Nitrous oxide fluxes from a Scottish grassland measured by eddy covariance: a comparison between different systems

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InGOS

Integrated non-CO_2 Greenhouse gas Observing System

Objectives of the WP5 **InGOS** field campaign

- Improve eddy-covariance methods for N_2O flux measurement as an alternative to more commonly used enclosure methods.
- Compare state-of-the-art EC flux measurement systems
- Give EU groups the chance to inter-compare their equipment and methods such as REA, aerodynamic gradient and eddy covariance
- Provide information to:
  - Standardise and improve QA/QC on non-CO_2 GHG flux measurements
  - Contribute to the discussion of standardised protocol for the measurements of N_2O EC fluxes.

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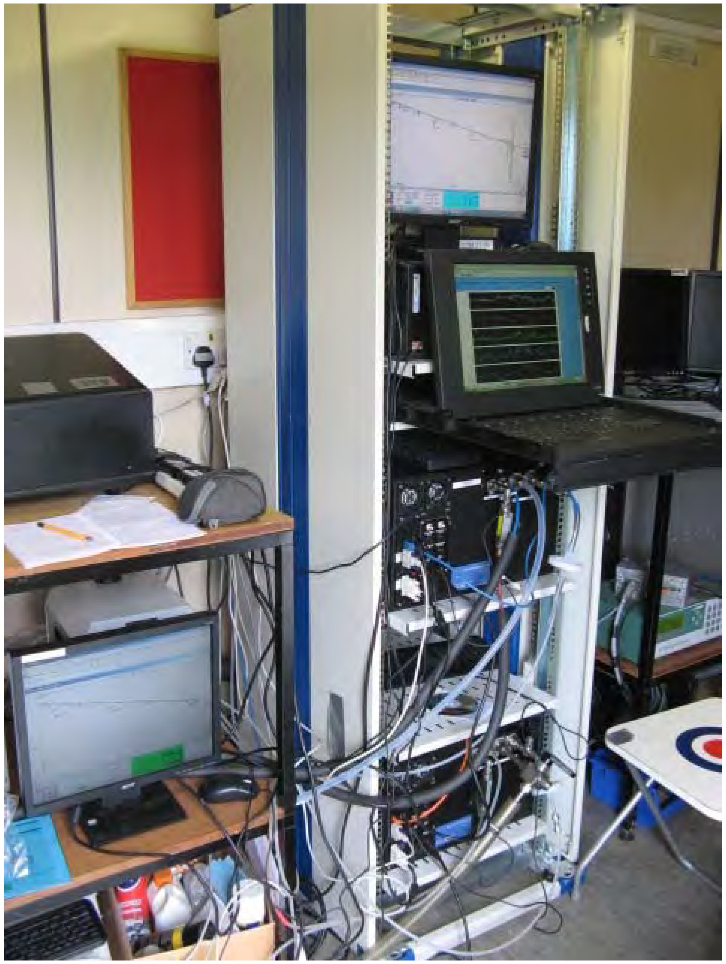
Instrumentation and project partners

Country	Institute	Instrument	Species measured	Method
Switzerland, The Netherlands, Germany, Australia	Ecotech/ Bremen University	Spectronus - FTIR trace gas analyser	all	Relaxed Eddy Accumulation
France	INRA Orleans	lab-built CW-QCL spectrometer "SPIRIT"	N_2O, CO_2, H_2O	Aerodynamic gradient
Italy	West Systems Srl	Trasportable accumulation chamber based fluxmeter.	N_2O, CO_2, CH_4	Dynamic enclosure
Finland	FMI	CRD Los Gatos Research + dryer	N_2O, CO, H_2O	Eddy Covariance
Finland	University of Helsinki	CRD Los Gatos Research	N_2O, CO, H_2O	Eddy Covariance
Denmark	Technical University of Denmark	CRD Los Gatos Research	N_2O, CO, H_2O	Eddy Covariance
Netherlands	ECN	Aerodyne Pulsed QCL	N_2O, CH_4, H_2O	Eddy Covariance
France	INRA Grignon	Aerodyne CW-QCL	N_2O, CH_4, H_2O	Eddy Covariance
United Kingdom	NERC - CEH	Aerodyne CW-QCL	N_2O, CO_2, H_2O	Eddy Covariance

Field cabin setup

3 x Los Gatos Research Lasers on same absorption lines for N_2O, CO and H_2O
Same model, but different firmware version/calibration, sample drying

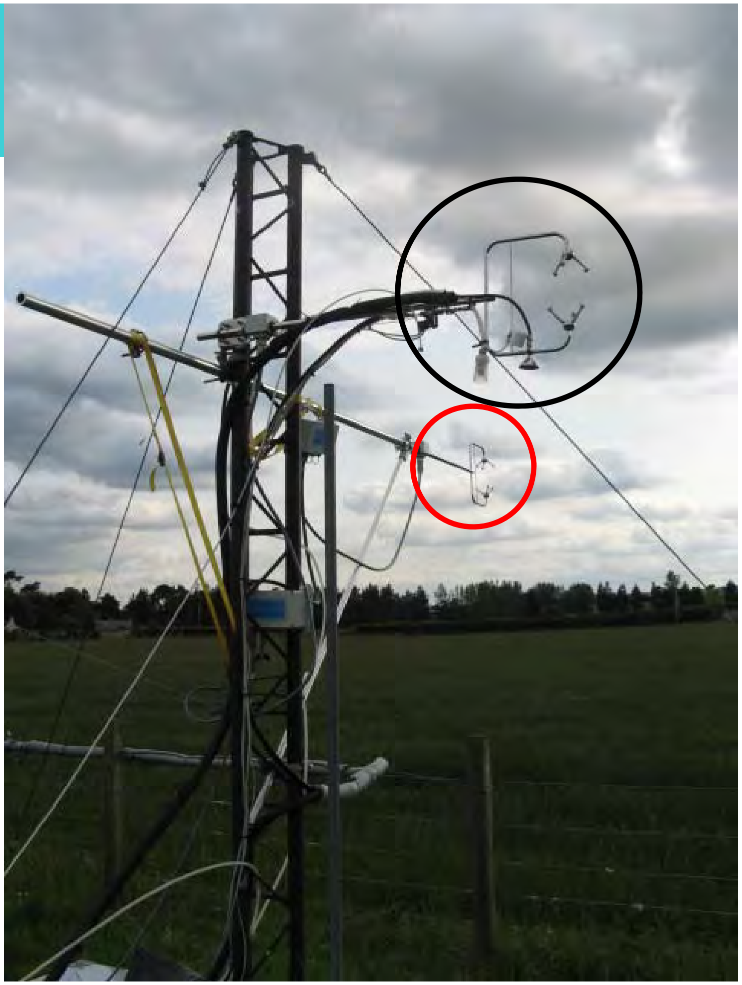


CW-QCL from Aerodyne Research x 2 systems: one optimised on absorption lines for CH_4, N_2O, H_2O, the other for H_2O, CO_2, N_2O
Pulsed-QCL from Aerodyne Research optimised on absorption lines for CH_4, N_2O, H_2O.

