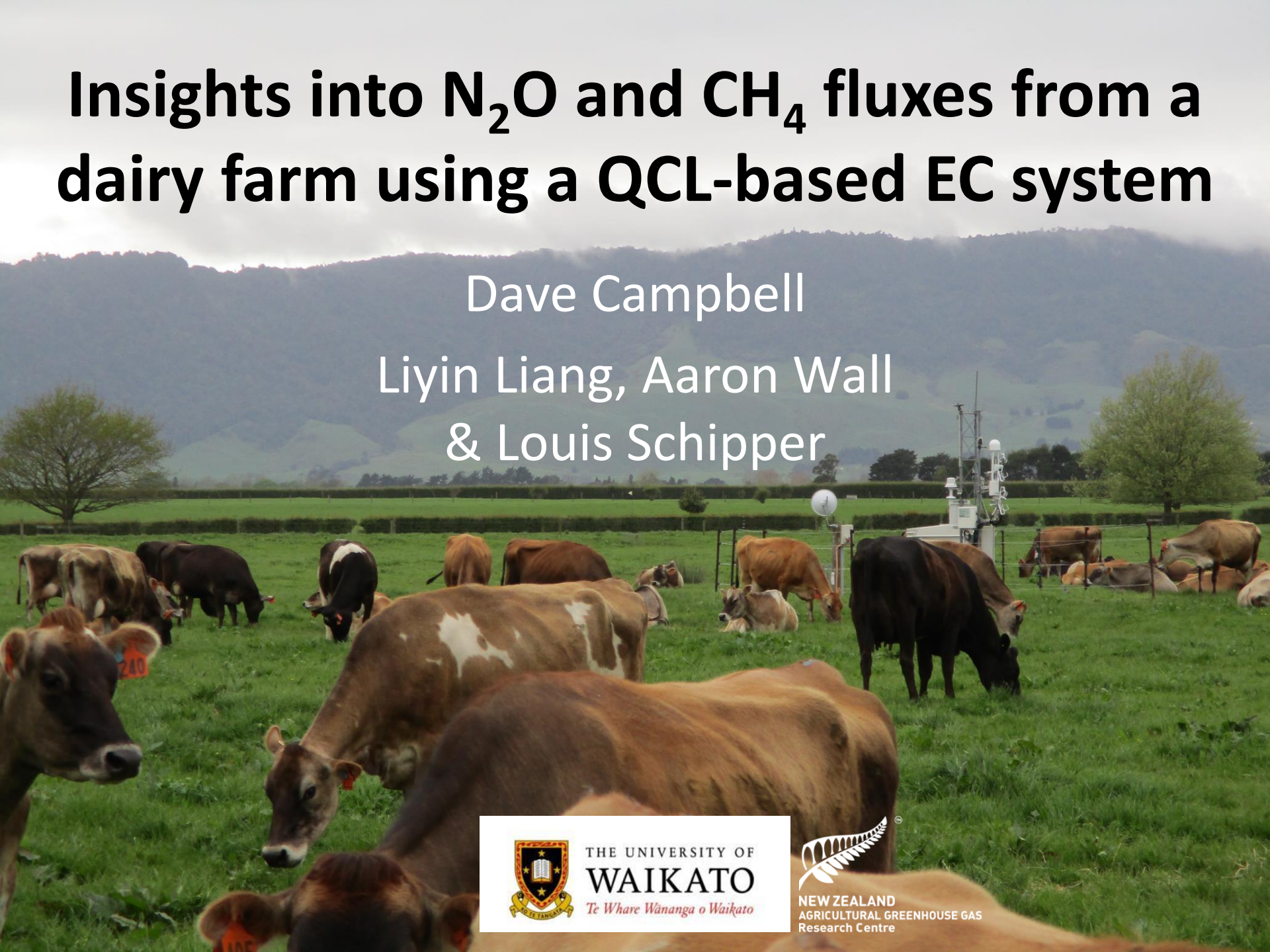
Insights into N_2O and CH_4 fluxes from a dairy farm using a QCL-based EC system

Dave Campbell

Liyin Liang, Aaron Wall
& Louis Schipper



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NZ's gross emissions profile in 2015

Other gases 2.0%

By gas:

53.2%

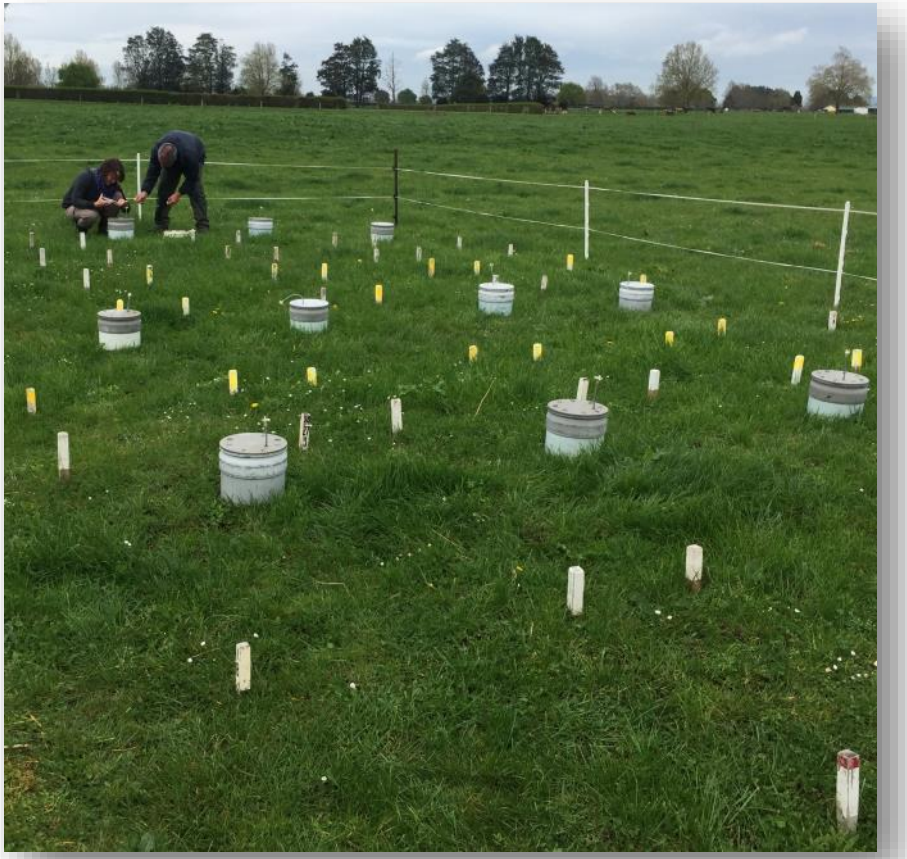
By sector:

Source: Ministry for the Environment 2017: NZ's GHG Inventory

IPCC inventory approach to agricultural N_2O emissions

"Bottom-up"

- NZ's N_2O emission categories and emission factors for:
  - Direct emissions:
    - inorganic N fertilisers
    - urine & dung from grazing animals
    - crop residues
  - Indirect emissions:
    - atmospheric deposition
    - N leaching and runoff

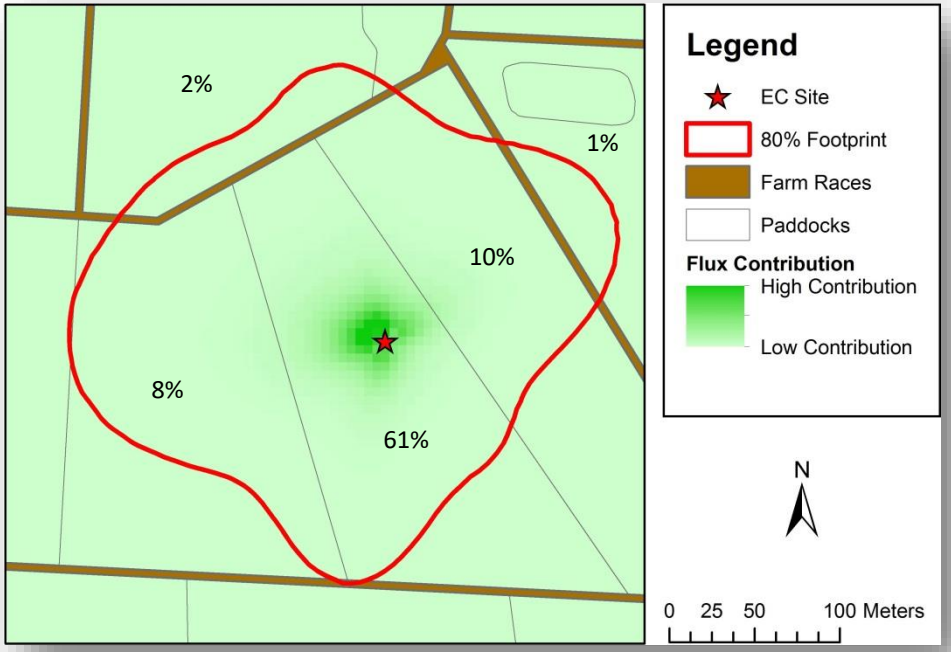


Small plot N_2O trial at Troughton Farm showing manual flux chambers

What knowledge gains can EC measurements of N_2O fluxes bring?

