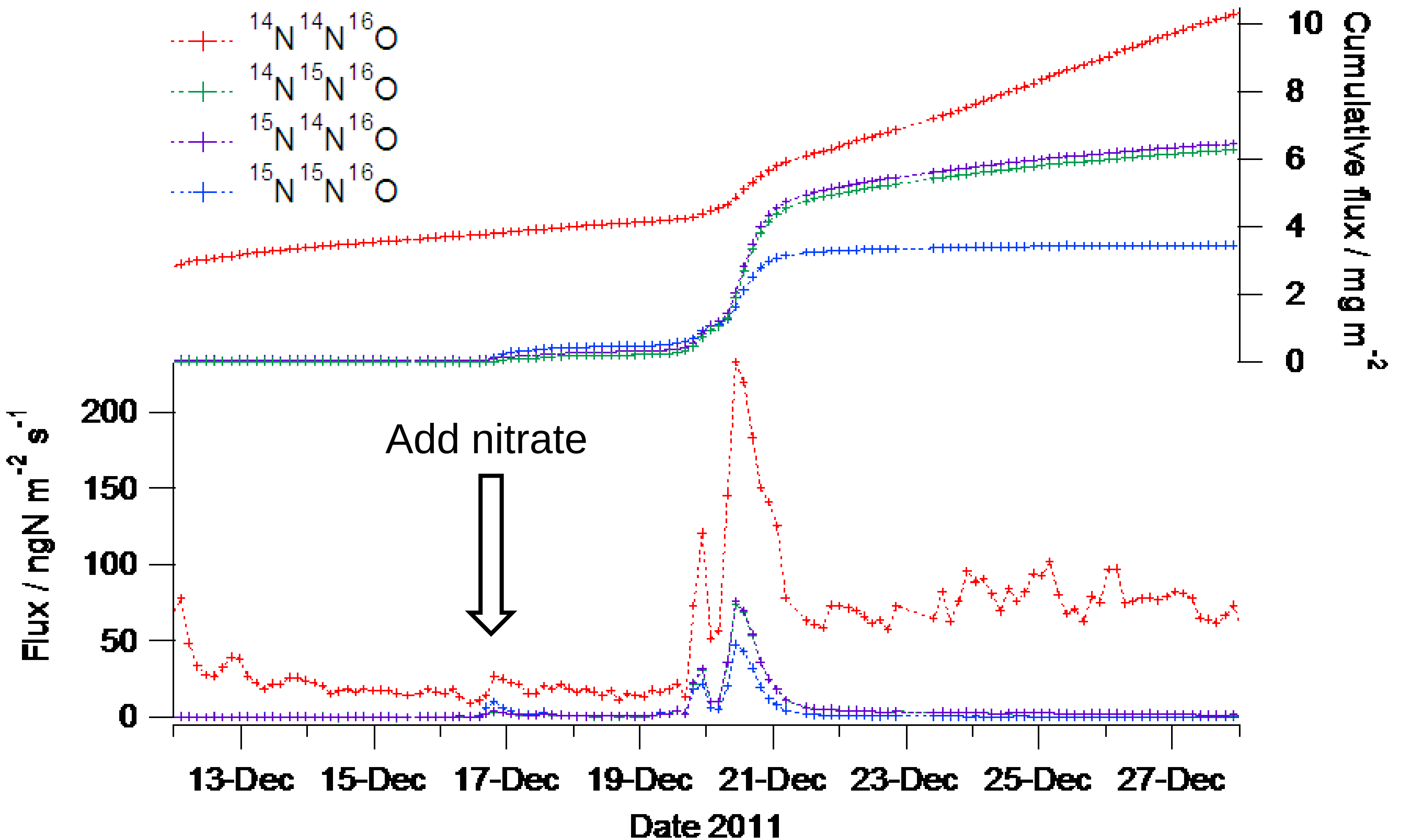


Trial 1: total ^{14}N and ^{15}N fluxes

relationship to rain



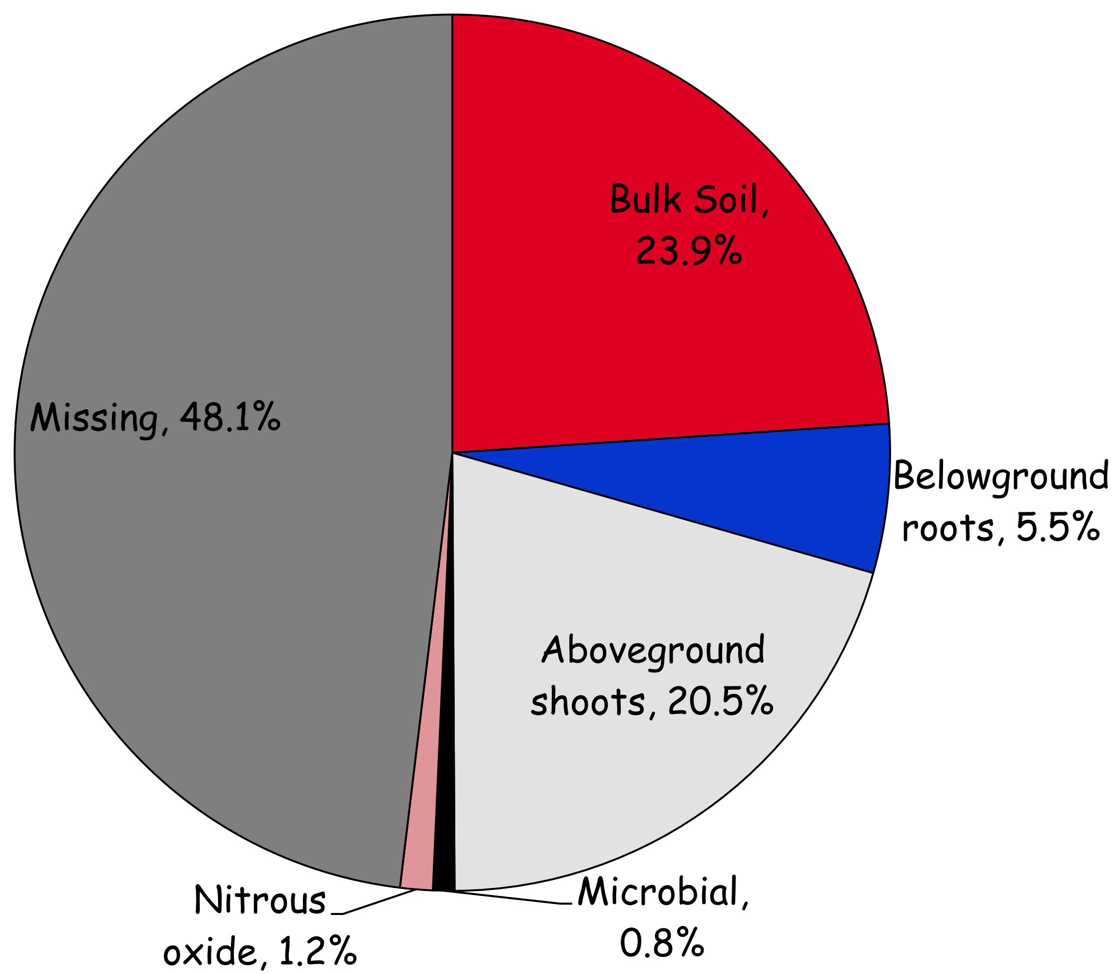
Cumulative fluxes, trial 1 nitrate addition