All systems logging on a communal PC running a custom-made LabView acquisition program, able to store data synchronously from the sonic anemometers and all EC-systems at 10Hz.

Field setup: inlets

Ultra sonic anemometers: 2 x Gill HS-50 disposed at a 90º angle, one along the fence line and one pointing into one of the fields (prevailing wind dir)
Inlet tubing was 3/8" OD, different materials were used: PE, Dekabon.
All lines were heated and insulated up to the analysers located indoors.
One LGR system moved between 2 sonics.



Flow rates:
Main common inlet = 43 l/min (4 combined)
DTU inlet = 30 l/min (1 system)
ECN inlet = 13.7 l/min (2 system, 1 REA)

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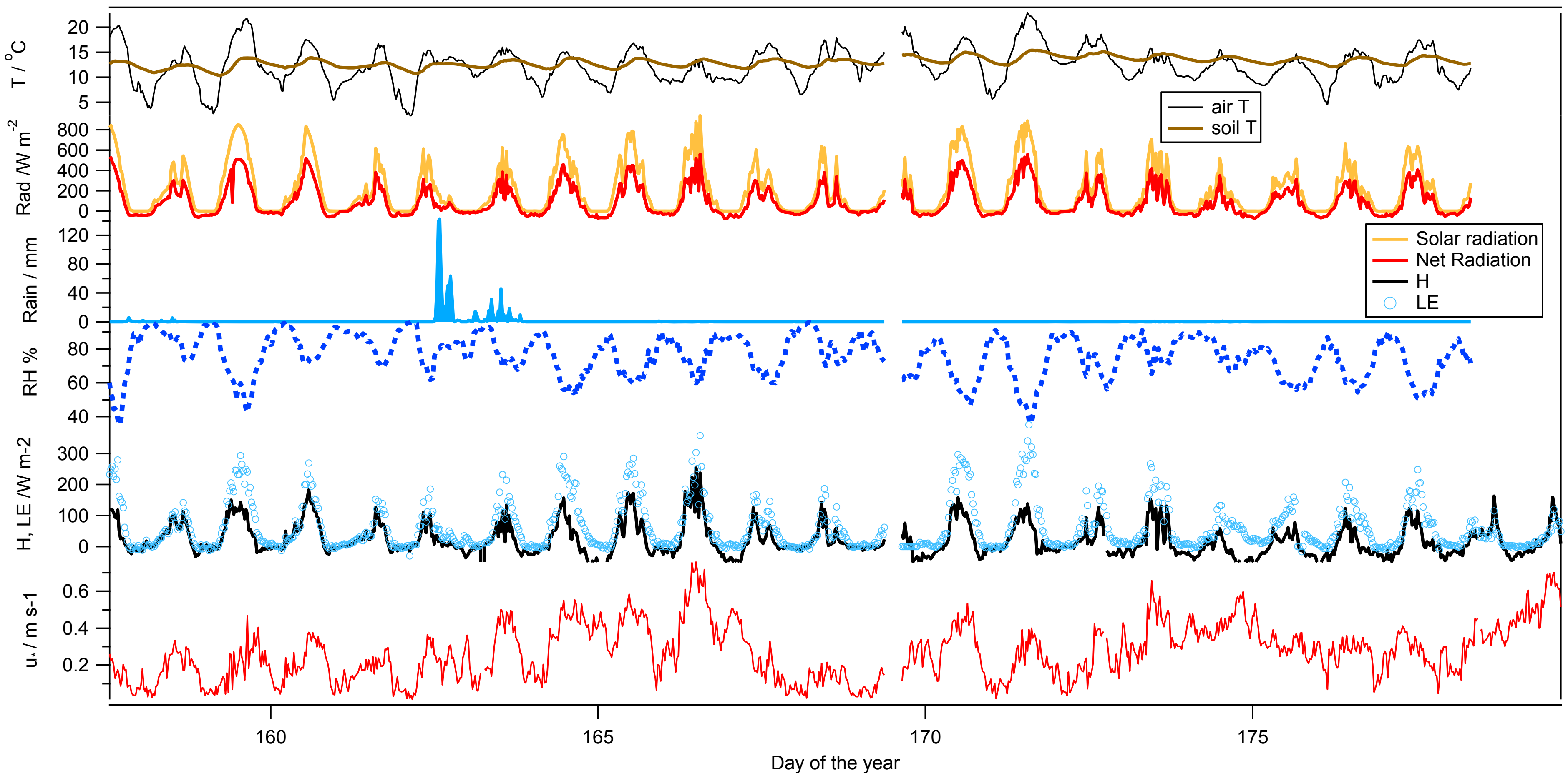
Intensively managed grassland with a permanent meteorological field station monitoring long term EC fluxes for CO_2, several years of N_2O by enclosure techniques.

Measurements started 3rd June 2013 and finished on 30th June 2013: first week of background measurements with sheep grazing on both fields

Both fields fertilised on 11th June, with NH_4NO_3 (34.5% N) at a rate of 150 kg/ha
Subsequent N_2O emissions measured for the following 3 weeks.

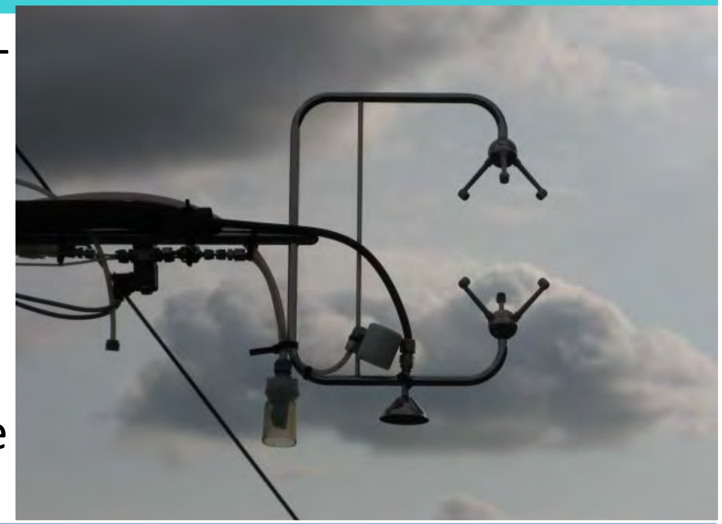
Easter Bush, Edinburgh Scotland 2013

Easter Bush meteorology June 2013



Easter Bush has a typical oceanic climate. In June 2013, the weather was unusually dry and sunny, with little rainfall, as a consequence of high pressure conditions. Turbulent fluxes of momentum and heat were in the typical range for the Easter Bush field site, representing a fairly stable summer month.