- Lacking full understanding of the role of biophysical and management-related drivers on N_2O emissions and seasonal variation
- A paddock-scale method for testing mitigation practices

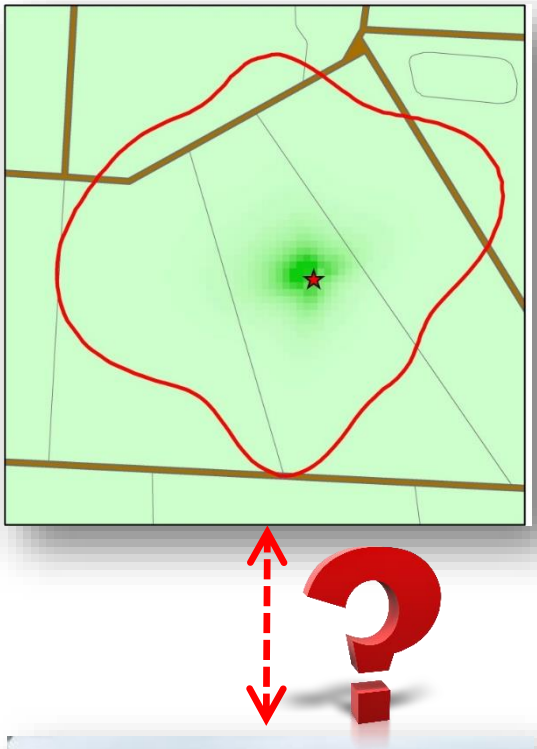
- "Hot spots" and "hot moments" for N_2O emissions
- Eddy covariance can facilitate advances in these: a "top-down" approach



Flux footprint map for N_2O EC site at Troughton Farm

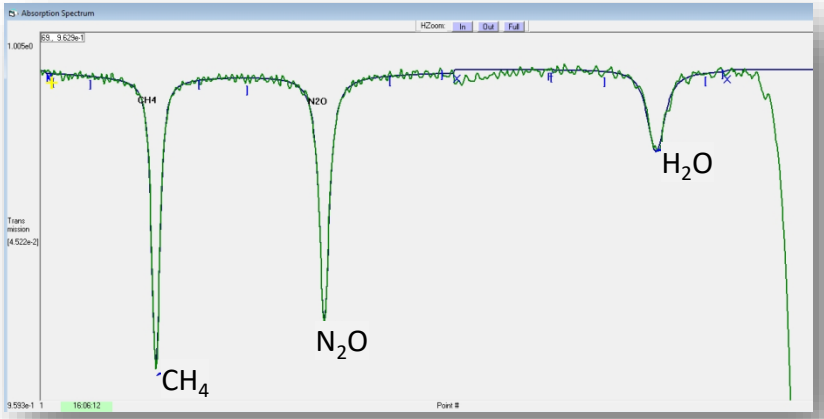
Initial research questions

- Can we make reliable and continuous N_2O flux measurements using EC?
  - Insights about biophysical/management drivers
- How do real farm N_2O emissions compare to a standard inventory approach?
- Can we reconcile the emissions measured at the chamber and EC flux footprint temporal and spatial scales?