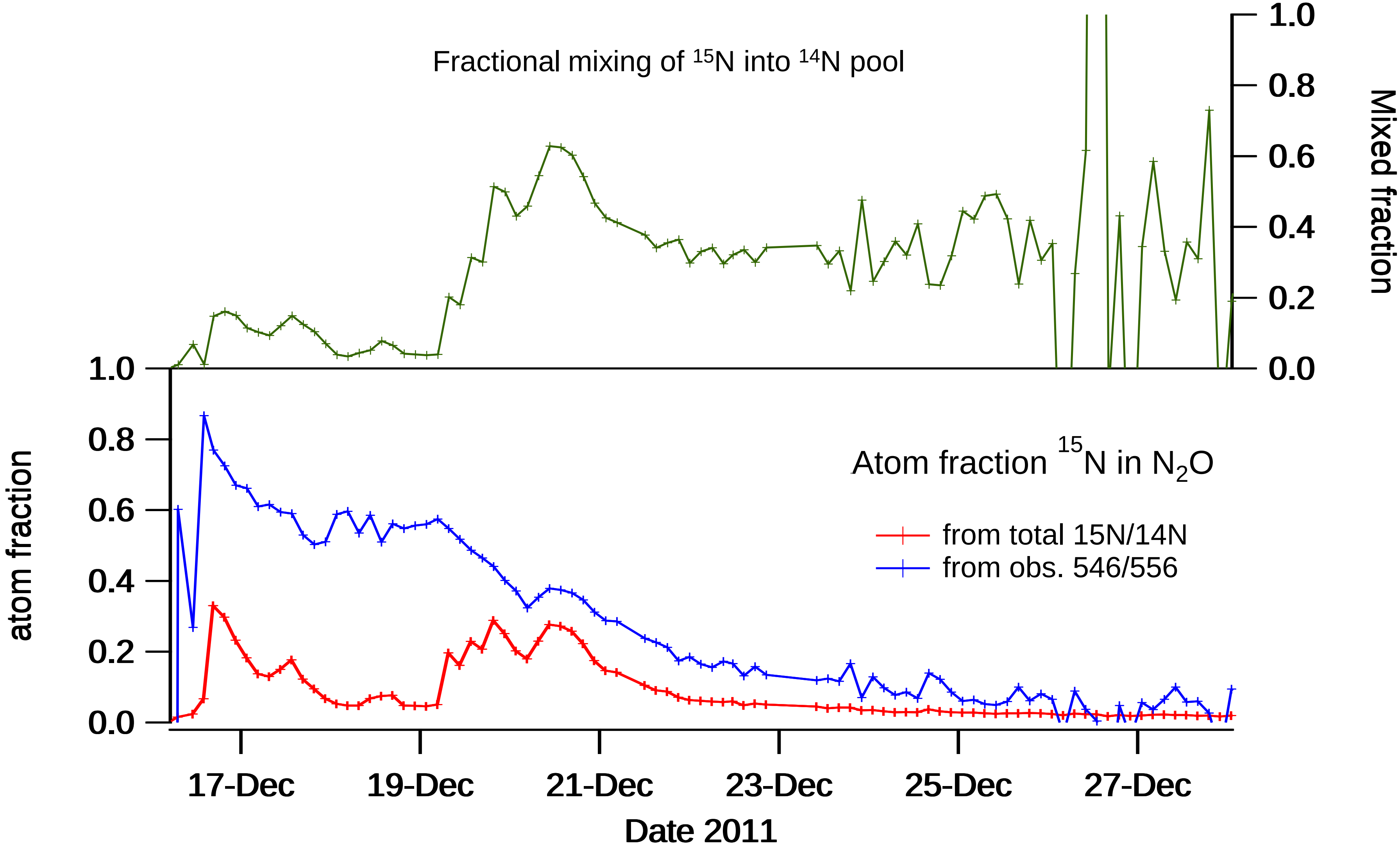
^{15}N recovery, all measurements

Chamber	Added 15N	Bulk Soil	Belowground roots	Aboveground shoots	Microbial	Nitrous oxide	Total 15N recovery	Total 15N recovery	Recovery as N2O
	mg/m2	mg/m2	mg/m2	mg/m2	mg/m2	mg/m2	mg/m2	%	%
1	858	205.4	47.1	175.8	6.8	10.3	445.4	51.9%	1.2%
2	858	139.7	25	121	9.2	10	304.9	35.5%	1.2%
3	503	202.5	13.1	83.6	14	9.55	322.8	64.2%	1.9%
5	503	208.5	39.9	68.8	30.3	3.95	351.5	69.9%	0.8%
4	0					-0.02			
1	419	134.6	40.4	71	16.7	3.04	265.7	63.4%	0.7%
2	419	236.7	25.7	35.8	8.6	4.19	311.0	74.2%	1.0%
3	415	177	32.2	36.3	13	3.75	262.3	63.2%	0.9%
4	415	340.3	25.6	28.2	14.4	1.55	410.1	98.8%	0.4%
5	0					-0.02			

^{15}N mass balance
Trial 1, chamber 2 (nitrate)