Calibration of all systems

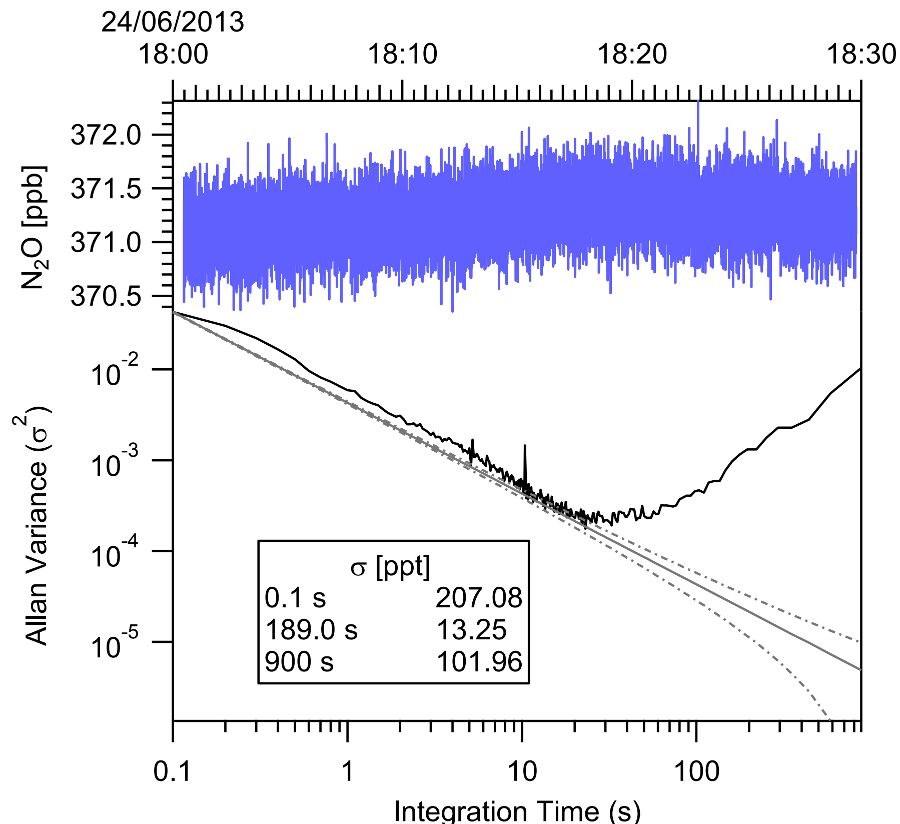


We used ordinary compressed air tanks as well as BOC-rated standard gas mixtures containing near-ambient levels of CH_4, CO_2, N_2O.
FTIR used as absolute value measurement, and reference to all others.
The compressed gas was overflowed at the inlet end near the sonic anemometer, to let all inlets sub-sample from it, for varying duration, min of 5 minutes.

	Measured values [ppb]			**Calibration factor rel. to FTIR**		
	Cylinder 1	**Cylinder 2**	**Cylinder 3**	**Cylinder 1**	**Cylinder 2**	**Cylinder 3**
		18.2 ppm CO			18.2 ppm CO	
LGR-FMI	387	334.3	381.5	0.929	0.944	0.927
LGR-UHEL	365	-6	360	0.985	-52.59	0.982
LGR-DTU	408	220.5	401.5	0.881	1.431	0.881
cwQCL-CEH	369.1	324	363.2	0.974		
cwQCL-INRA	378		371.2	0.951		0.953
pQCL-ECN	399		392	0.901		0.902
cwQCL-INRA(Spirit)	371			0.969		
FTIR		315.52				

N_2O precision and stability

As an outcome of the calibration exercise, an *Allan variance* study determines the precision at different rates of acquisition (here shown in pptV) for all systems



Instrument	0.1 s	best	15 min	RMSE
ECN QCL	767	213	636	137
CEH cw-QCL	200	19	38	20
INRA cw-QCL	207	13	102	23
DTU LGR	540	32	256	56
FMI LGR	1046	27	194	91
UHEL LGR	621	40	172	81

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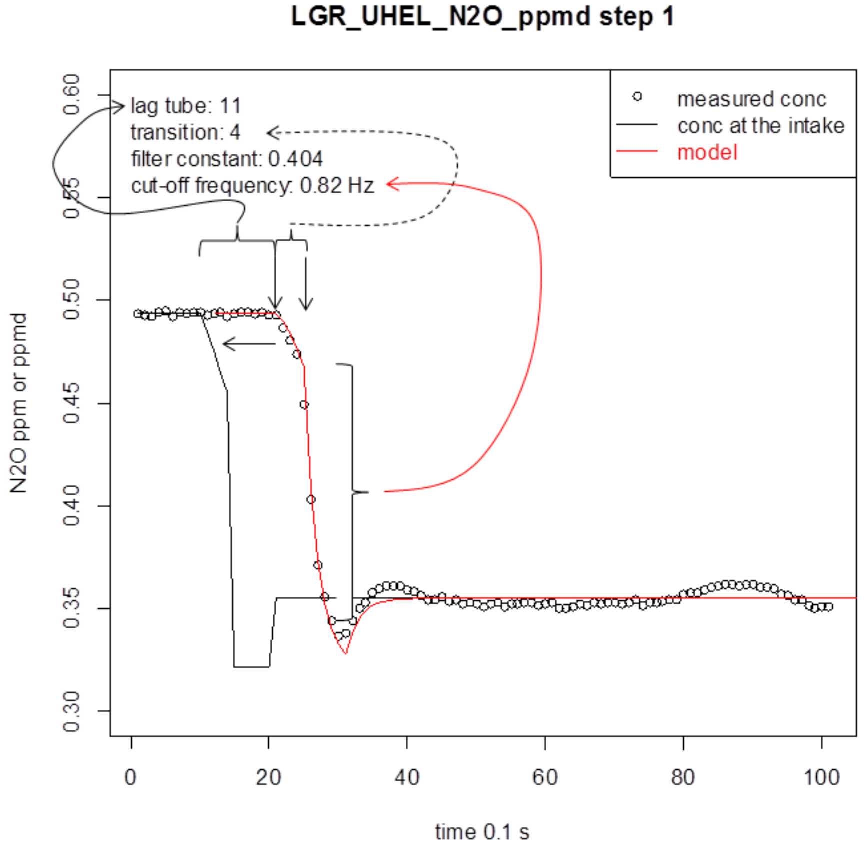
Time Response: field study

Objective: Estimate the time lag and high frequency attenuation for the N_2O sensors with a simple field experiment. Then compare the time lags obtained with the post-processed data by maximization of covariances method.

