Micrometeorological contributions to greenhouse gas research in NZ

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Long-term eddy covariance studies

- NZ funding system does not favour long-term studies
- Those undertaken embedded in larger programmes and with focus on process understanding
- Natural ecosystems:
  beech forest, tussock, West Coast rainforest, peatlands
- Grazed pasture
- Pasture reverting to shrubland

Old-growth forest, Maruia, South Island

- 9 months in 1989/90
- Undisturbed stand of *Nothofagus,* 400 m a.s.l.
- Focus on testing of light response and respiration models

Hollinger et al., Ecology 75: 134-150 (1993)

Grassland, Mackenzie Basin, South Island

- 7 months in 1998/99
- Native tussock and invaded species, extensive sheep grazing
- Focus on drought effect limiting CO_2 uptake

Hunt et al., Agric. For. Meteorol. 111: 65-82 (2002)

Pasture on peat soil, Waikato, North Island

12 months in 2002/03

First annual CO_2 and C budget

NEE = 45 (±500) kg C/ha/a; carbon loss via milk production and CH_4 emissions of cattle

Nieveen et al., Global Change Biology 11: 607-618 (2005)

Pasture on mineral soil, Waikato, North Island

4 years (2008-2012)

Influence of climate variability and cultivation on CO_2 and C balance

Site small sink (600-900 kg C/ha/a) for C in first two years, despite severe drought in 2008 and cold winter in 2009.

Mudge et al., Agriculture, Ecosystems and Environment, 144: 271-280 (2011)

Pasture converted to shrubland, Oxford, South Island

7 years since 2005, ongoing

Kanuka planted in 2007

Grass dominating carbon budget for first 5 years since planting

Hunt et al. (in preparation)

Bare peat mine, Waikato, North Island

2005-2007

Controls of microbial respiration and photodegradation

NEE ~ 2700 kg C/ha/a, with 20% of CO_2 lost of abiotic origin. In summer, up to 60% loss from photodegradation

Rutledge et al., Global Change Biology 16: 3065-3074 (2010)

Long-term eddy covariance CO_2 sites in NZ

Period	Site	Ecosystem	Publication
Jul 1989 – Mar 1990	Maruia	Beech forest	Hollinger et al. (1993)
Oct 1998 – Apr 1999	Twizel	Tussock grassland	Hunt et al. (2002)
1999 – 2000	Moanatuatua	Wetland	Campbell et al. (in prep.)
Nov 2001 – May 2002	Okarito	Coniferous rain forest	Tissue et al. (2006)
May 2002 – May 2003	Wallace farm	Dairy pasture on peat	Nieveen et al. (2005)
Sep 2002 – Aug 2003	Rakaia Island	Regenerating kanuka woodland	
2004	Opuatia	Wetland	
2005 – now	Oxford	Pasture 2005, fallow 2006, converted to kanuka shrub 2007	Brown et al. (2009), Hunt et al. (in prep.)
2005 – 2007	Torehape	Bare peat (mine)	Rutledge et al. (2010)
2008 – 2012	Scott Farm	Dairy pasture on mineral soil	Mudge et al. (2011)