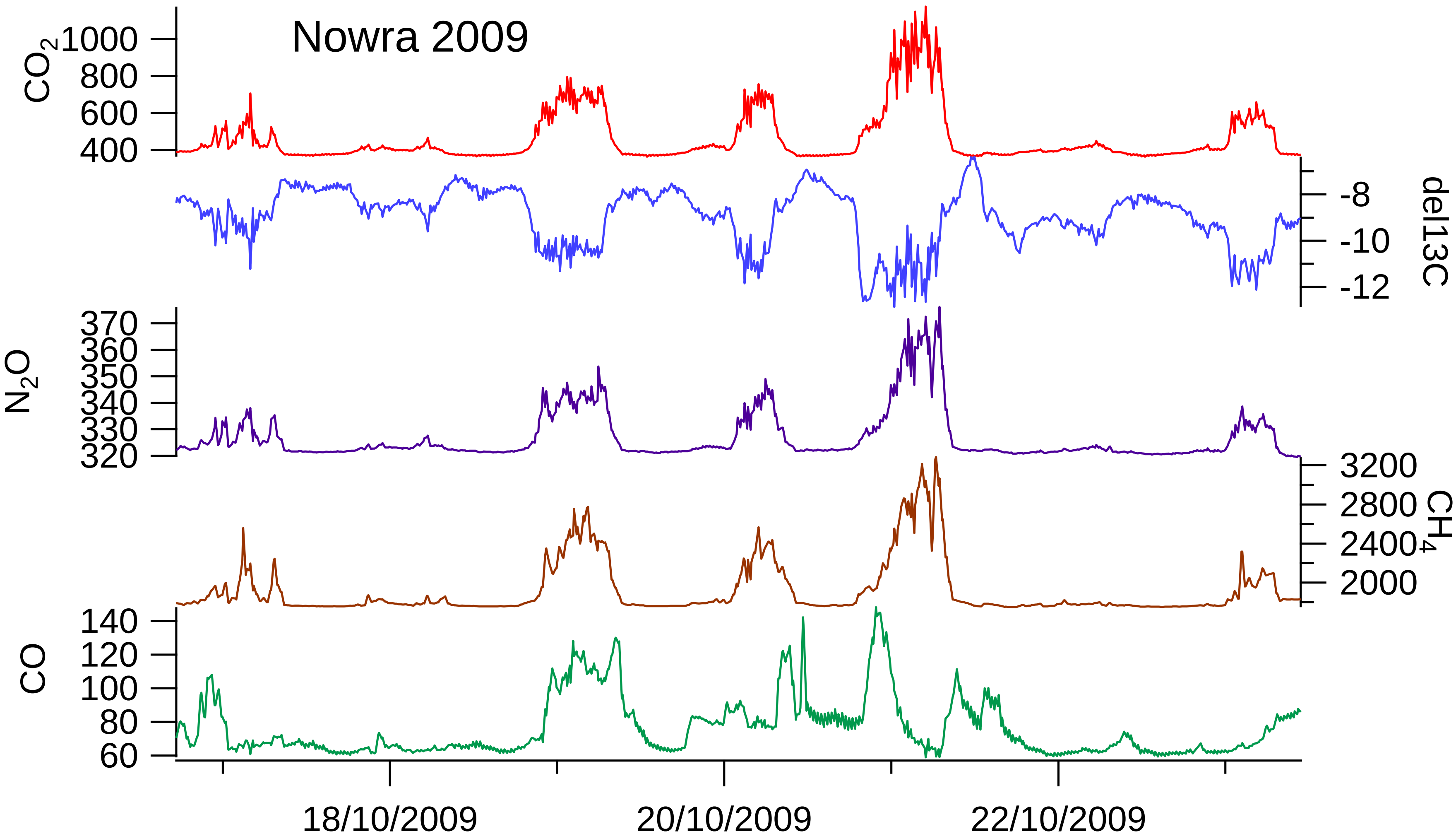
^{15}N mixing into the ^{14}N pool



Summary - ^{15}N chambers

- Partition N_2O emissions from added ^{15}N and existing soil ^{14}N pool
  - Direct measurement of $\Delta N_2O/\Delta$fertiliser
- Recover ~ 50-60% of added ^{15}N
  - N_2O
  - Soil
  - Roots
  - Shoots
  - Microbial
- ~1% of added N emitted as N_2O
  - Consistent with IPCC tier 1 guideline
- Added ^{15}N mixes with only 40% of soil pool

2. N_2O fluxes from tracer measurements in the NBL



An earlier FTIR study (open path)

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Measuring nitrous oxide emission rate from grazed pasture using Fourier-transform infrared spectroscopy in the nocturnal boundary layer

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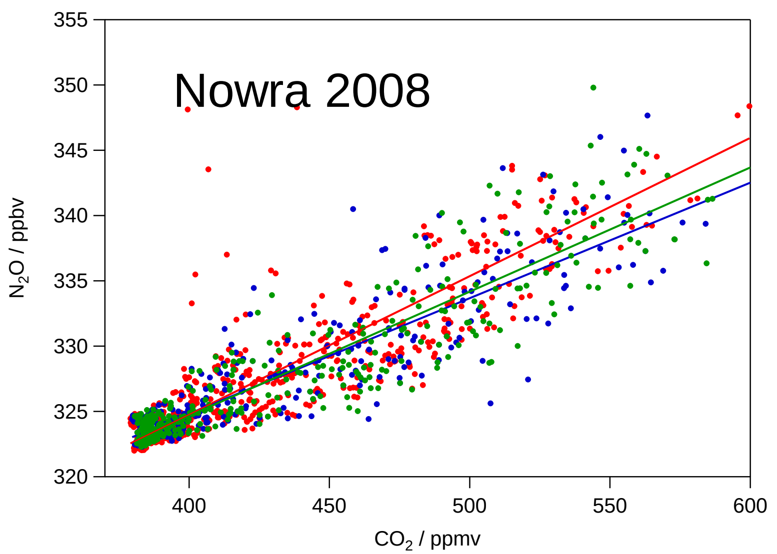
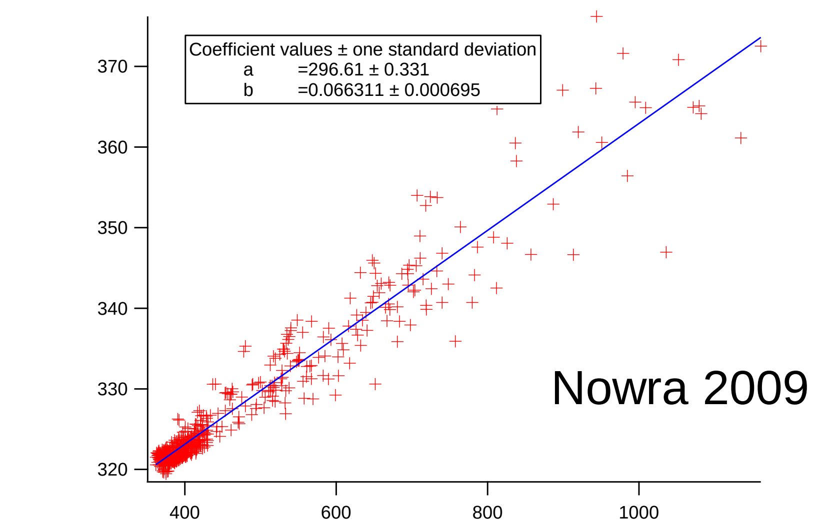
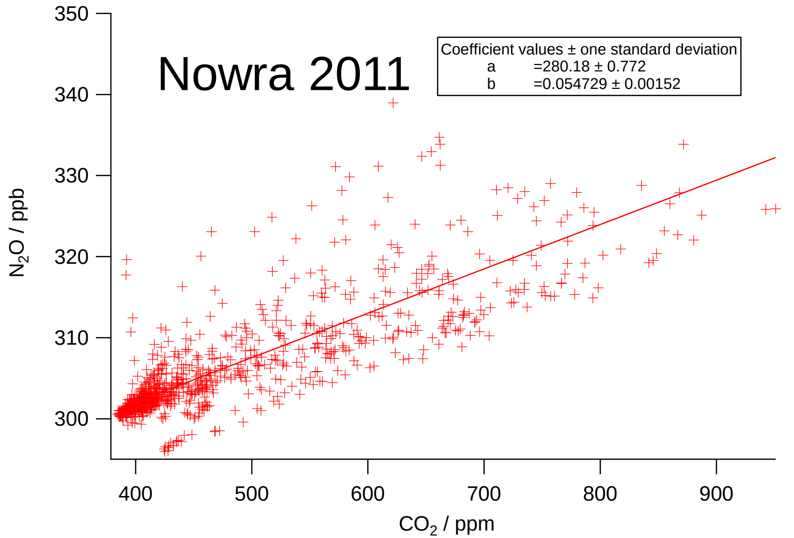
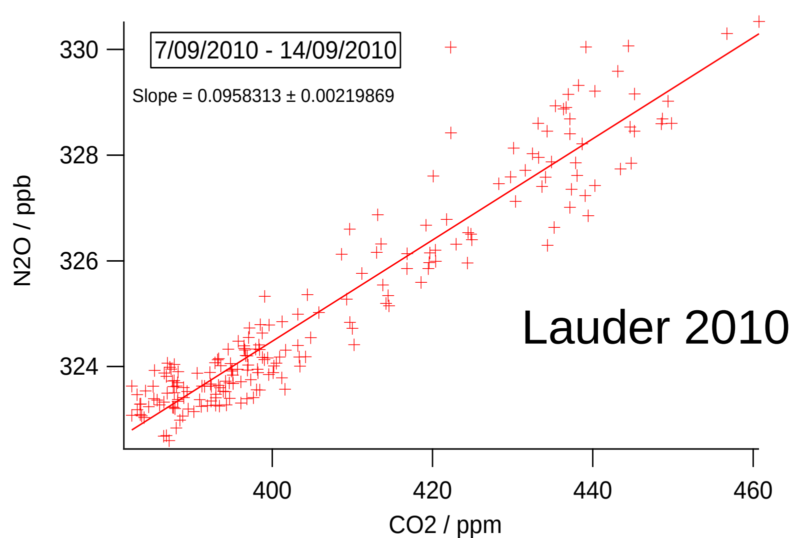
FTIR measurements of N_2O vs CO_2