N_2O sensor	f_c Hz	τ_{tube} s
LGR_DTU	**0.7**	**1.2**
LGR_FMI	**0.46**	**1.2**
LGR_UHEL	**0.67**	**0.9**
cwQCL_CEH	**1.14**	**0.825**
cwQCL_INRA	**1.06**	**1.2**



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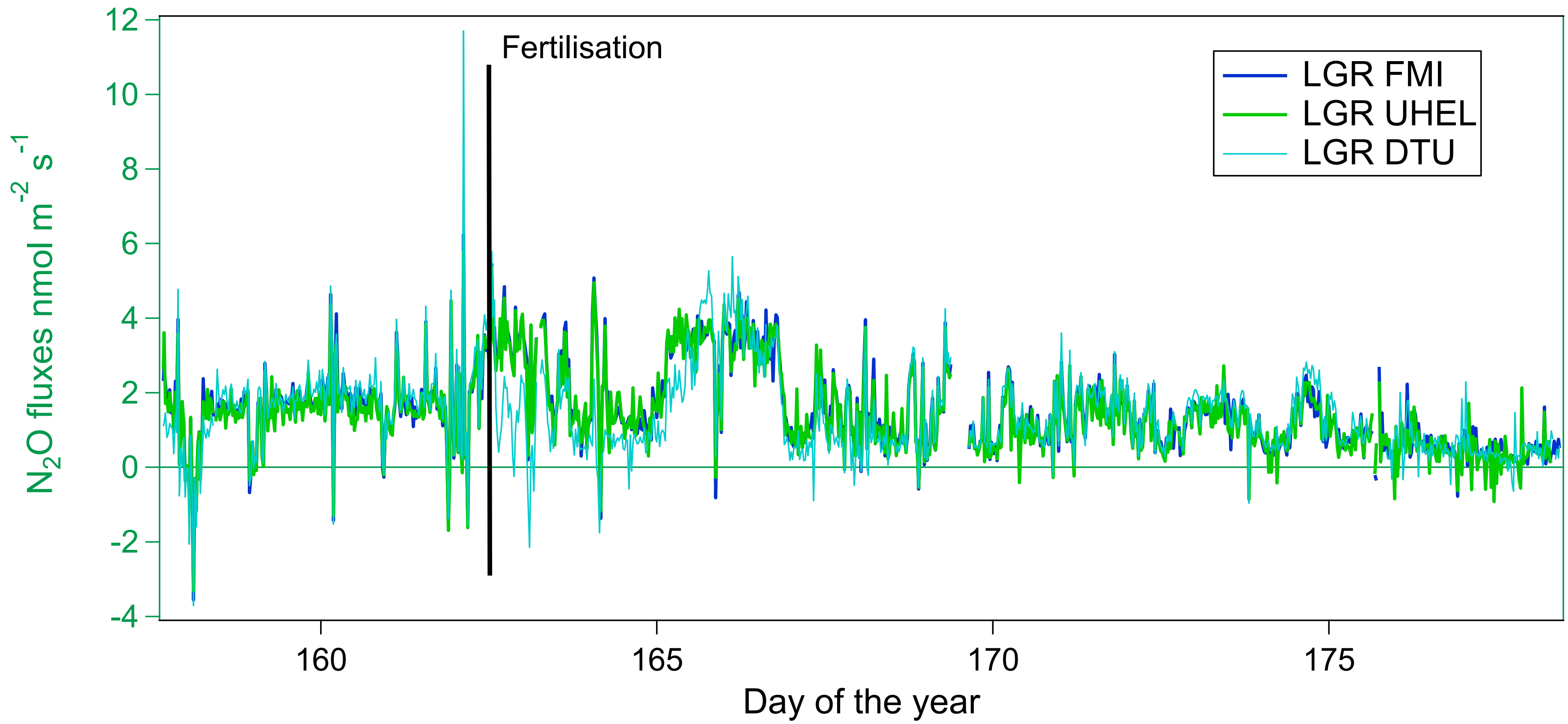
N_2O fluxes time series LGR



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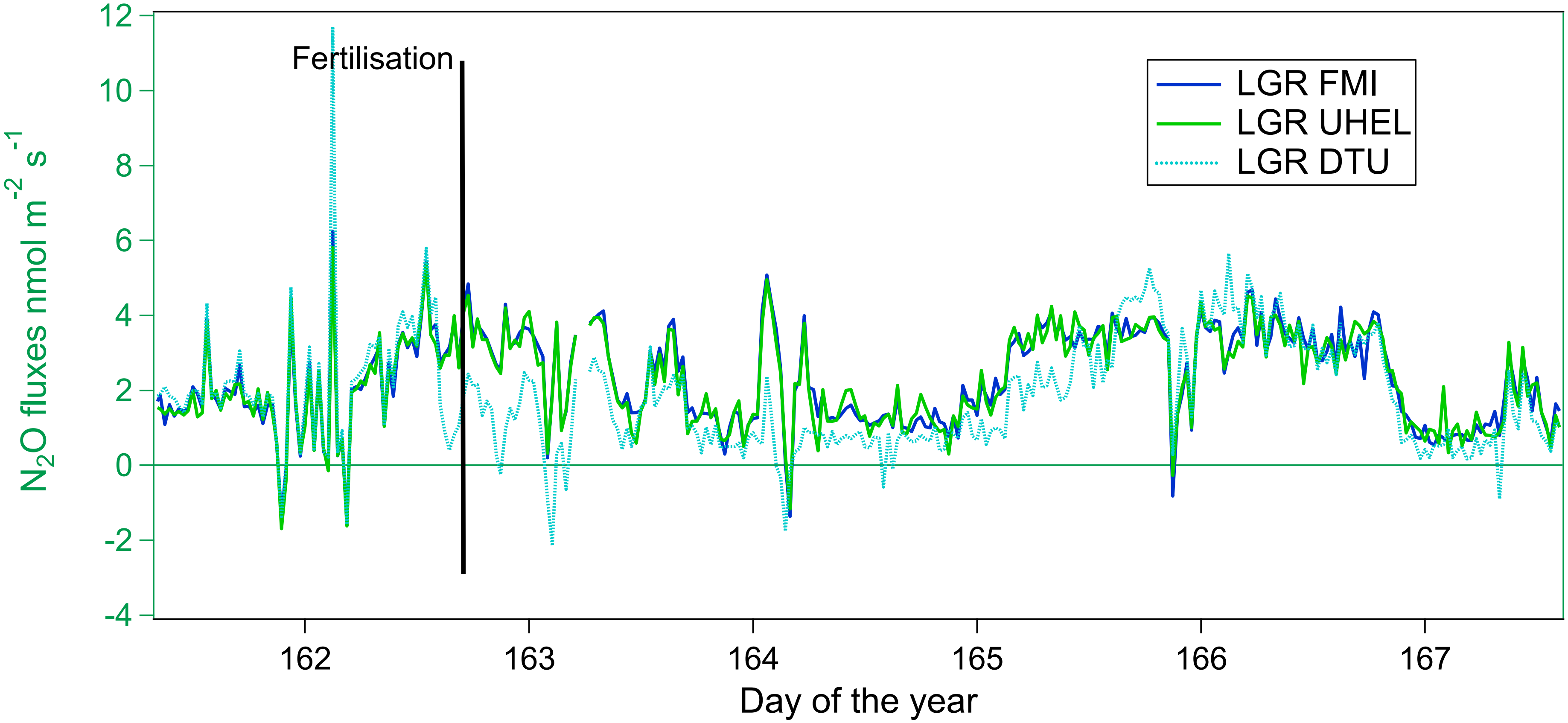
N_2O fluxes time series LGR