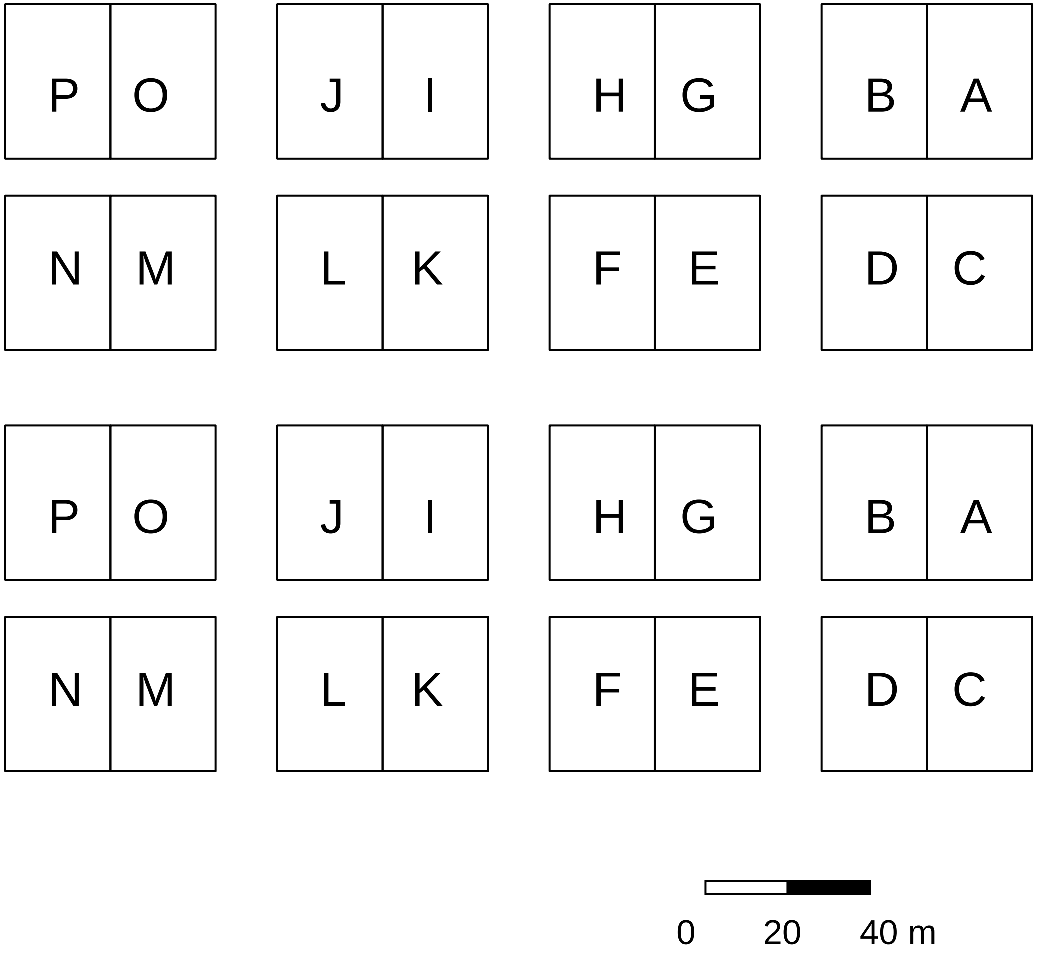
Present Kiwiflux sites

Period	Site	Ecosystem	Techniques
2011 – now	Kopuatai (Hauraki Plains)	Peat bog	EC
2011 – now	Three Springs (Methven)	Dairy pasture	EC
2011 – now	Wakanui (Ashburton)	Cropland	EC
2011 – now	Troughton Farm (Waikato)	Dairy on mineral soil, two pasture types	2 x EC
2012 – now	Beacon Farm (Dunsandel)	Dairy pasture, irrigated and un-irrigated	2 x EC for CO_2, FG for CH_4 and N_2O

Other micrometeorological approaches

- NZ interest primarily on CH_4 and N_2O (big agric. sources)
- Targeted campaigns to: - estimate emission factors
  - test mitigation approaches
- Flux-gradient, Mass-budget, BLS, NBL-budget, NBL-ratio, Tracer-ratio methods have all made contributions
- Common criticisms: - no treatment comparisons
  - no statistical replication

CH_4 emissions from grazing cattle: can difference between two groups be detected?



Cattle group 1:
oil-sprayed grass

Cattle group 2:
untreated grass

Laubach et al., in preparation

Open-path laser system:

- ⬬ ▪ ▪ Remote head
- ◆ ▪ ▪ ▪ Retroreflector
- ■ Main unit (in vehicle)

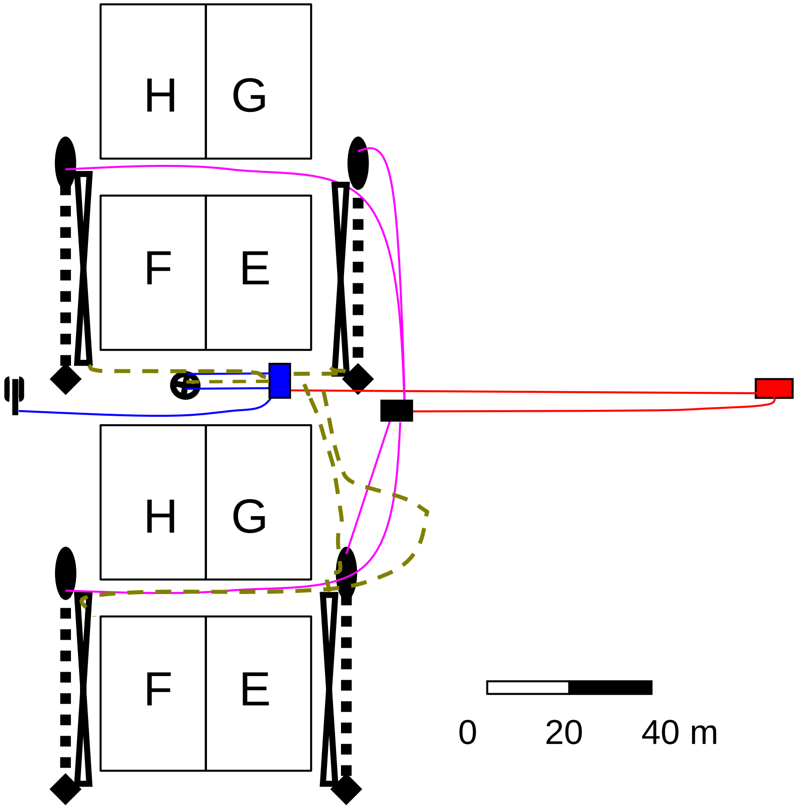
Other instruments:

- ⊕ Wind profile mast
- ⧗ Air intake line
- 🟦 Van
- Sonic anemometer

Power supply:

- 🟥 Generator

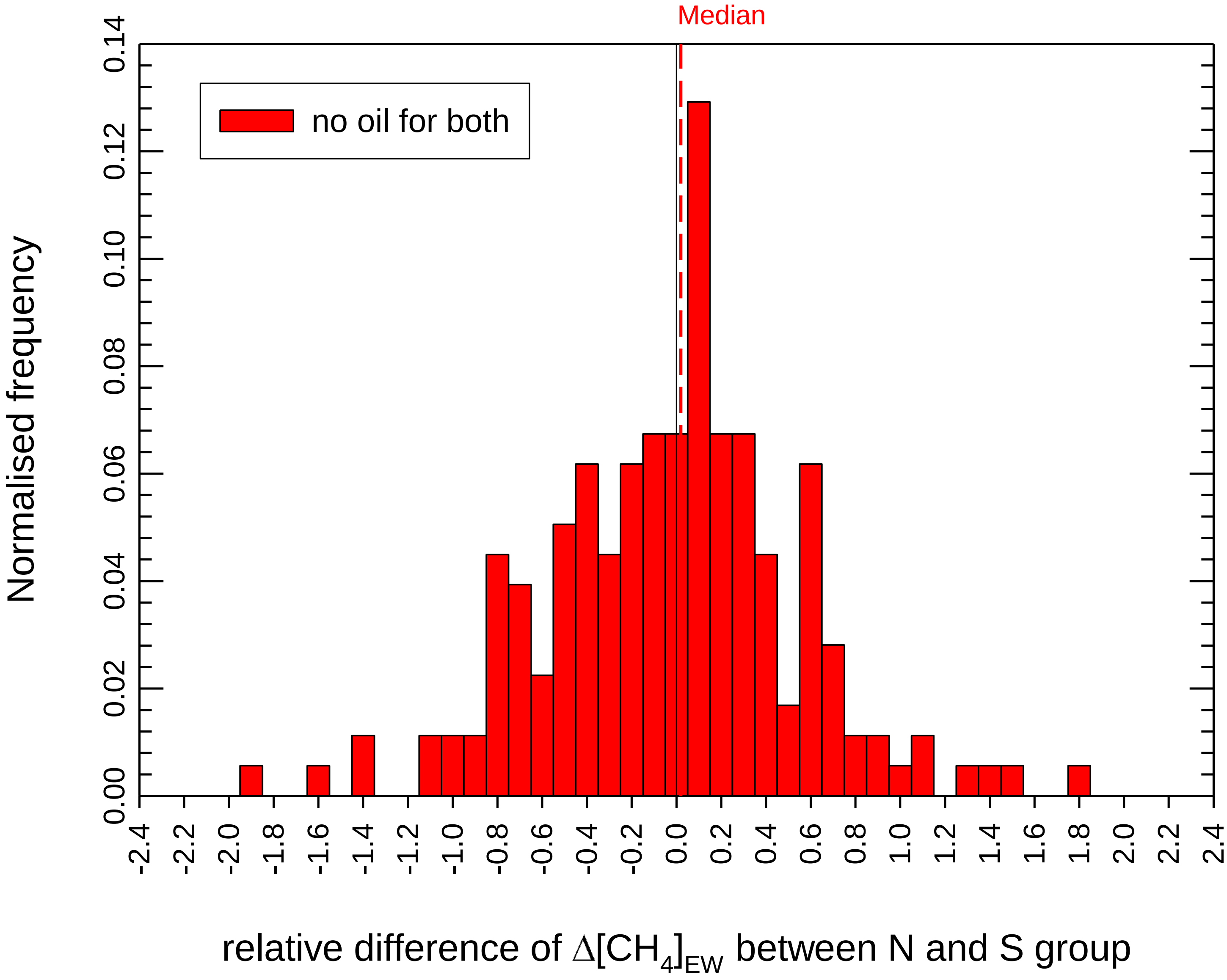
(symbols not to scale)