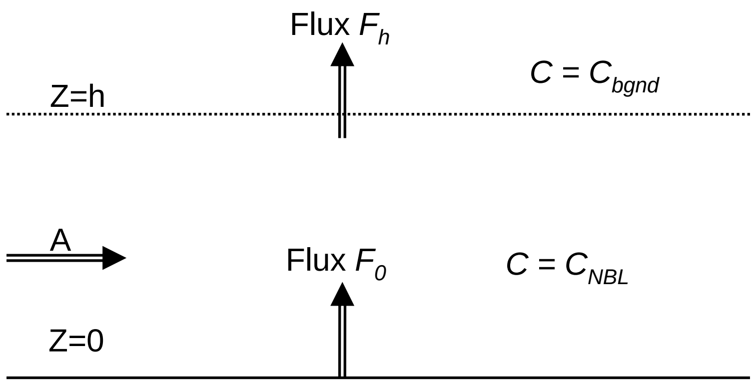








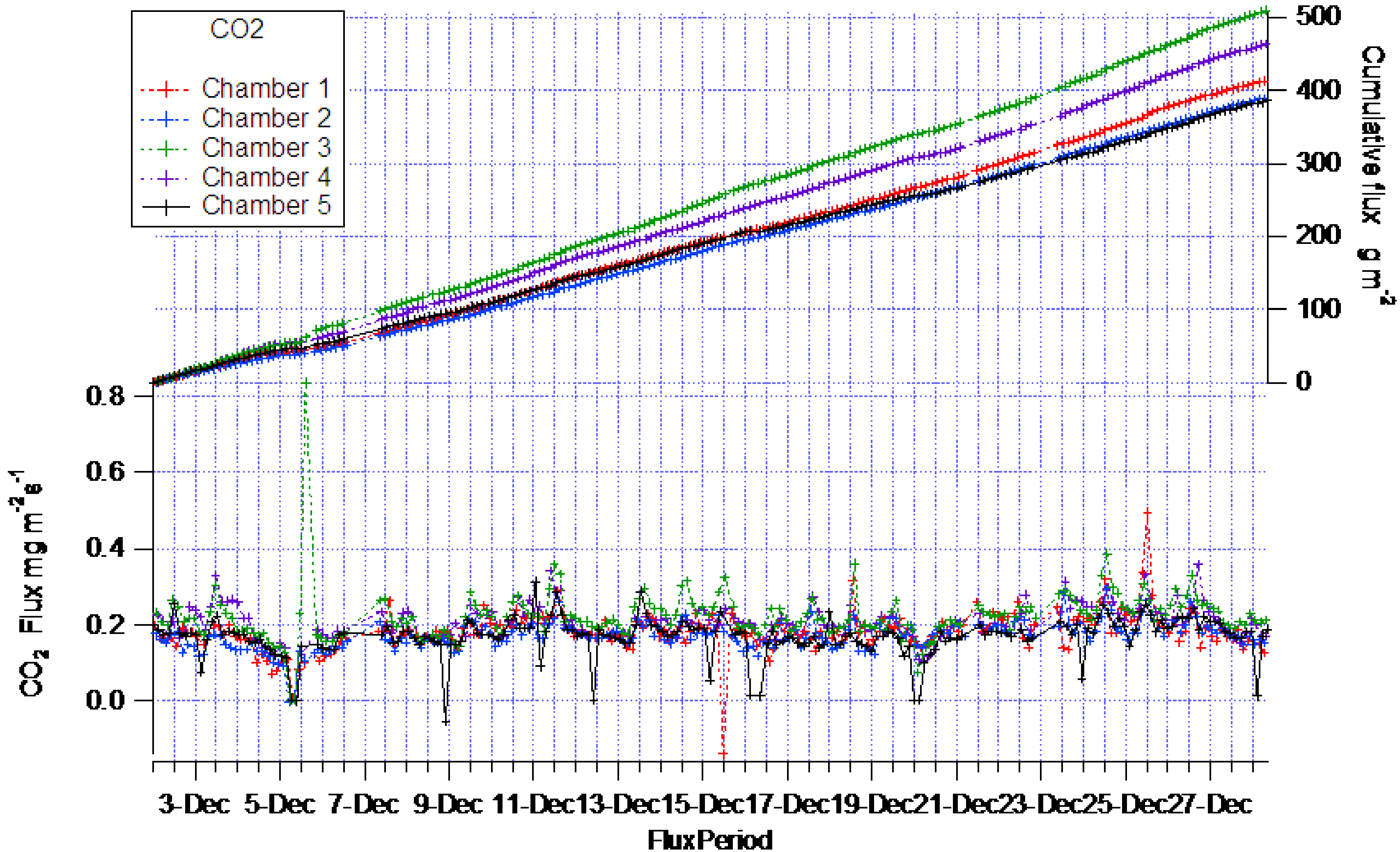
NBL tracer model



$$F_{0,N_2O} = F_{0,CO_2} \cdot \frac{dC_{NBL,N_2O}}{dC_{NBL,CO_2}}$$

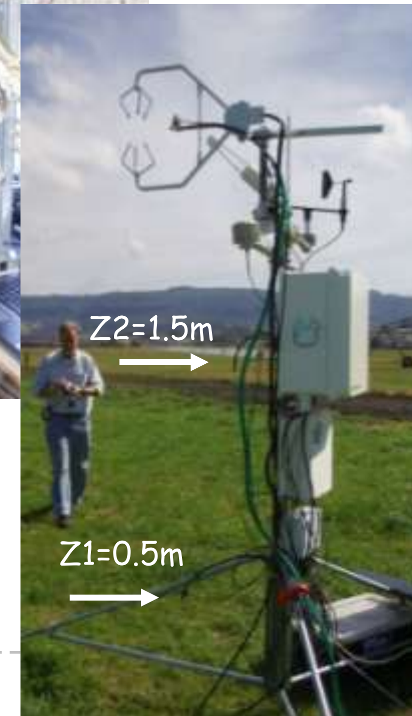
- Assumptions / limitations
  - A=0: no advection (infinite horizontal extent)
  - N_2O and CO_2 releases have same footprint (surface)
  - $F_h\ \alpha^{nl}\ C_{NBL} - C_{bgnd}$ entrainment flux depends on gradient at *h*
  - Point measurements of *C* are α^{nl} to C_{NBL}
  - $C_{NBL} \sim C_{BGND}$ at t=0 (start of the night)