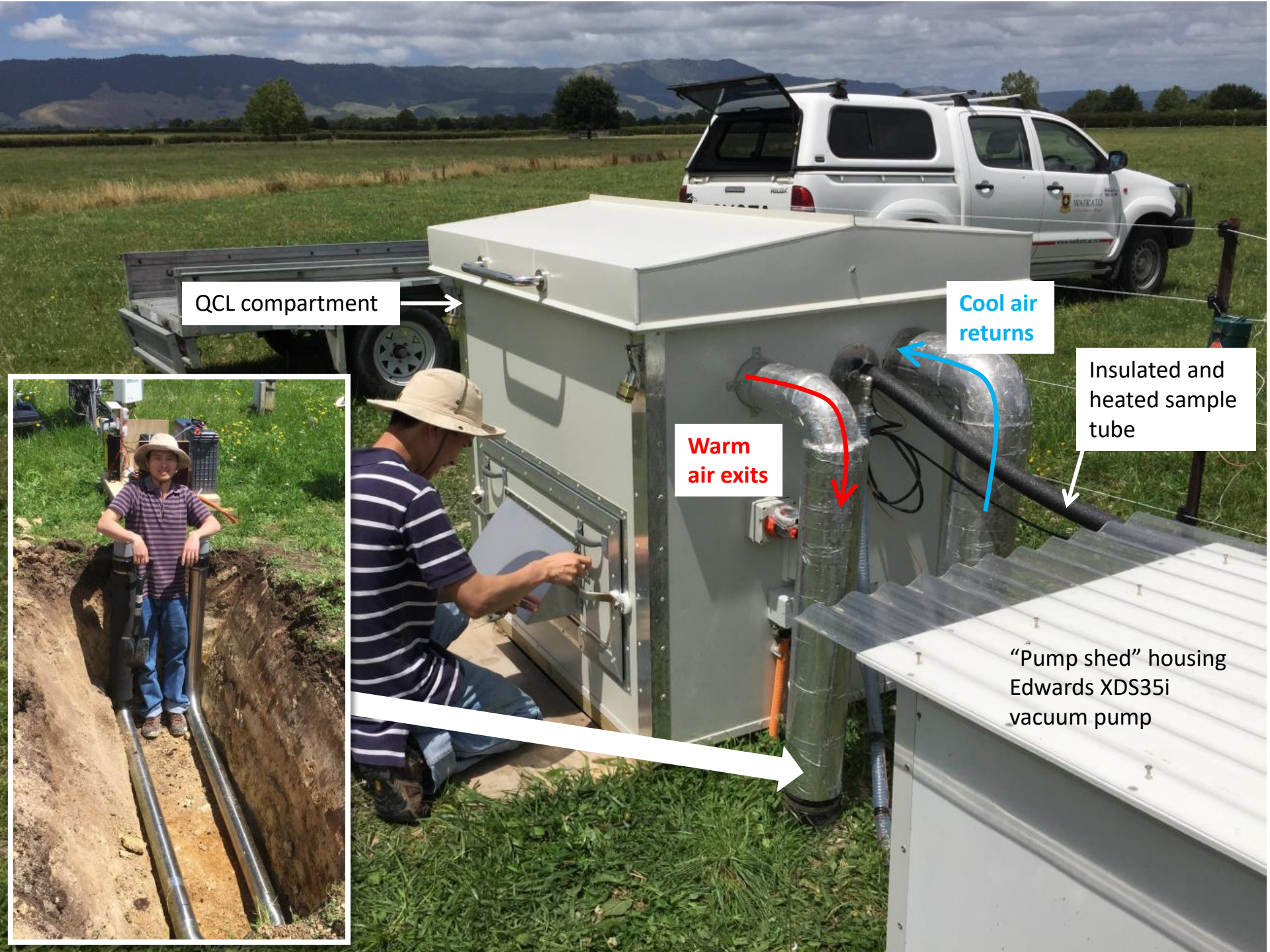


EC system design

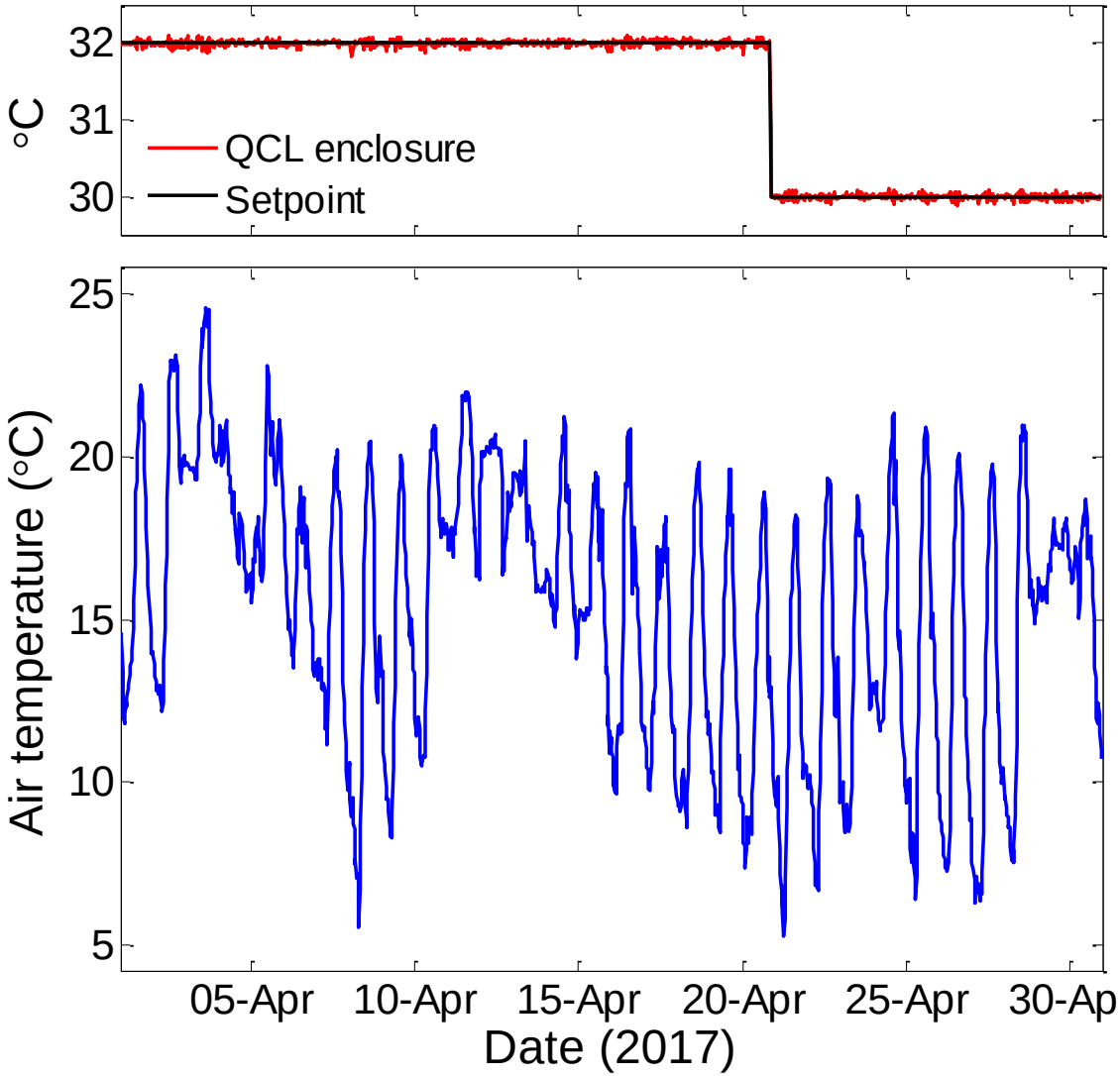
- Aerodyne single laser mini QCL
  - True 10 Hz, high-flow
  - Requires stable temperature



- Custom temperature-controlled environmental enclosure
  - Goal was setpoint ±0.2°C, 24/7, no air conditioner


QCL compartment
Cool air returns
Insulated and heated sample tube
Warm air exits
"Pump shed" housing Edwards XDS35i vacuum pump

Temperature control performance



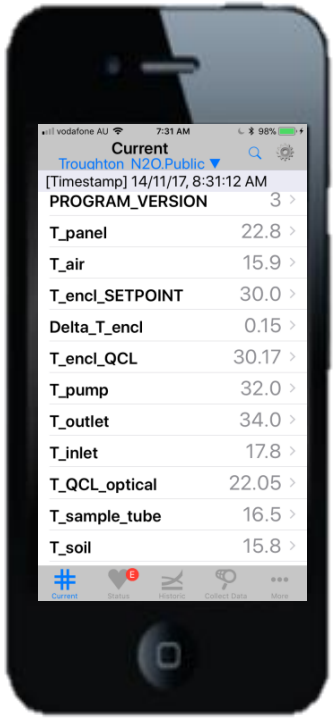
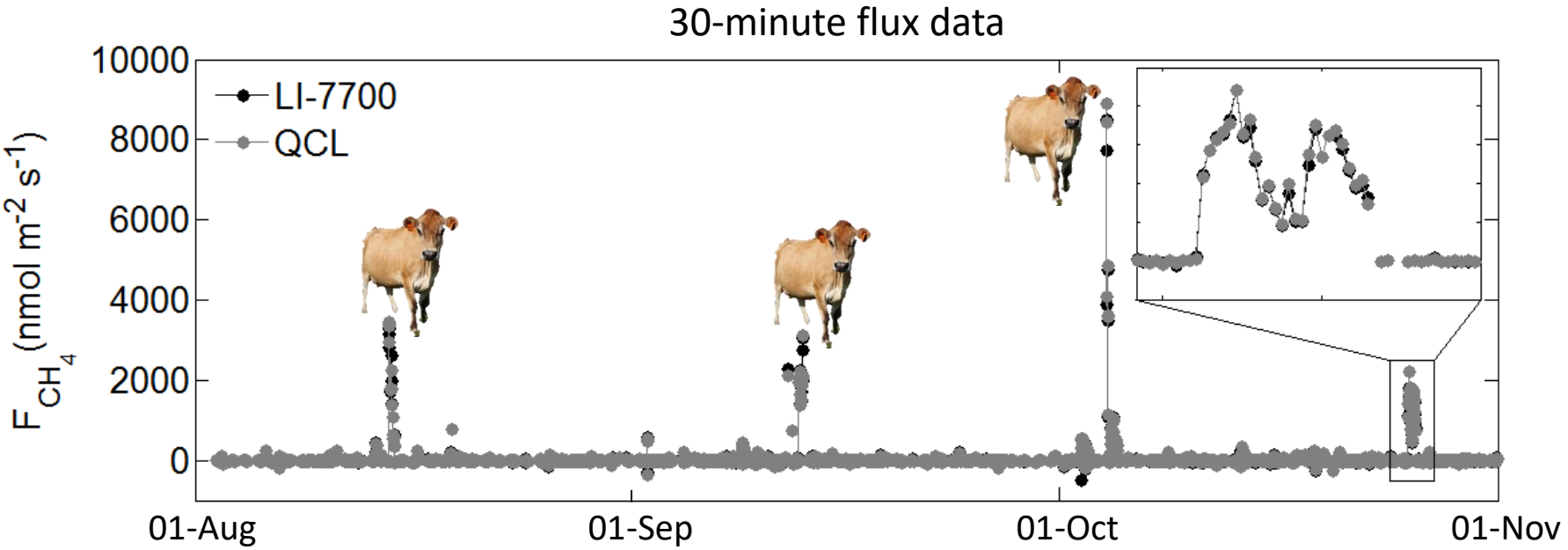
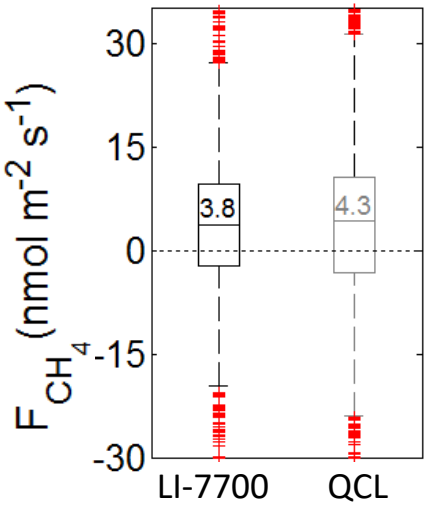