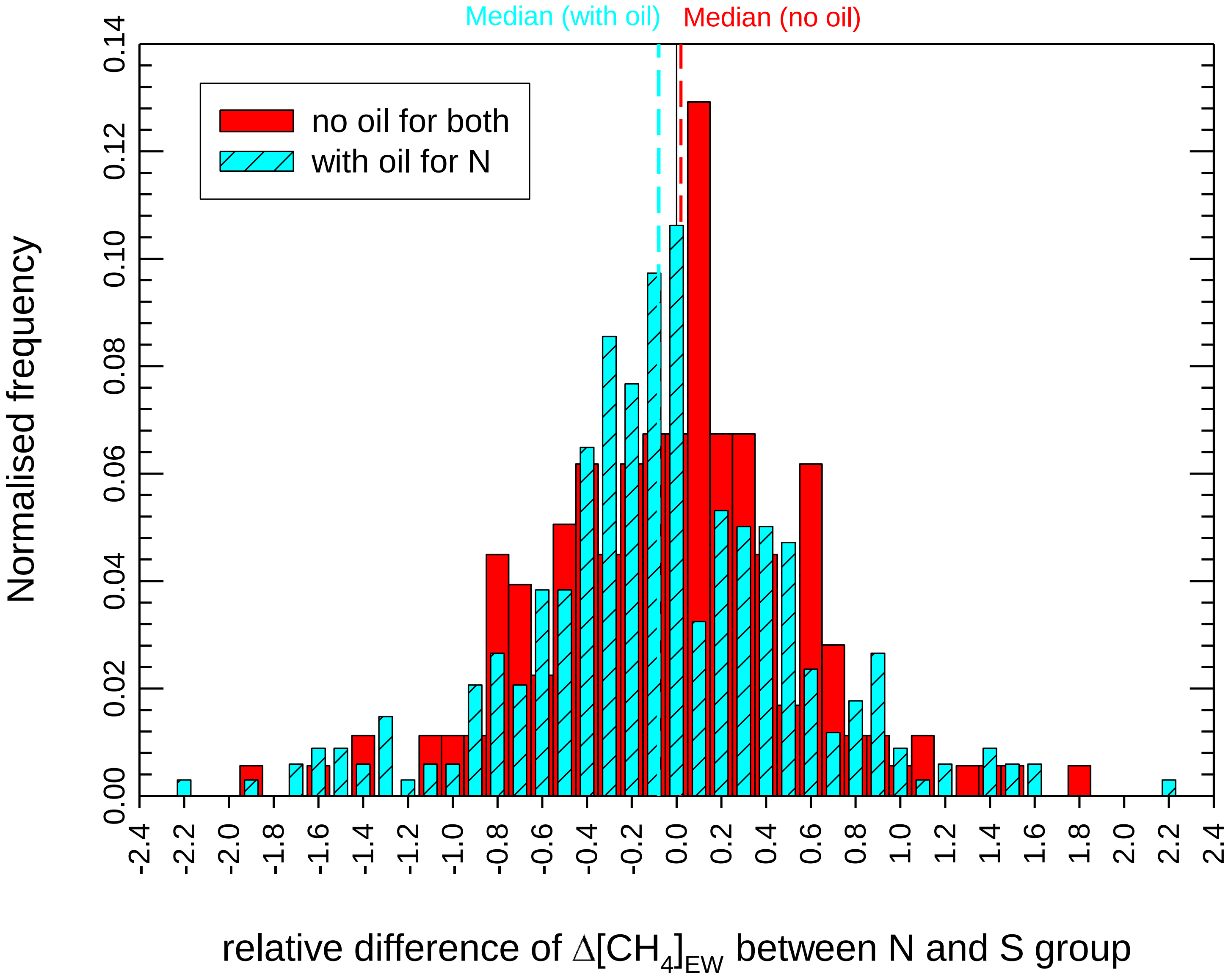


- 30 cattle in each group
- Shifting to new paddock every day
- Optimised for W and E wind directions
- Switching cycle for 4 line concentrations