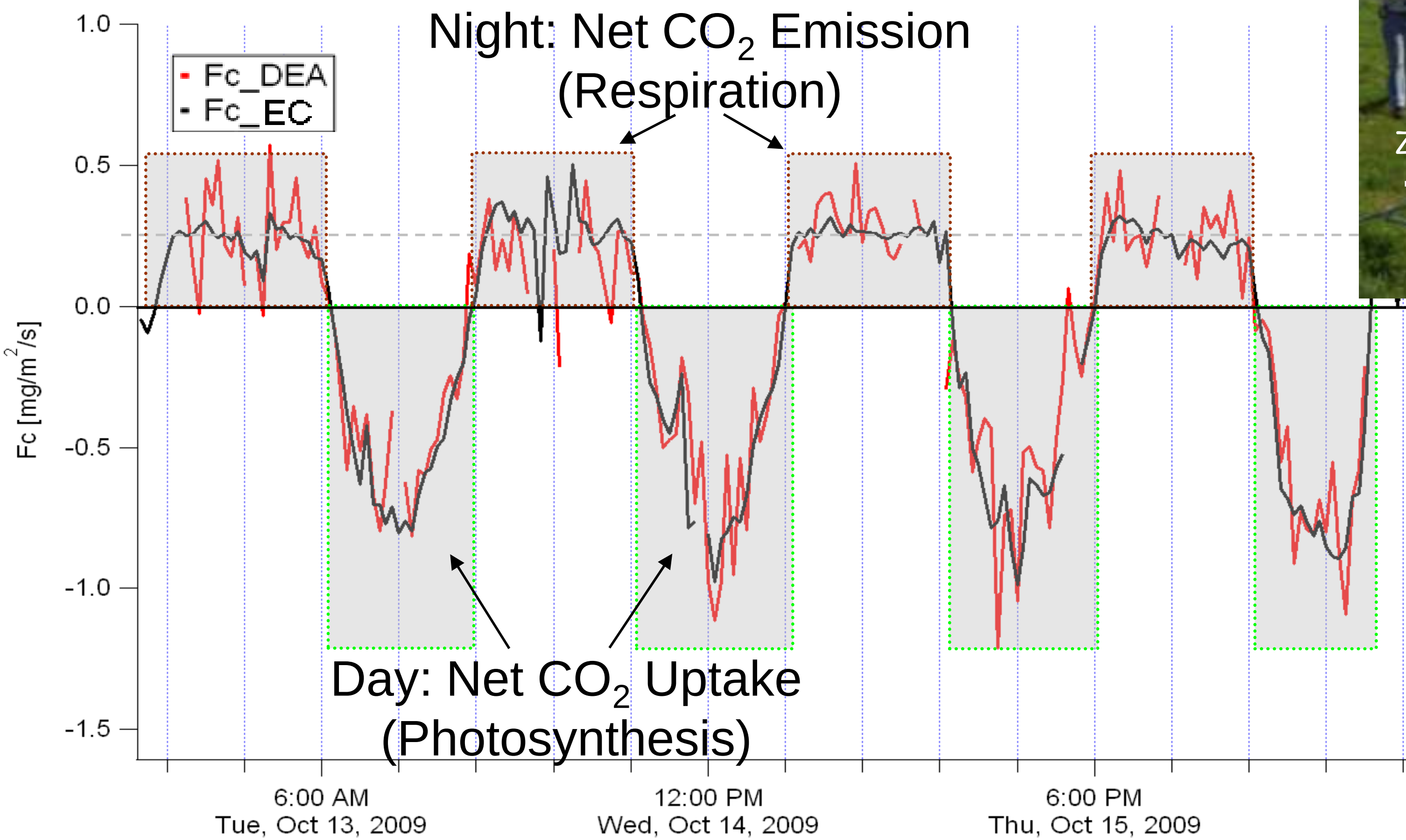
CO_2 flux, chambers, trial 1



Fluxes: flux gradient and eddy accumulation methods

Here: Disjunct Eddy Accumulation



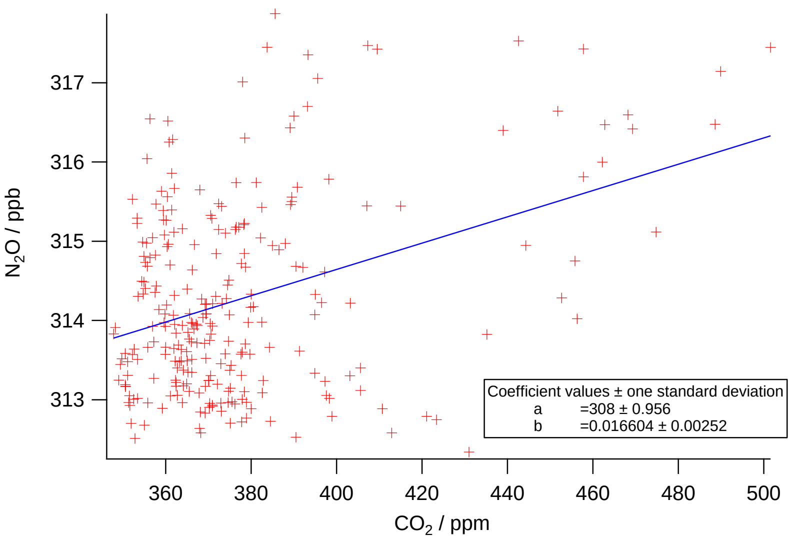


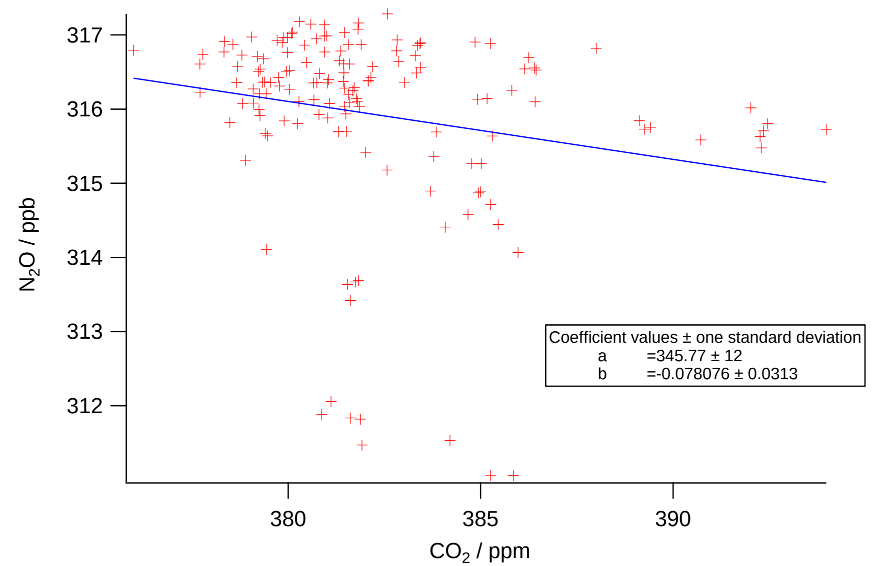
Regional N_2O emissions estimates

Location	Slope ppb/ppm	F_{CO2} mgCO2 m^{-2} s^{-1}	F_{N2O} ngN m^{-2} s^{-1}
Nowra Aug 2008	0.092	0.1	5.8