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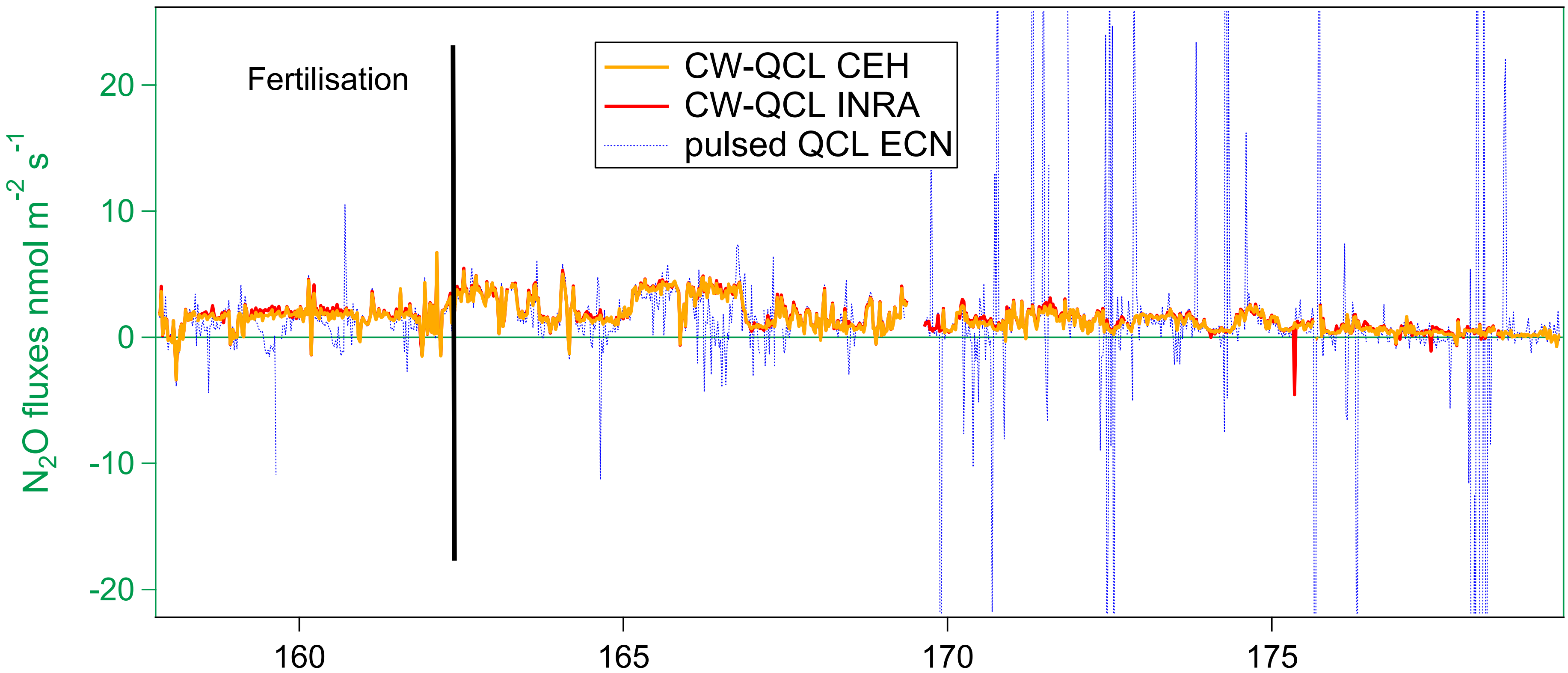
N_2O fluxes time series QCL



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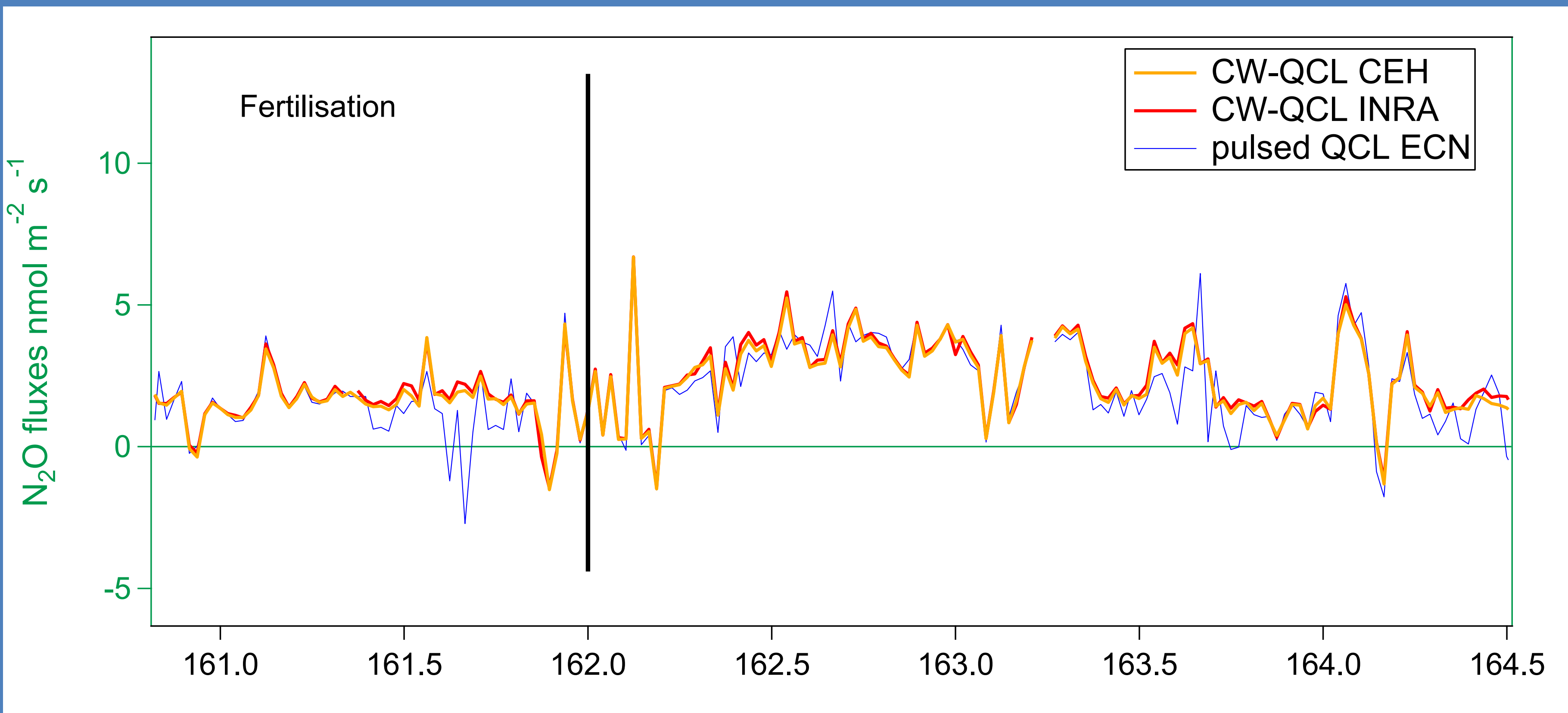
N_2O fluxes time series QCL