Procedure

- Select wind directions within ± 40° of E or W
- Form concentration differences for N and S groups, divide by actual number of cattle: $D_{EW} = \Delta[CH_4]_{EW} / n$
- Normalise for each run by mean of N and S: $\langle D_{EW} \rangle$ and form relative difference: $(D_{EW,\,N} - D_{EW,\,S}) / \langle D_{EW} \rangle$
- 6 days of “no oil” vs “no oil”, to estimate random variability
- 10 days of “oil” in N vs “no oil” in S


Median
🟥 no oil for both
Normalised frequency
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0.14
-2.4
-2.2
-2.0
-1.8
-1.6
-1.4
-1.2
-1.0
-0.8
-0.6
-0.4
-0.2
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
relative difference of $\Delta[CH_4]_{EW}$ between N and S group


Median (with oil)
Median (no oil)
no oil for both
with oil for N
Normalised frequency
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0.14
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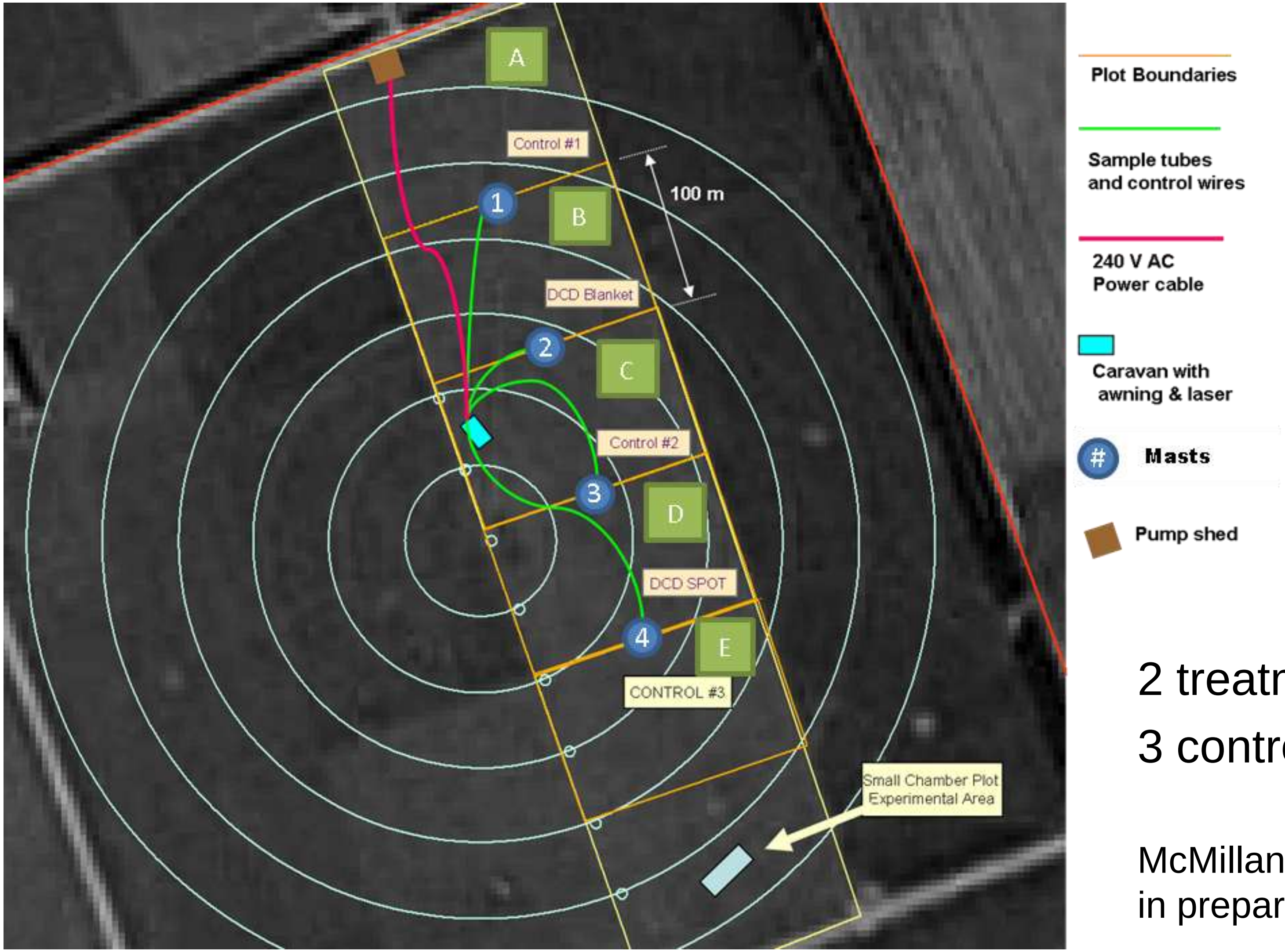
relative difference of $\Delta[CH_4]_{EW}$ between N and S group

N_2O emissions from cattle excreta: does a nitrification inhibitor make a difference?