Nowra Oct 2009	0.066	0.25	10.5
Nowra Dec 2011	0.056	0.2	7.1
Lauder Sept 2010	0.095	*0.1**	*6.0*

* *guesstimate*

It doesn't always work!

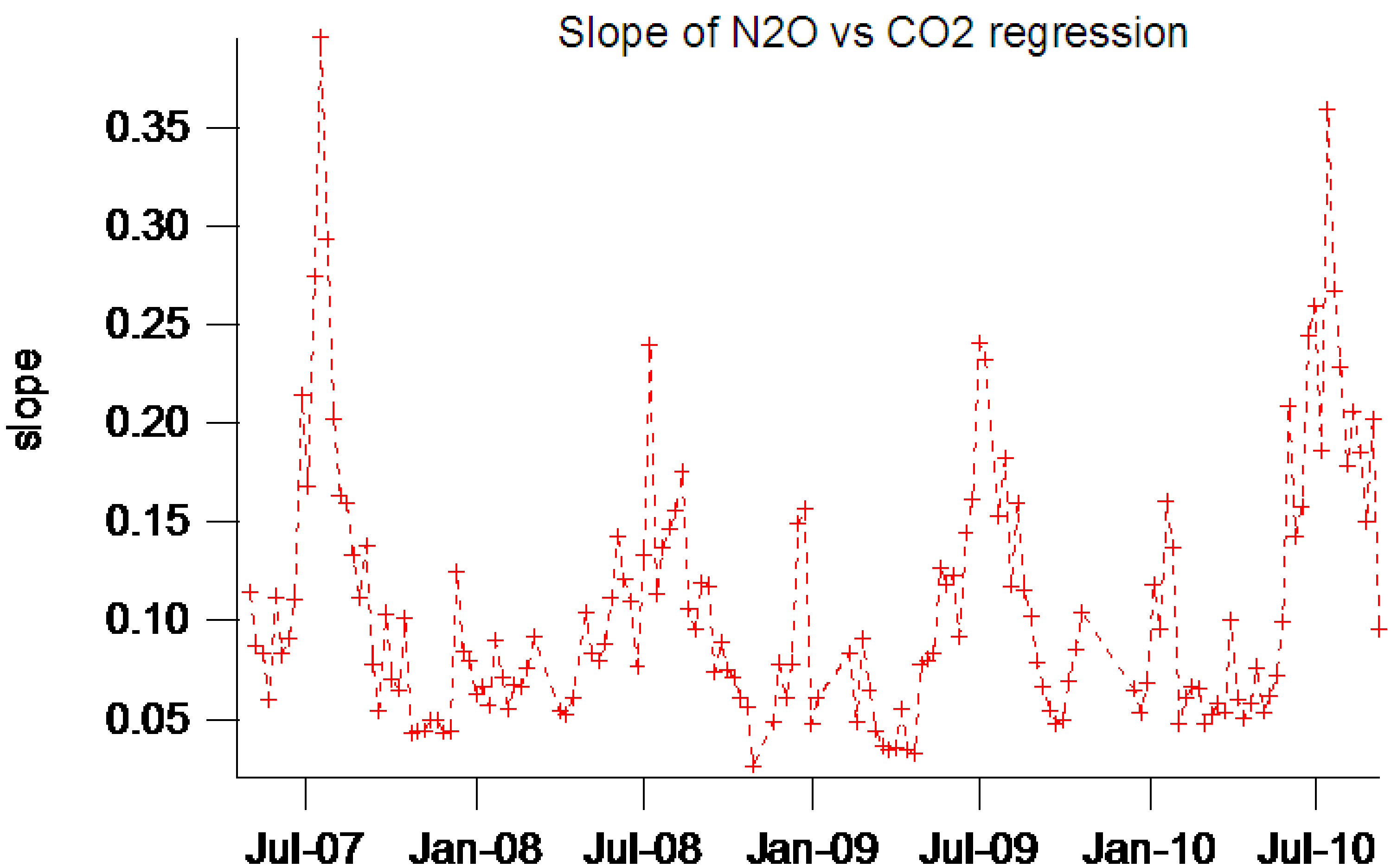




- OASIS – Wagga Wagga
- October 1995
- 22m tower, mixed agriculture
- Spring lucerne pasture

- Ozflux tower, Tumbarumba
- Nov 2006
- 70 m tower, eucalypt forest
- Weak N_2O uptake?