Photo: Anne Wecking, UoW

Validation – methane fluxes





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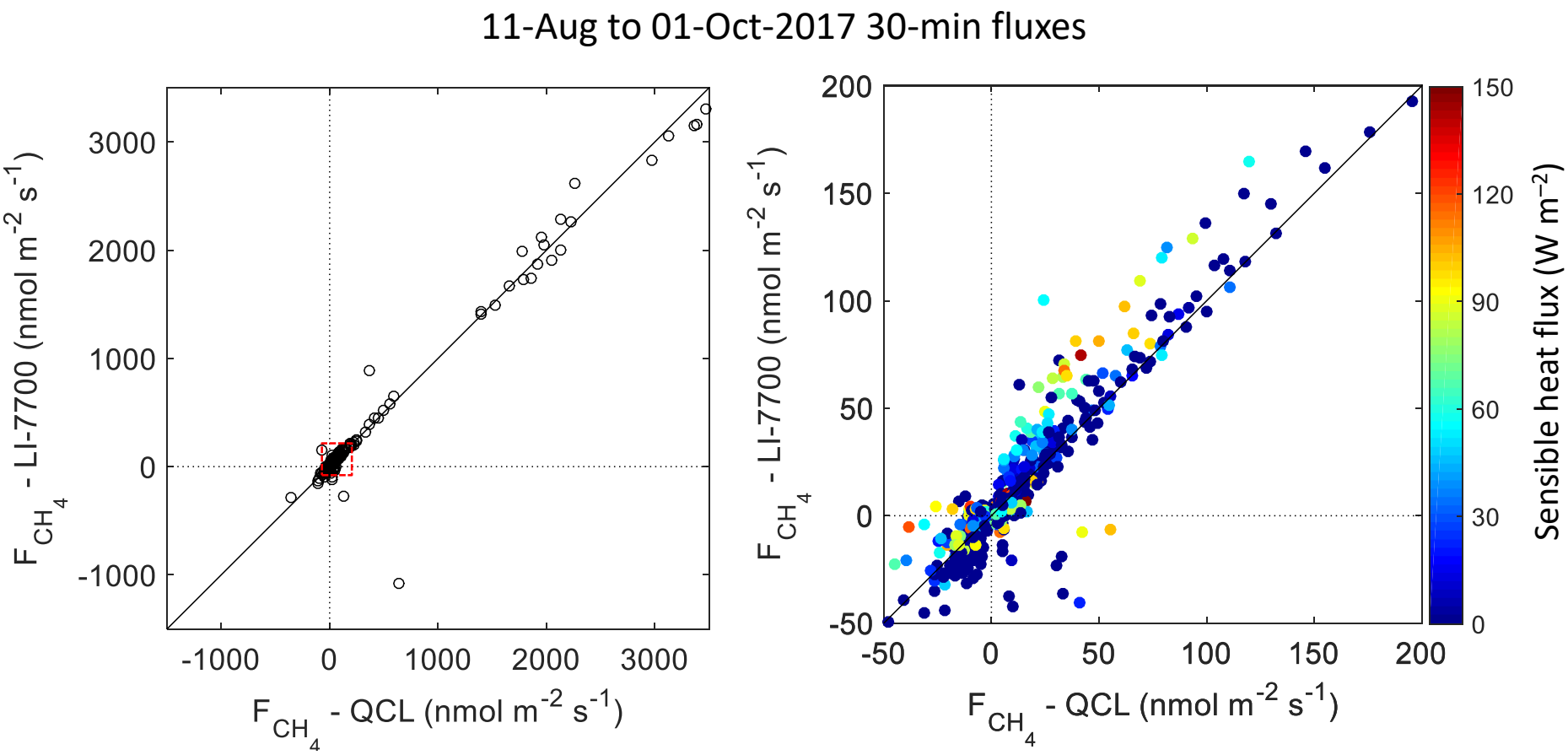
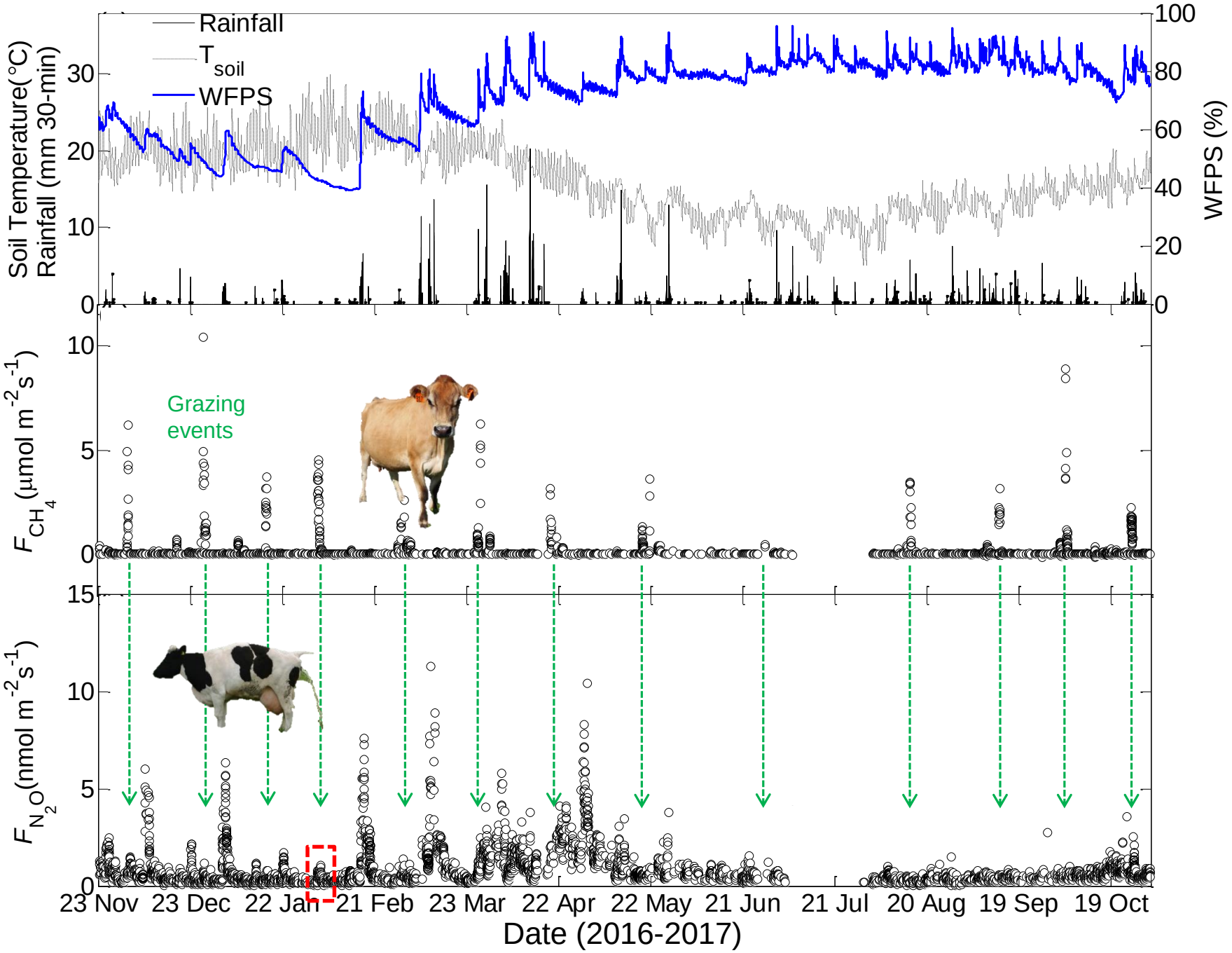
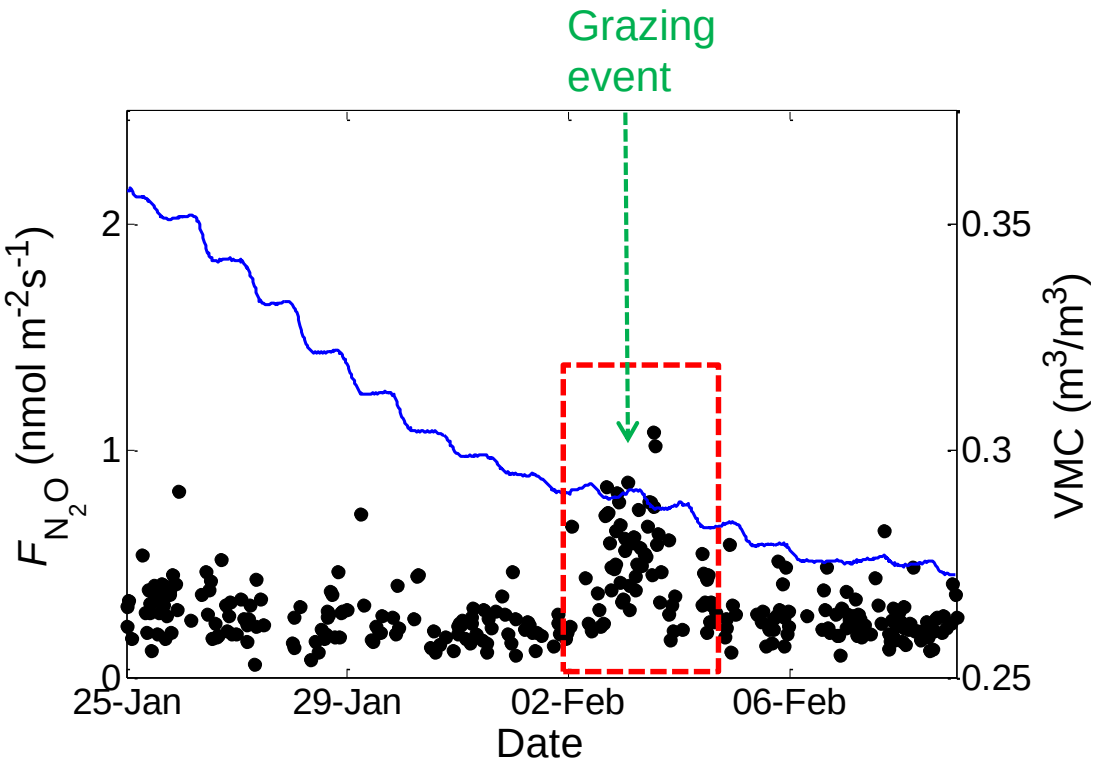