2 treatments,

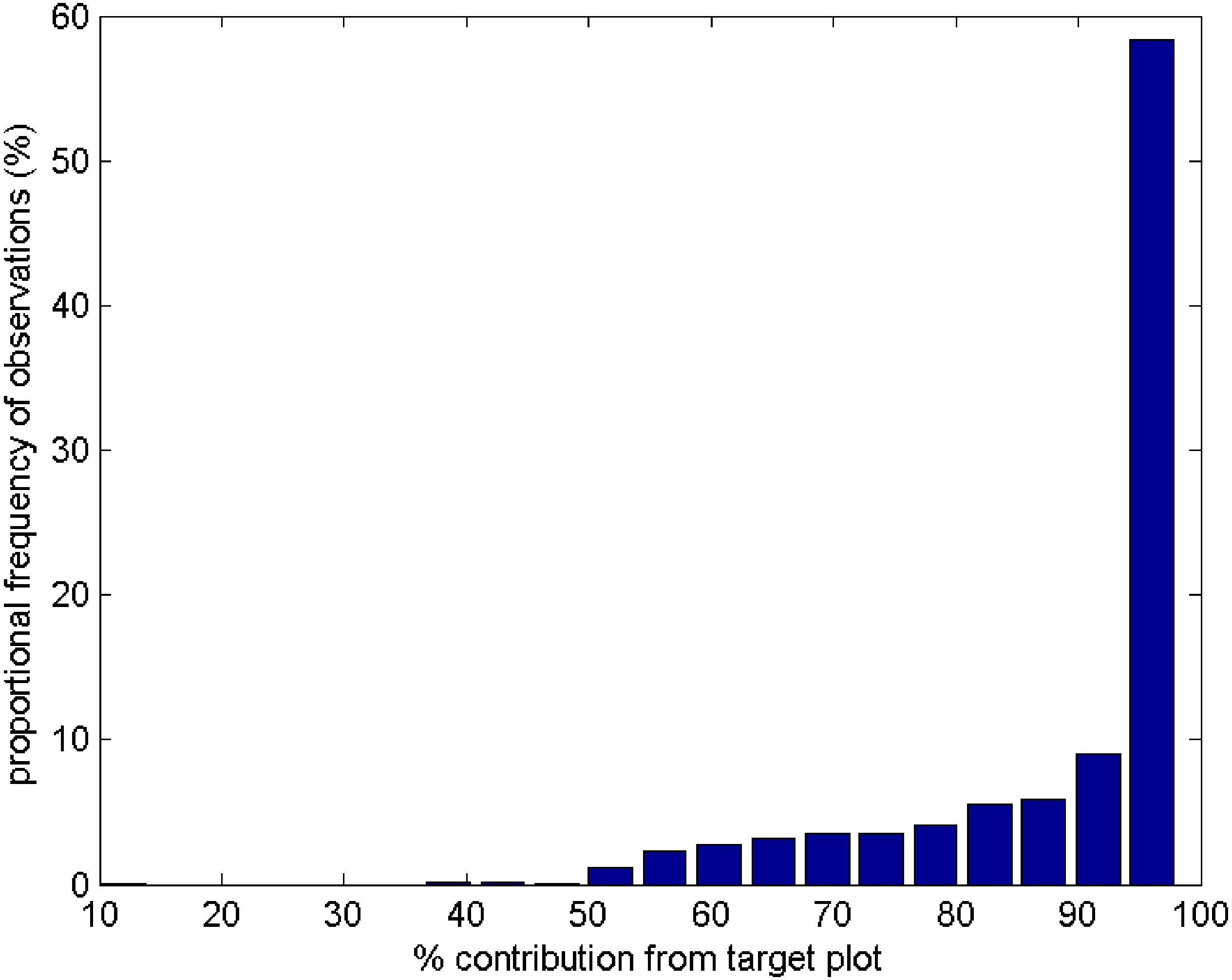
3 controls

McMillan et al.,
in preparation