Lauder time series dN_2O/dCO_2



Summary - NBL regional estimates

- Require 2 measurements:
  - $dN_2O/d(tracer)$
  - an independent estimate of F_{tracer}
    - Here tracer is CO_2

$$F_{0,N_2O} = F_{0,CO_2} \cdot \frac{dC_{NBL,N_2O}}{dC_{NBL,CO_2}}$$

- If
  - N_2O and tracer (CO_2) emissions are co-located
  - Uniform emissions landscape
- Then
  - Regional emissions estimates to < 2 ngN m^{-2} s^{-1}
    - 2 ngN m^{-2} s^{-1} => vertical gradient of ~ 0.02 ppb m^{-1}
- Suitable for background emissions over large uniform areas
  - Eg cropping & pasture
  - Ozflux sites
  - Canterbury Plains – Landcare's FTIR
  - CH_4 too?

Thank you

- UoW:
  Chris Caldow, Graham Kettlewell, Travis Naylor, Martin Riggenbach
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- CSIRO:
  Ray Leuning, Tom Denmead
- Uni Bremen:
  Katinka Petersen, Thorsten Warneke

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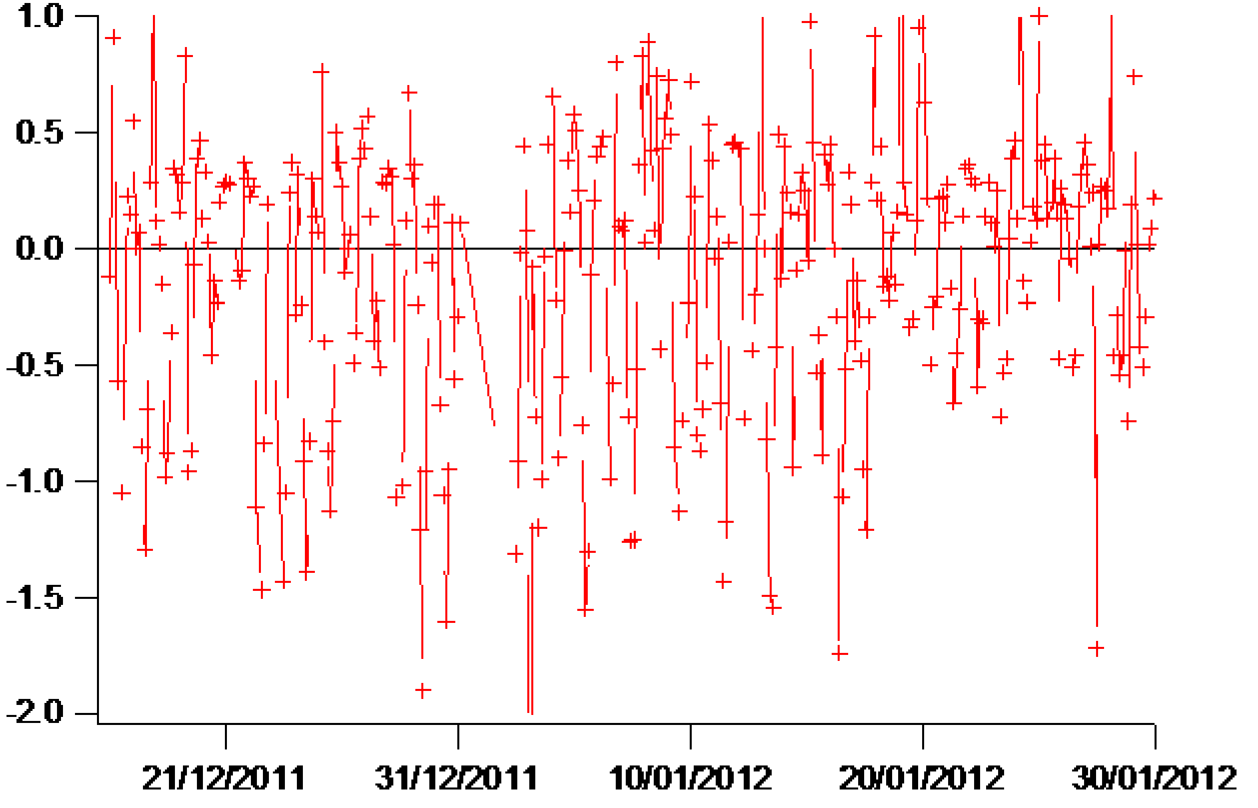
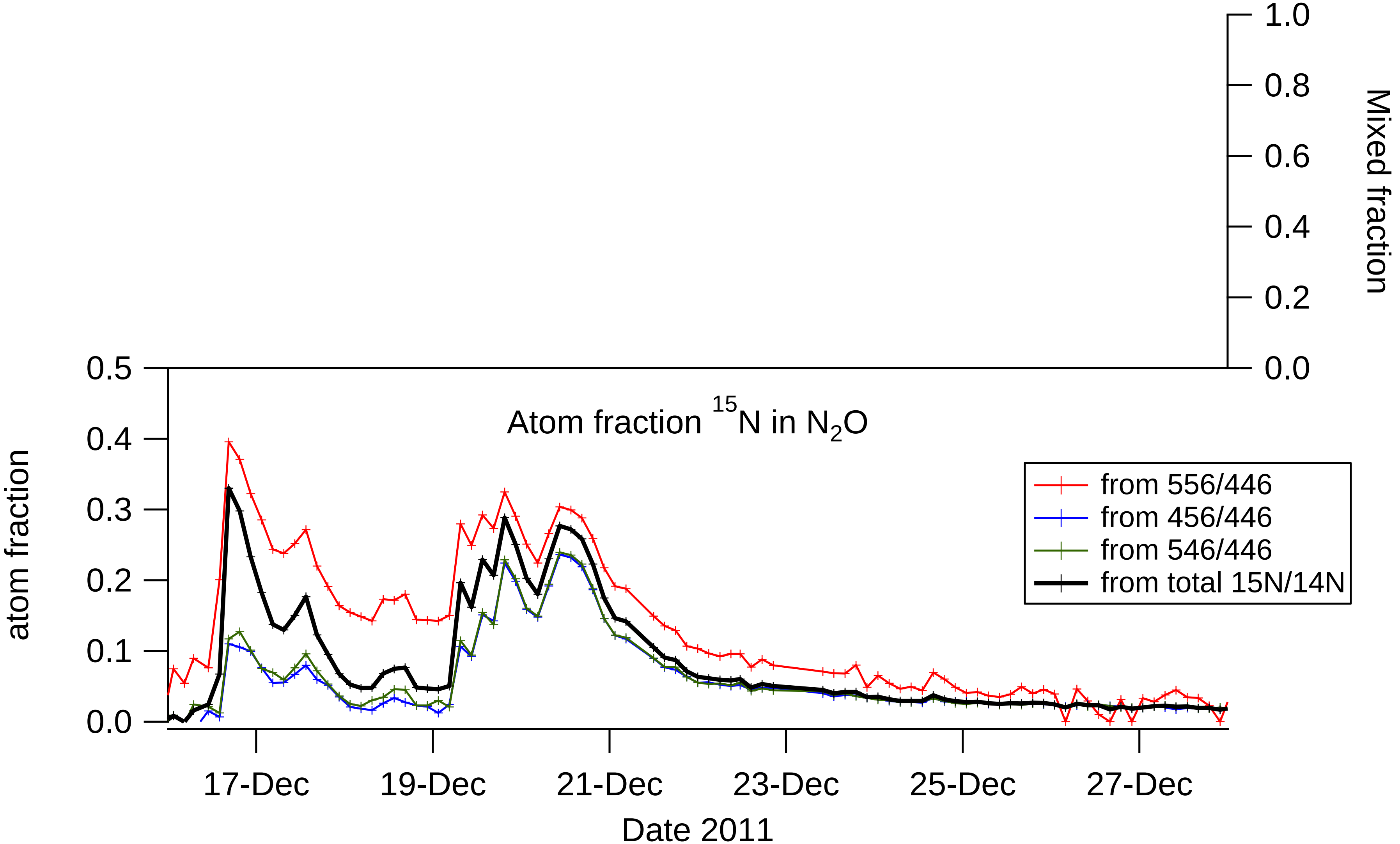
CO_2 flux – eddy covariance