Flux patterns under rotational dairy grazing

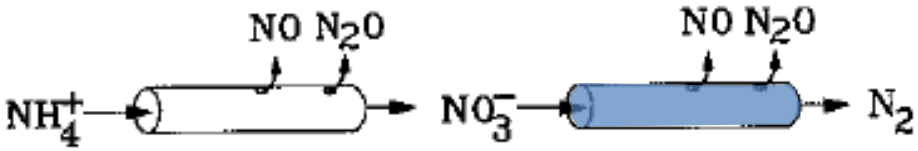

Rainfall
T_{soil}
WFPS
Soil Temperature(°C)
Rainfall (mm 30-min)
WFPS (%)
Grazing
events
F_{CH_4} (µmol m^{-2}s^{-1})
F_{N_2O}(nmol m^{-2}s^{-1})
23 Nov
23 Dec
22 Jan
21 Feb
23 Mar
22 Apr
22 May
21 Jun
21 Jul
20 Aug
19 Sep
19 Oct
Date (2016-2017)

Direct grazing effect



Soil moisture controls on F_{N2O}

"Hole-in-the-pipe" model - Firestone & Davidson (1989)



Nitrification
(aerobic)

Denitrification
(anaerobic)

Soil moisture controls on F_{N2O}

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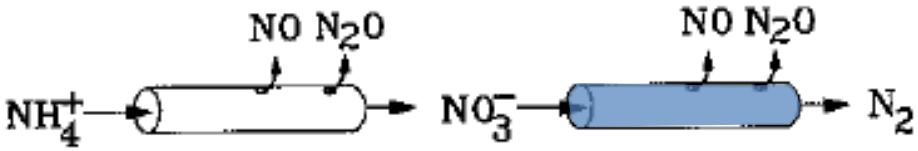
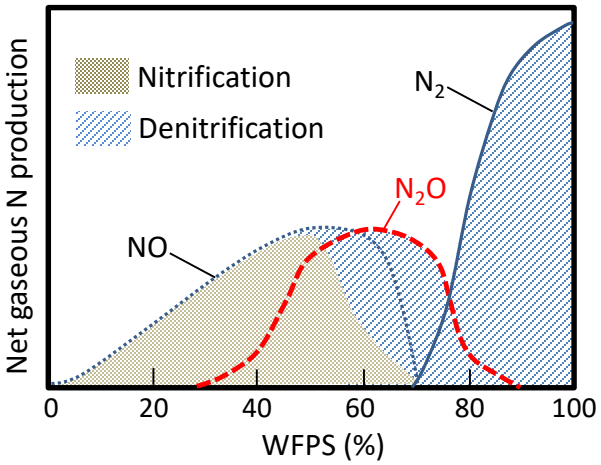


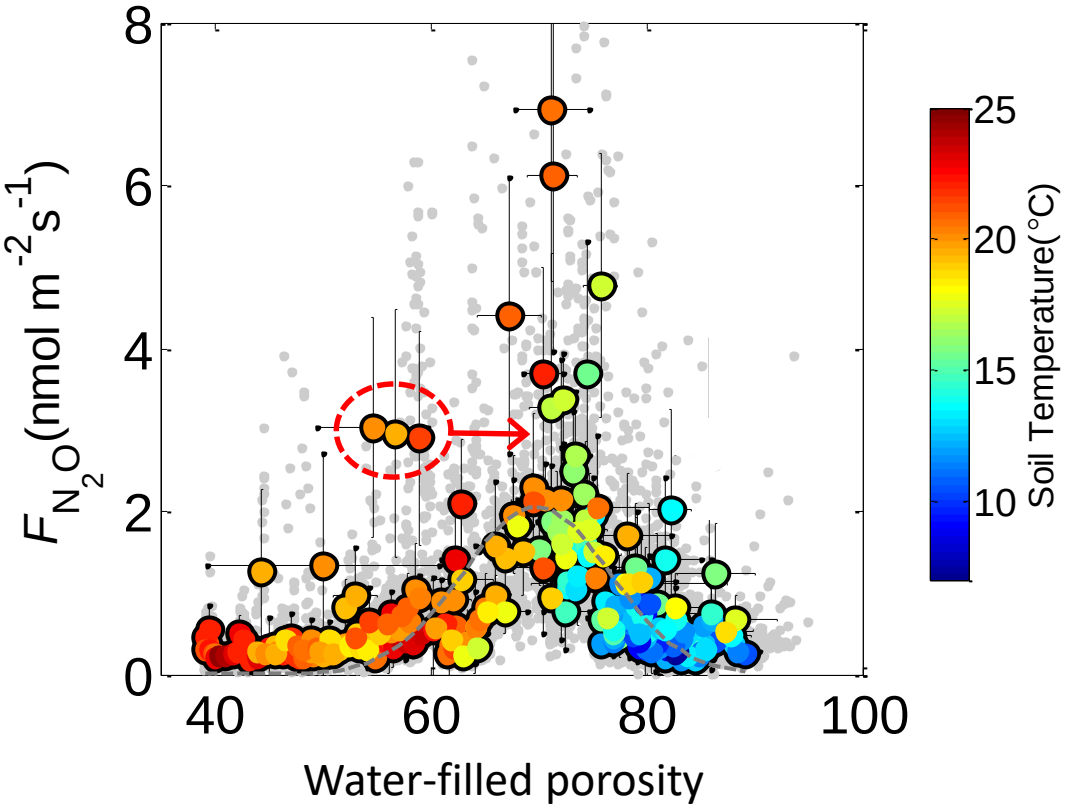
Nitrification (aerobic)

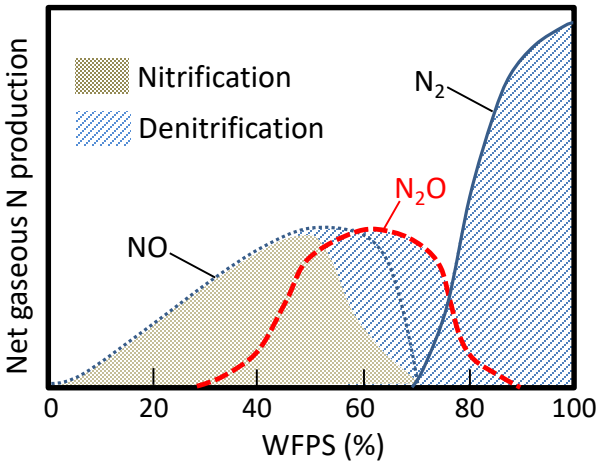
Denitrification (anaerobic)



Davidson (1991)