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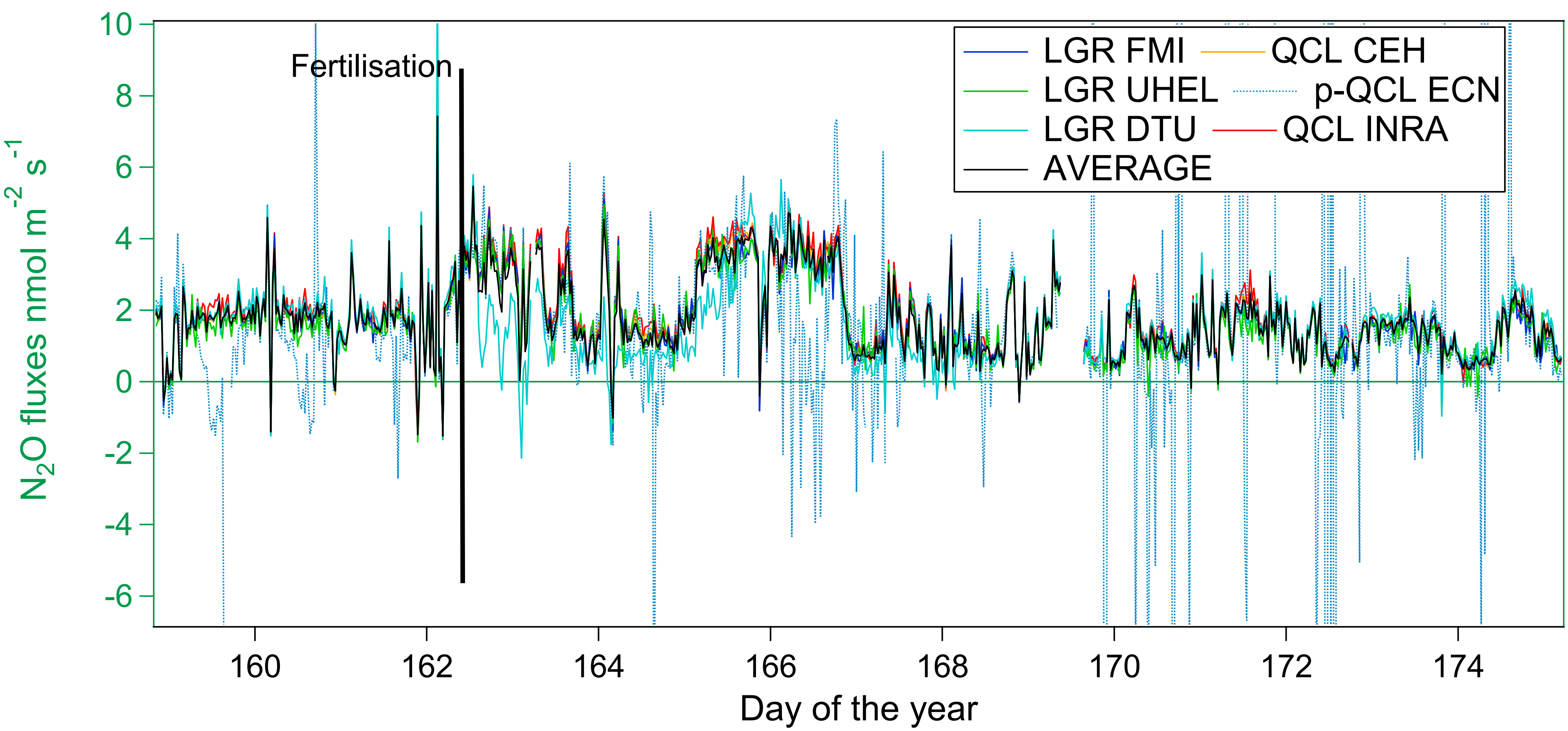
N_2O fluxes time series