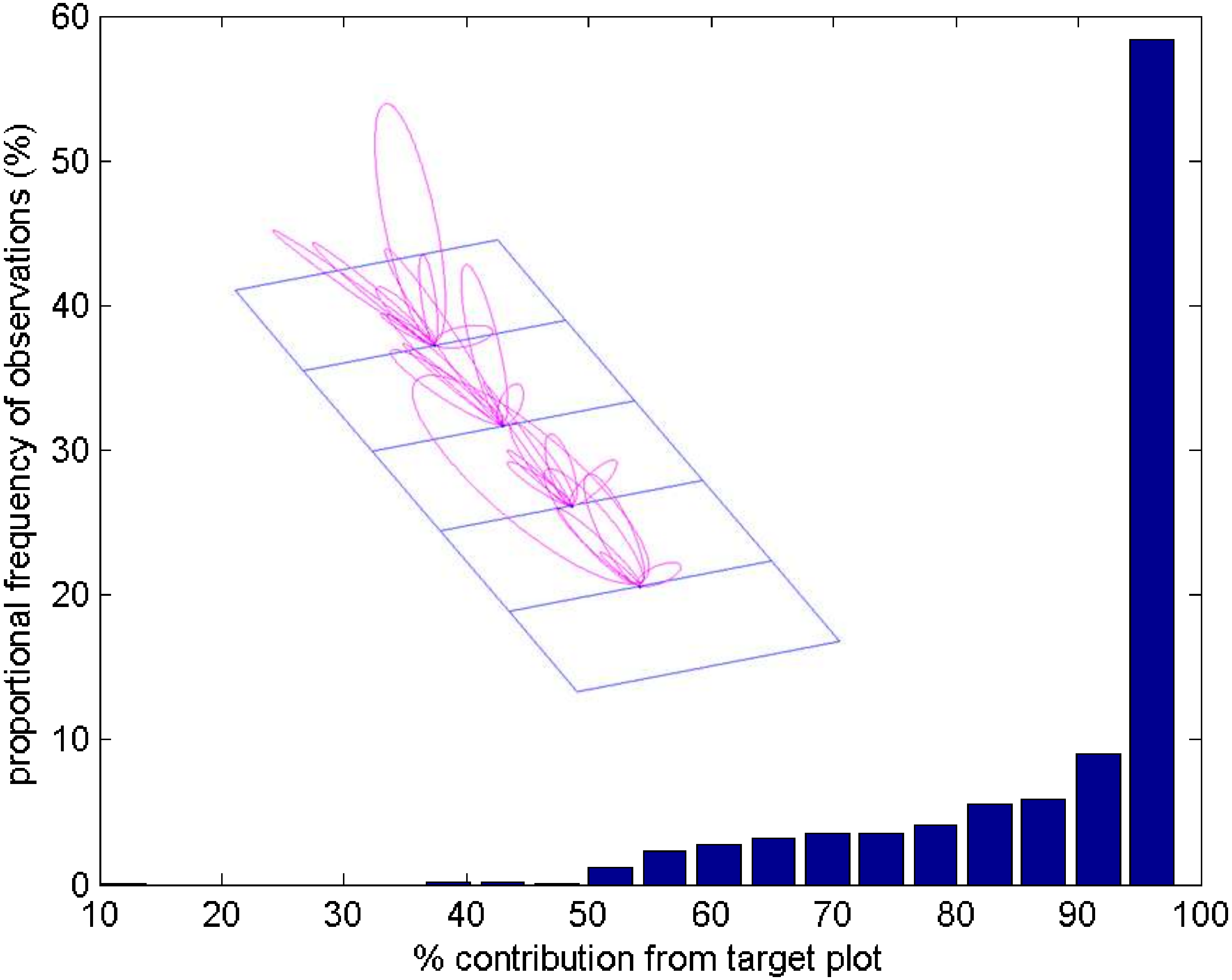
N_2O emissions from cattle excreta: does a nitrification inhibitor make a difference?