Soil moisture controls on F_{N2O}

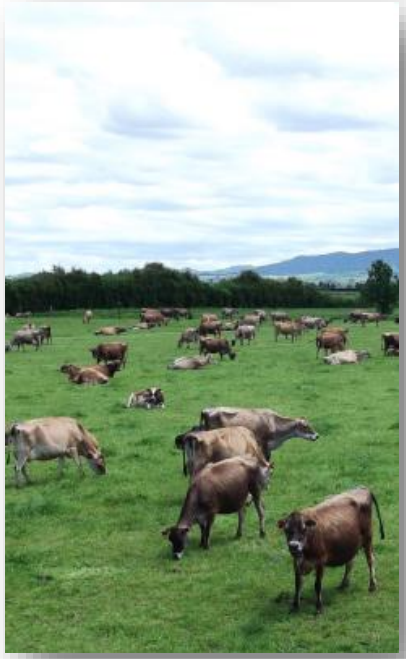




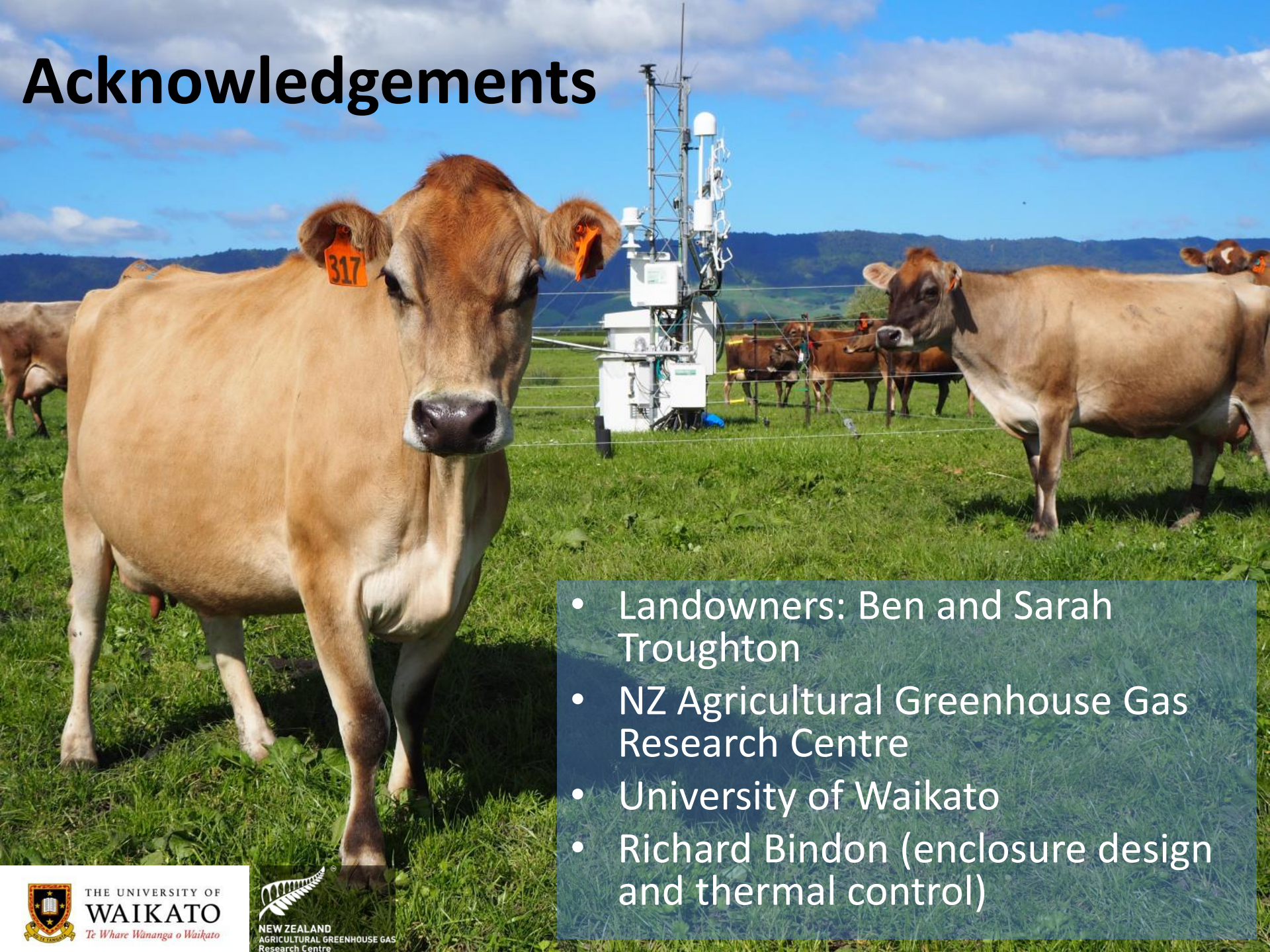
Davidson (1991)

Summary

- A reliable and low-maintenance $N_2O/CH_4/H_2O$ EC system
- Insights into drivers of N_2O fluxes at a farm operational scale
- Soil moisture (WFPS) critical for N_2O "regime"
  - Shallow soil source of much N_2O?
- Future work
  - Plantain sward (cow urine has reduced N)
  - Peat soils GHG work and a second QCL



Acknowledgements



- Landowners: Ben and Sarah Troughton
- NZ Agricultural Greenhouse Gas Research Centre
- University of Waikato
- Richard Bindon (enclosure design and thermal control)

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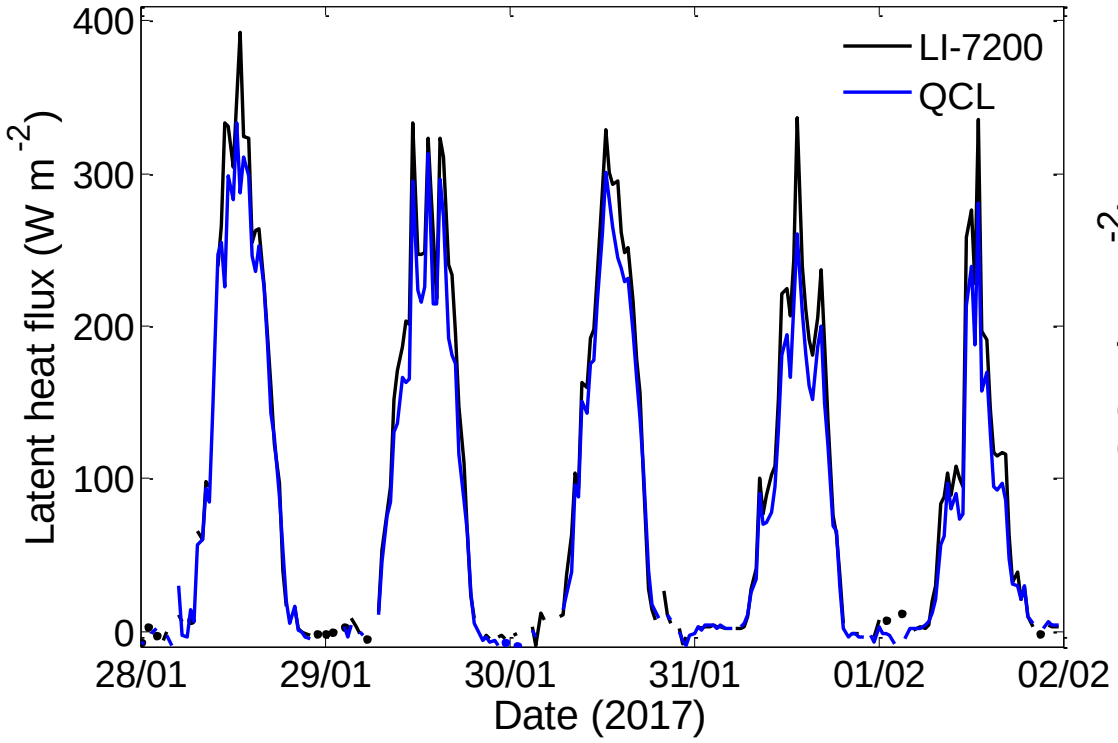
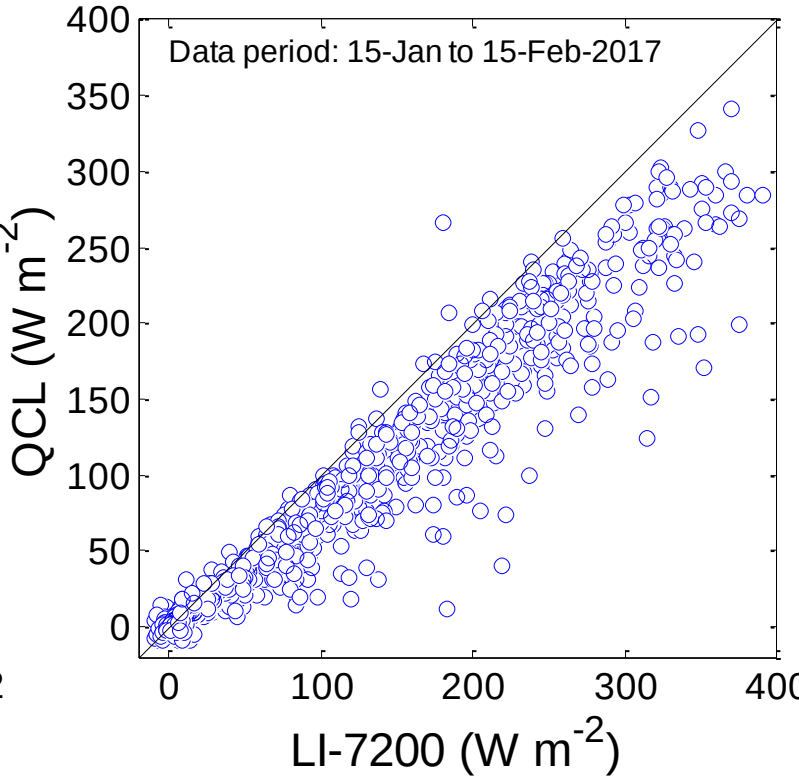
Firestone, M. & Davidson E. Microbiological basis of NO and N_2O production and consumption in soil (1989). Pp 7–21. In: Andreae, M. & Schimel (Eds) Exchange of trace gases between terrestrial ecosystems and the atmosphere. John Wiley & Sons.

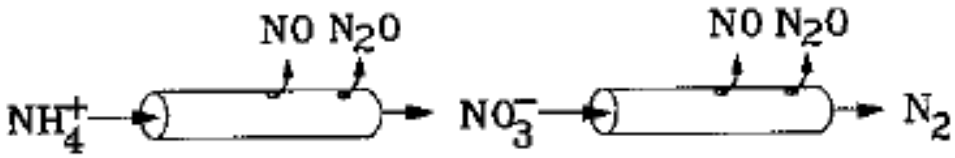
Davidson, E. (1991) Fluxes of nitrous oxide and nitric oxide from terrestrial ecosystems. Pp 219–235. In: Rogers, J. & Whitman, W. (Eds) Microbial production and consumption of greenhouse gases: methane, nitrogen oxides and halomethanes. Washington DC: American Society for Microbiology.