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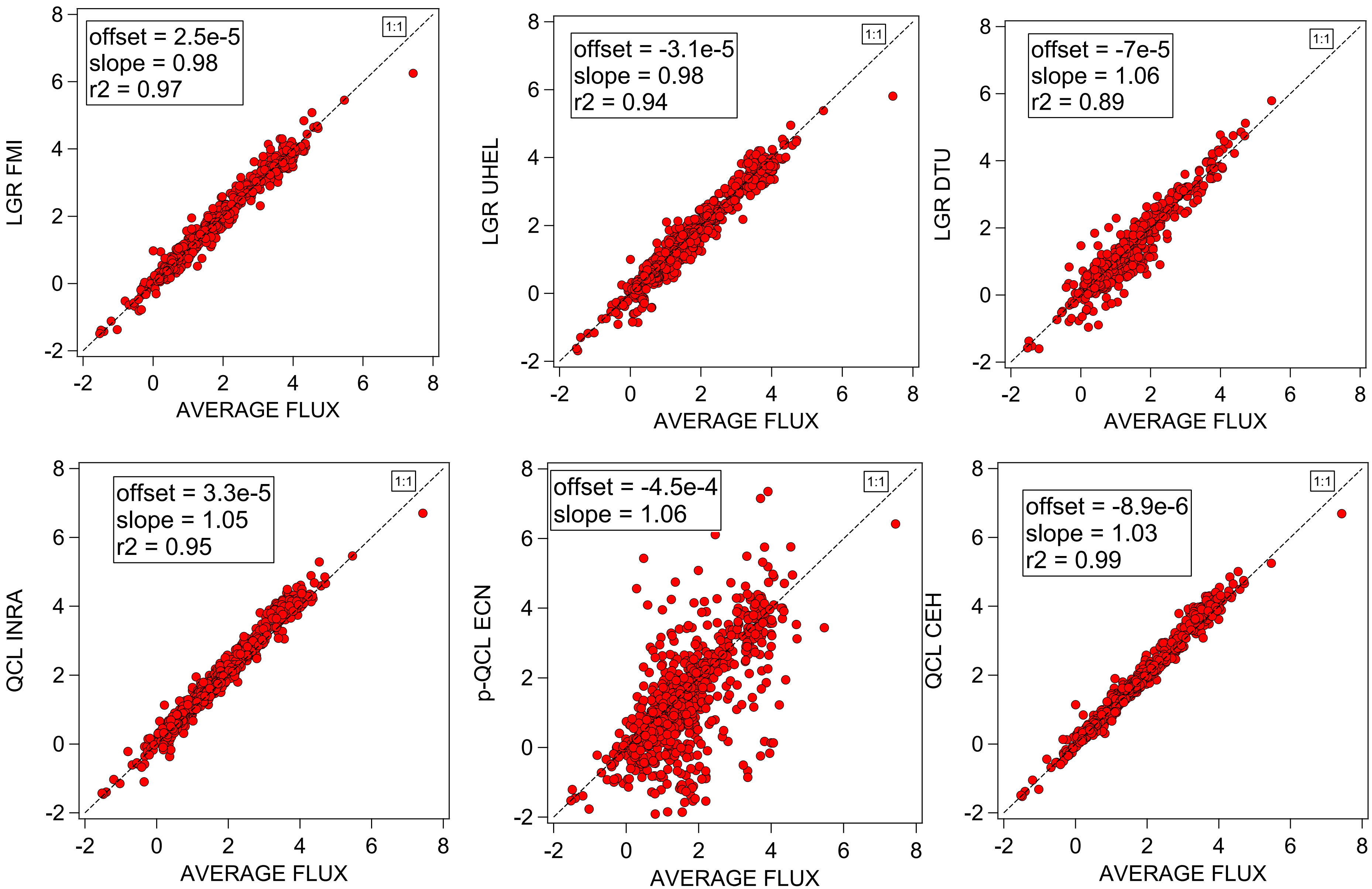
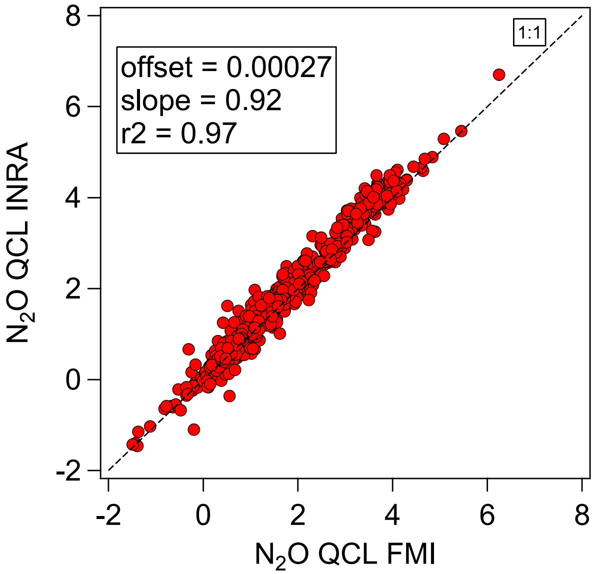
Comparison of fluxes *[nmol / m² s]* with average

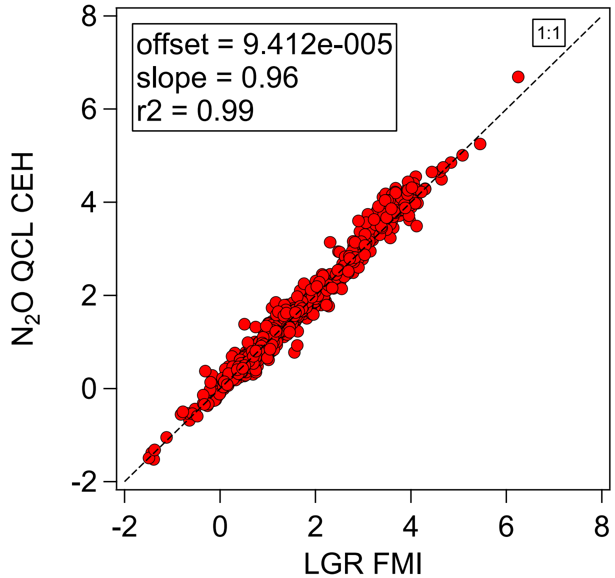
Each sensor (Y axes) against the “average sensor” (X axes)

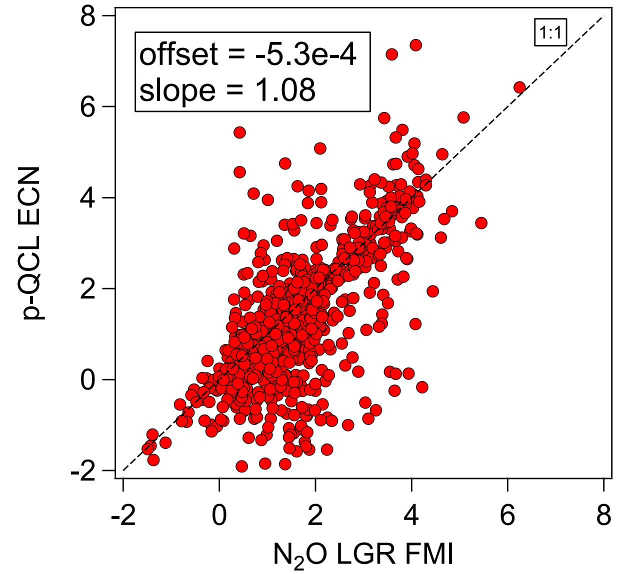


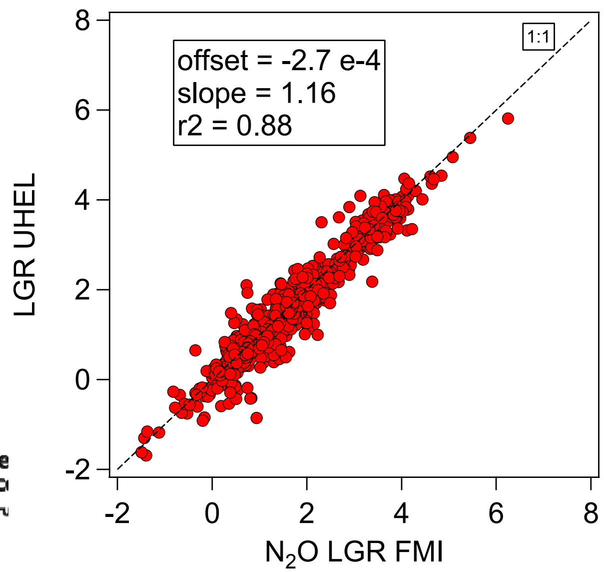
Comparison of fluxes *[nmol / m^2 s]* with dried sample