- Spring and autumn campaigns
- Flux-gradient method, diffusivity from nearby-sonic data
- Closed-cell tunable-diode laser
- Fast switching between paired intakes: every 6 or 9 s
- Slow switching between 4 intake pairs: every 20 or 30 min
- Footprint computation for each run

Small cross-contamination thanks to small footprint

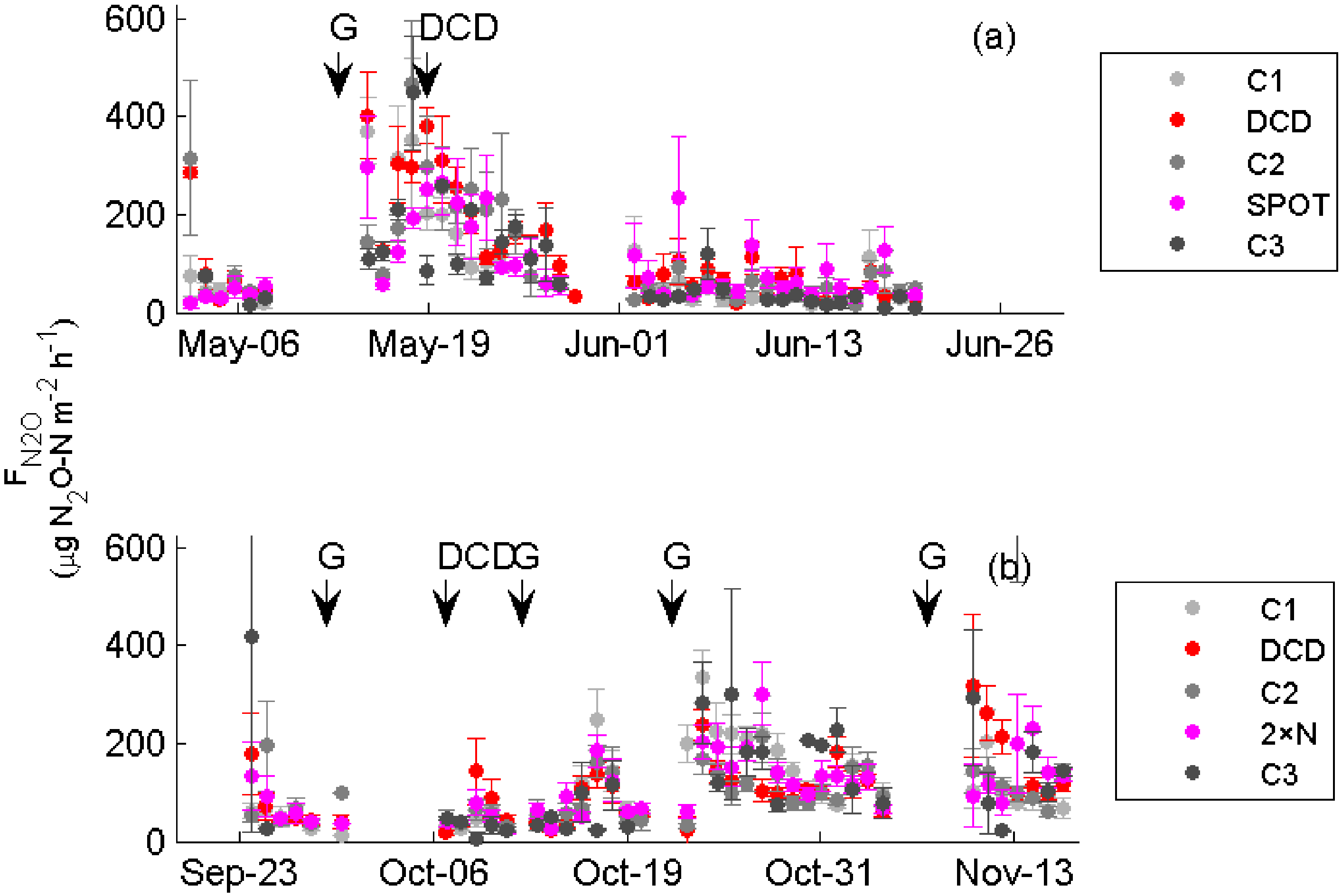


Small cross-contamination thanks to small footprint



Preliminary results

McMillan et al.,
in preparation



Summary

- So far, in NZ only two handfuls of long-term eddy covariance studies
- Strong focus on agricultural emissions, of all three major greenhouse gases
- Targeted studies to obtain emission factors, or to test mitigation approaches
- Micrometeorology contributes to these, but usually not with eddy covariance

Outlook

Recent/renewed interest in:

- Total greenhouse gas farm budgets
- Soil carbon (budgets and processes)
- Effects of land-use changes
- Water constraints and allocation issues

providing momentum to establish several new sites – hence birth of “Kiwiflux”