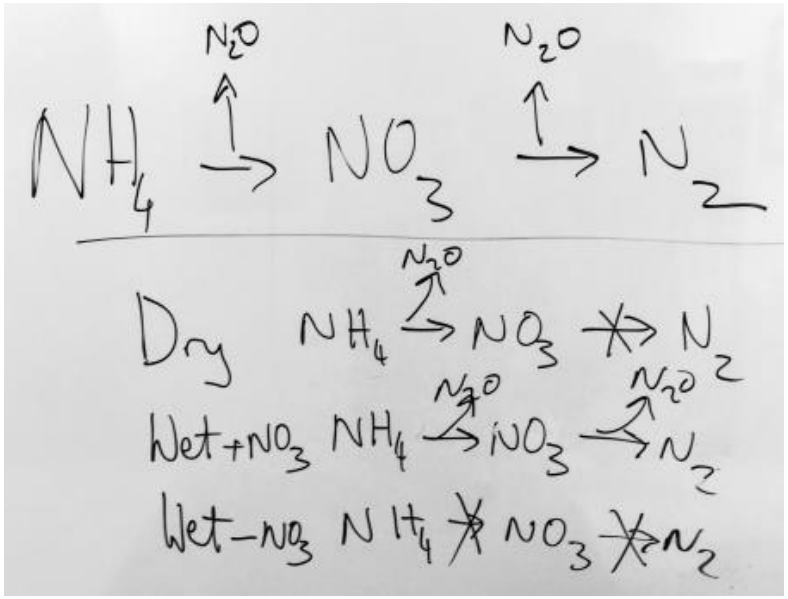
Validation – latent heat fluxes





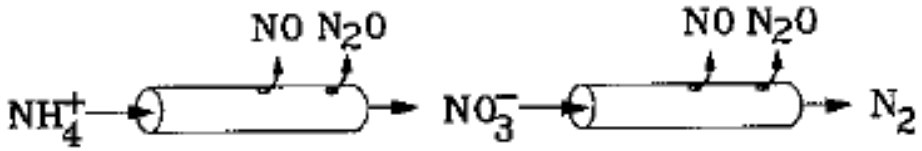
Leaky pipe model for N_2O production

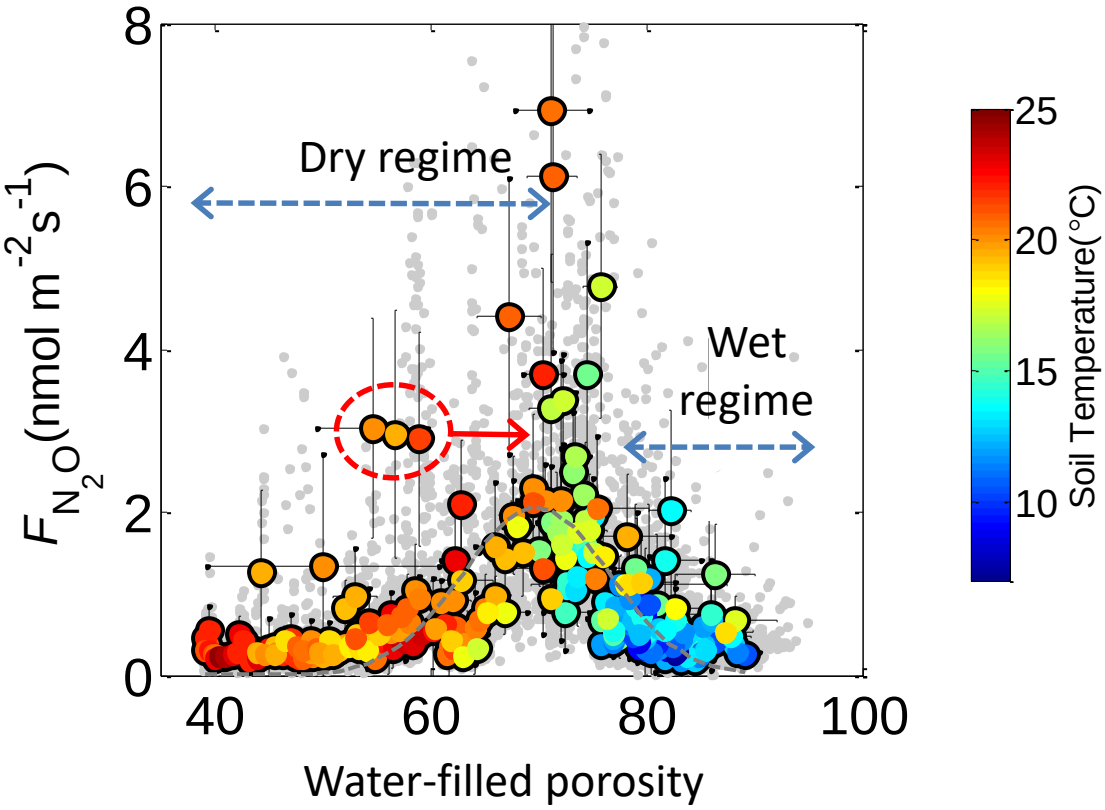




Firestone & Davidson (1989) Microbiological basis of NO and N_2O production and consumption in soil. *Exchange of Trace Gases between Terrestrial Ecosystems and the Atmosphere.*