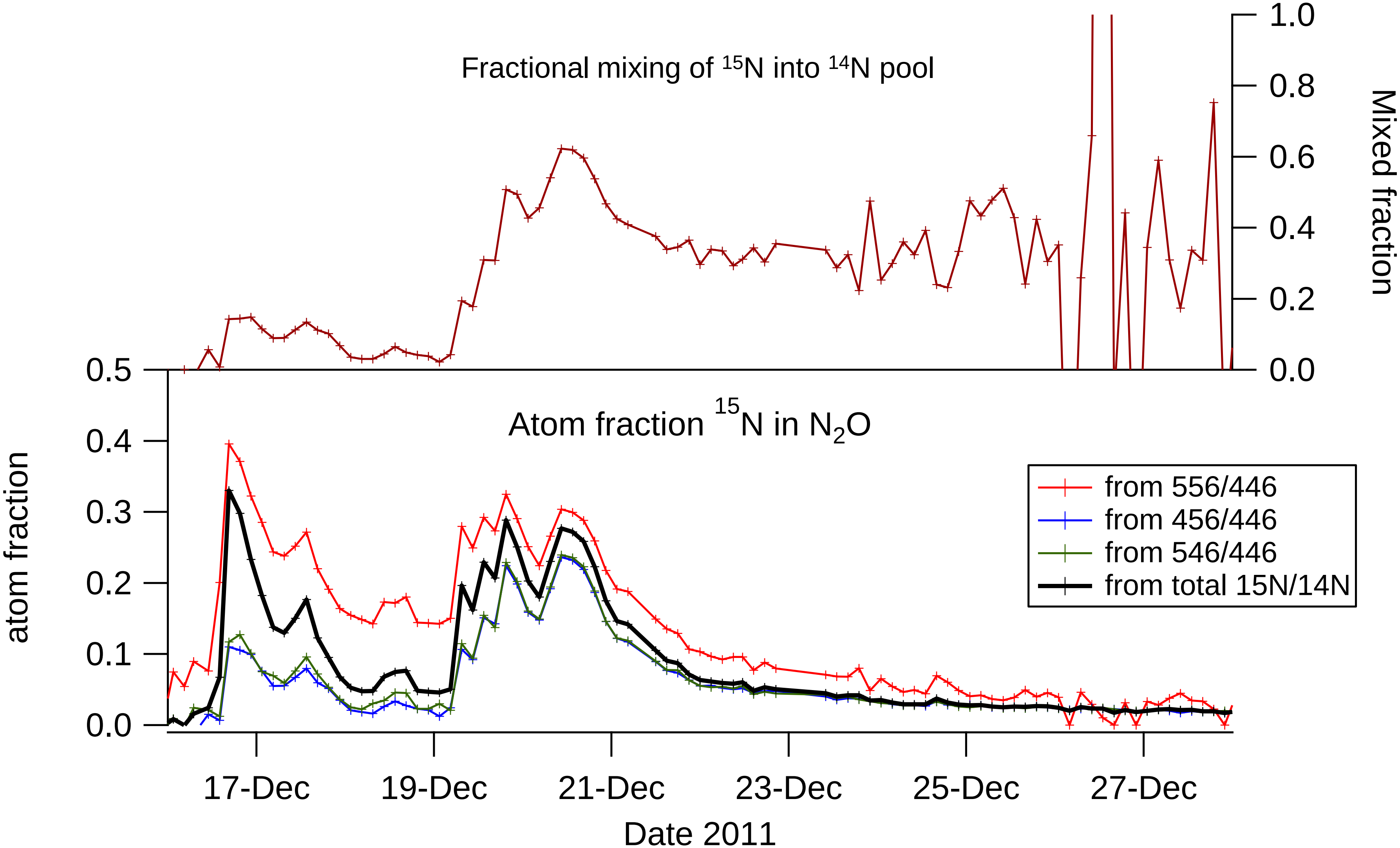


^{15}N mixing



1.0
0.8
0.6
0.4
0.2
0.0
Mixed fraction
0.5
0.4
0.3
0.2
0.1
0.0
atom fraction
Atom fraction 15N in N2O
from 556/446
from 456/446
from 546/446
from total 15N/14N
17-Dec
19-Dec
21-Dec
23-Dec
25-Dec
27-Dec
Date 2011

^{15}N mixing



Fractional mixing of 15N into 14N pool
Mixed fraction
1.0
0.8
0.6
0.4
0.2
0.0
Atom fraction 15N in N2O
atom fraction
0.5
0.4
0.3
0.2
0.1
0.0
from 556/446
from 456/446
from 546/446
from total 15N/14N
17-Dec
19-Dec
21-Dec
23-Dec
25-Dec
27-Dec
Date 2011