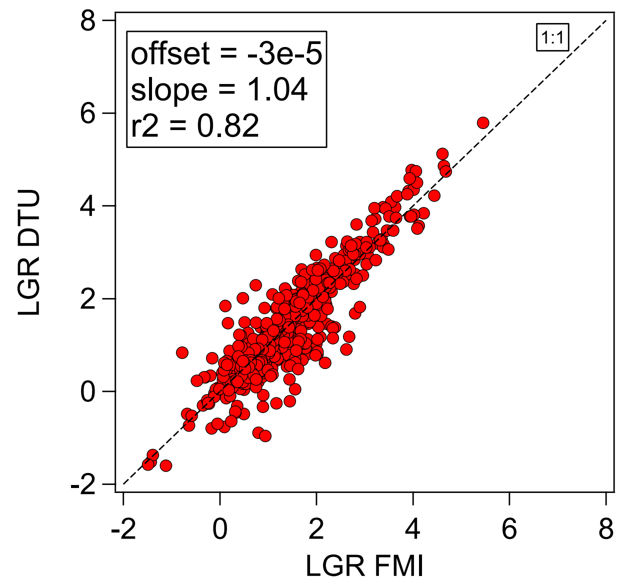
Each sensor (Y axes) against the "dried sample sensor" (X axes)











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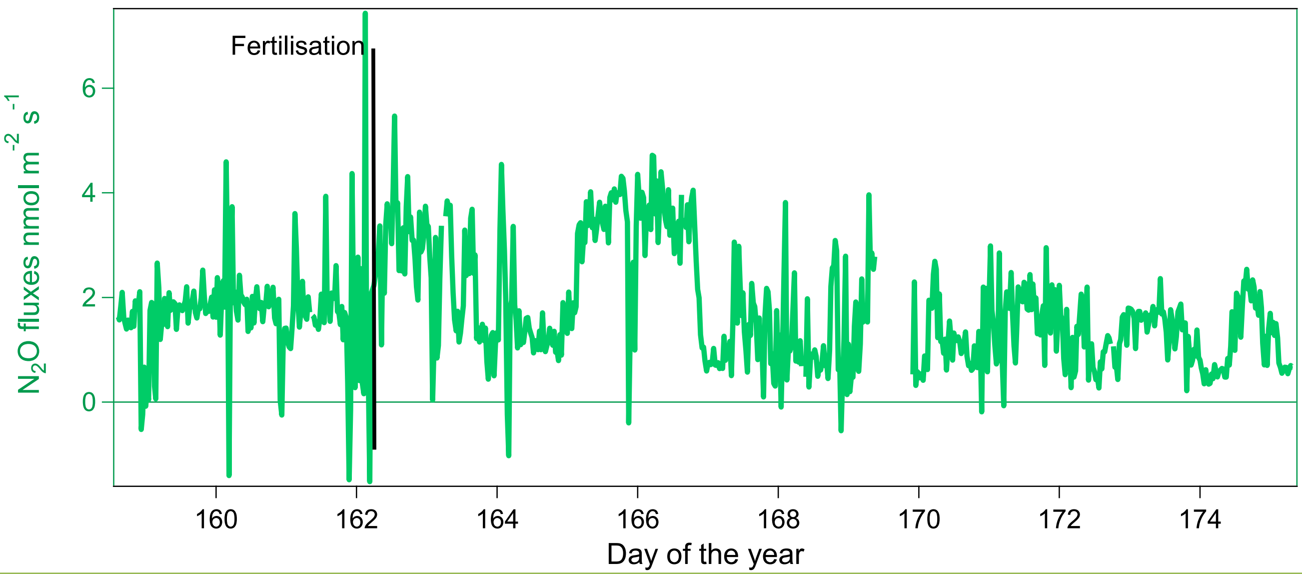
N_2O cumulative fluxes



Averaged N_2O emissions from 6 to 27 June 2013: only overlapping measuring periods were considered.

	FMI	INRA	UHEL	DTU	ECN	CEH	
mean	1.53	1.64	1.46	1.38	1.13	1.49	nmol m-2 s-1
stdev	1.09	1.18	1.1	1.15	7.8	1.15	nmol m-2 s-1
min	-3.56	-4.56	-3.32	-3.70	?	-3.37	nmol m-2 s-1
max	6.25	6.7	5.81	11.7	?	6.79	nmol m-2 s-1
cumulative	1509.16	1616.81	1445.79	1398.67	1154.9	1548.78	nmol m-2 s-1
cumulative	2.71	2.91	2.602	2.517	2.078	2.787	mmol m-2 period-1
cumulative	**20.57**	**21.98**	**19.7**	**19.02**	**15.7**	**21.06**	g N_2O-N ha-1 day-1

Summary

- 6 N_2O eddy covariance systems have been compared during a field campaign over 25 days, 20.54 of data capture for all.
- The N_2O fast monitors were calibrated via gaseous standards, and statistical analysis showed precisions ranging from 0.2 and 1 ppbV at 10Hz.
- The averaged N_2O emission over the period was evaluated at 19.67 g N_2O-N ha^{-1} day^{-1} (EF ~0.8)
- With the latest generation lasers, it is possible to measure very small fluxes, potential for non-agricultural fluxes and uptake studies.
- the latest generation of instruments generate cumulative fluxes agreeing within 10%
- Potential benefit from physically drying the sample when using CRD LGR systems, but spectroscopic correction for water vapour appears to be working correctly
- All LRG systems work slightly differently (i.e. output formats, CO correction?) despite being the same model.

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Summary of outputs

- Information for development of ICOS protocols
- Compilation of a wish list for field deployment and manufacturers> ongoing
- Dataset available to the Fluxnet community for assessment of own processing packages.
- Comparison of three micrometeorological techniques (REA, EC, AGM) > ongoing
- Subsets of instruments will be assessed for performance on CO_2, CH_4, CO, both for concentration and fluxes > ongoing

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Thank you!

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