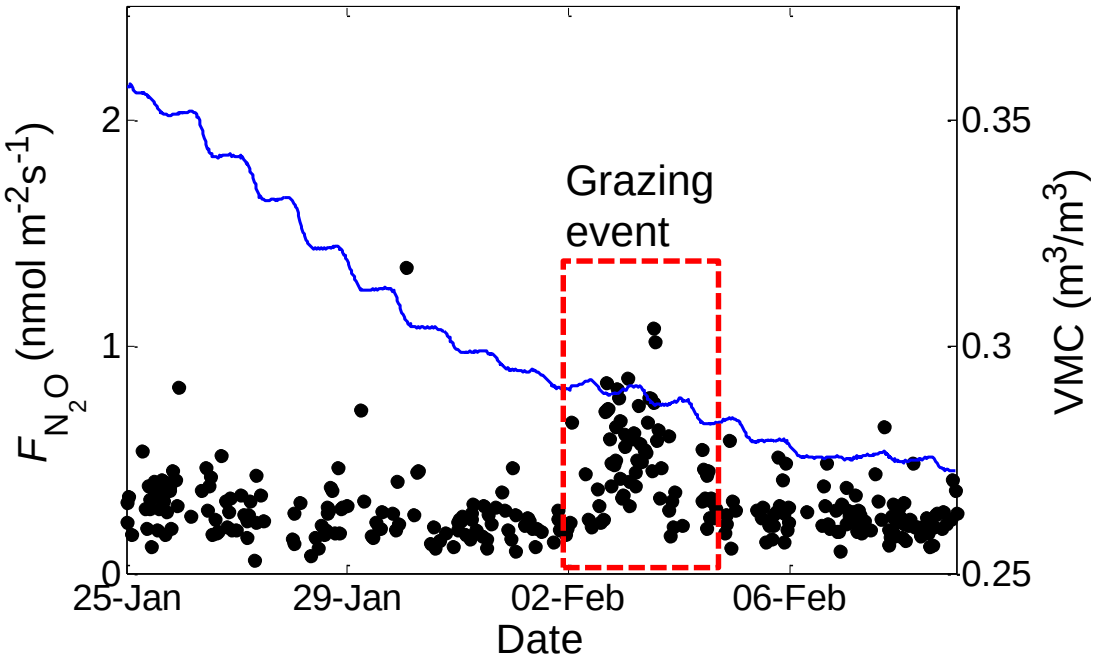
Soil moisture controls on F_{N2O}

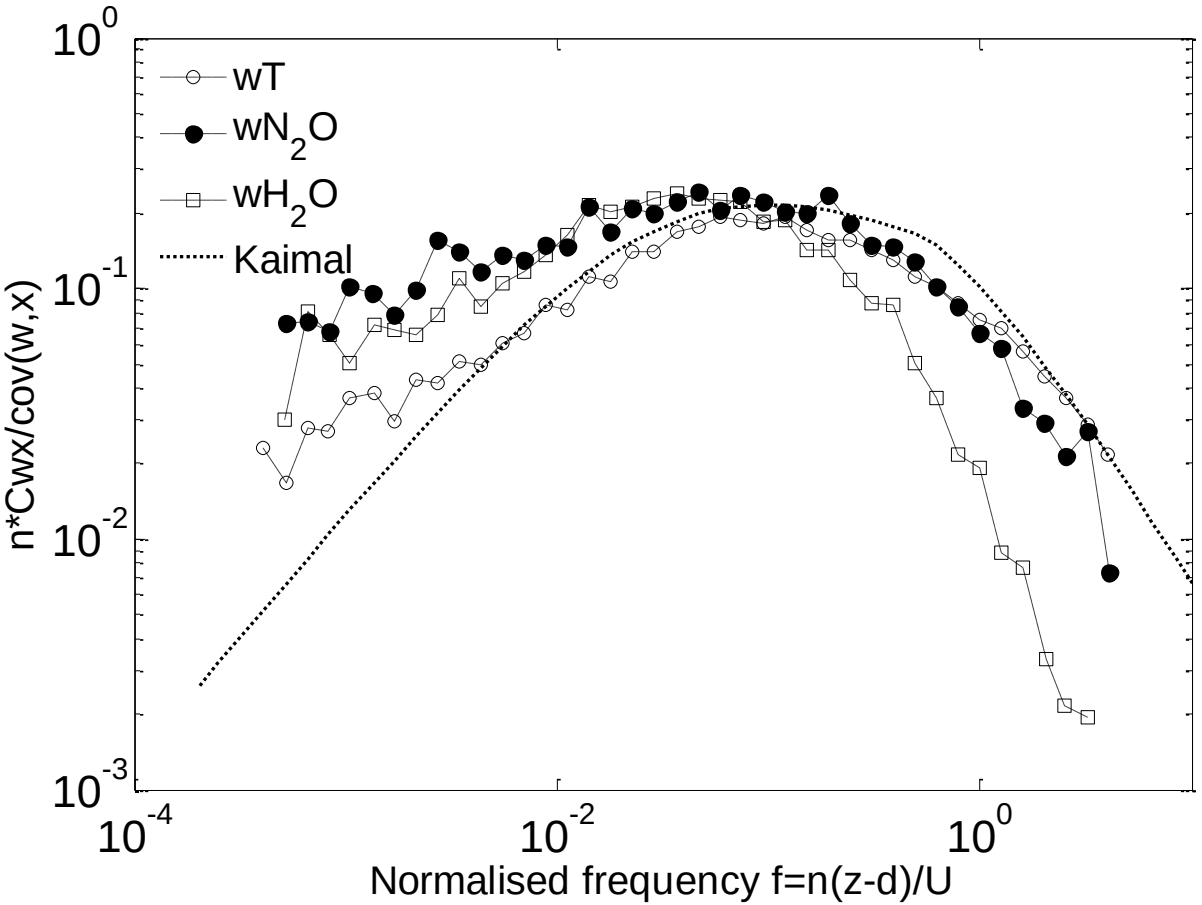




"Leaky pipe model"
Firestone & Davidson (1989)

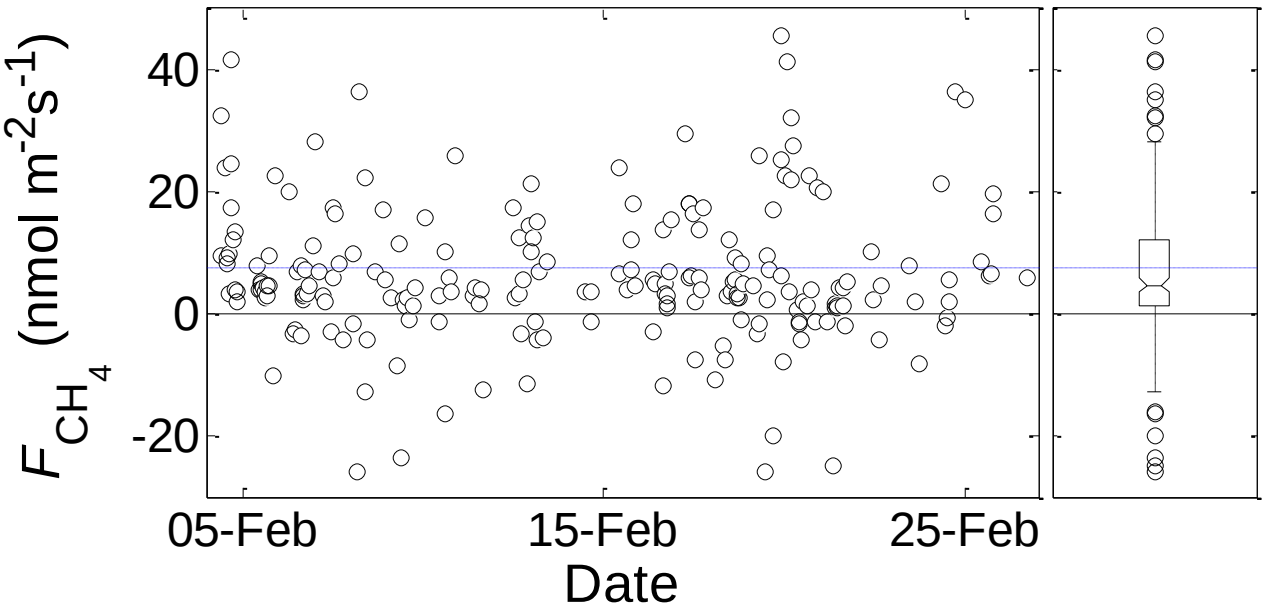
Other observations





Normalised N_2O and H_2O cospectra from the QCL, and air temperature (T) from the CSAT3B, for periods of high F_{N2O}.

Baseline F_{CH4}



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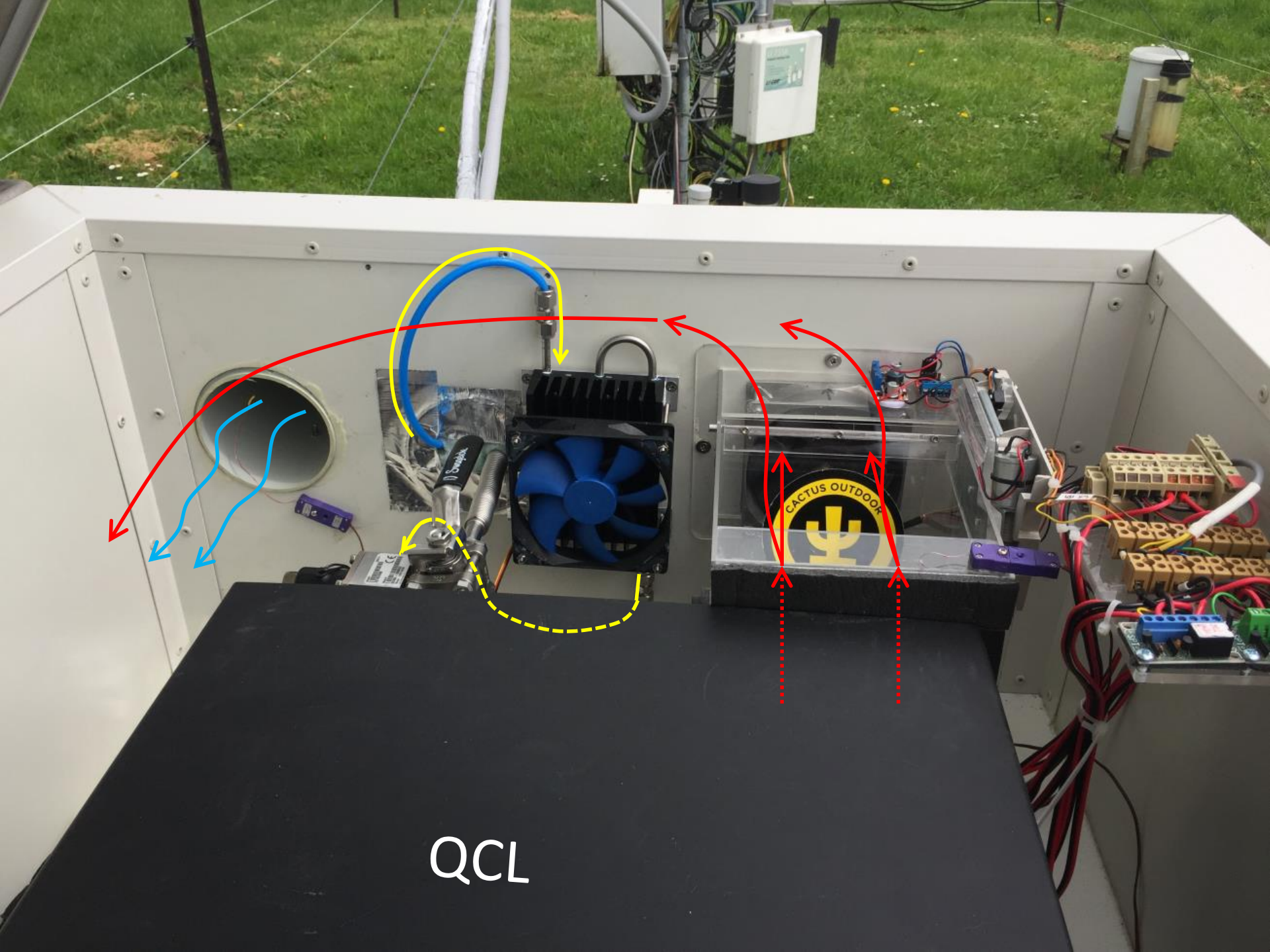
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QCL