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Measuring CH_4 & N_2O Fluxes from Field to Landscape Scales using Fast-response Tunable Diode Lasers

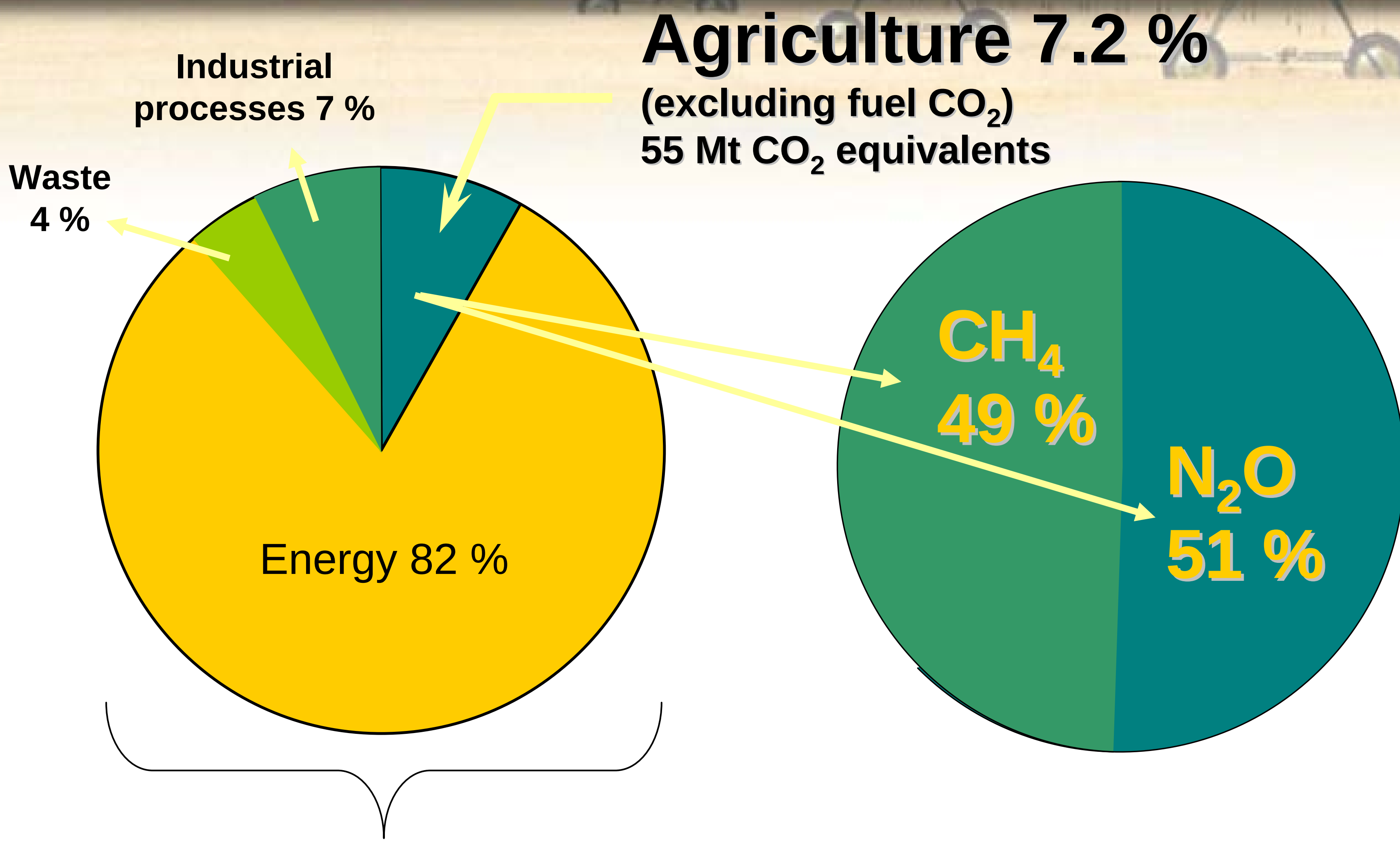
Elizabeth Pattey

Coll.: Ray Desjardins, Elyn Humphreys (Carleton University)

Ameriflux Meeting, Boulder CO
17-19 Oct. 2007

Canada

GHG emissions from the Canadian Agricultural Sector, 2004



All Sector Total :
758 Mt CO_2 equivalents

Open-path lasers for measuring CH_4 fluxes from point sources

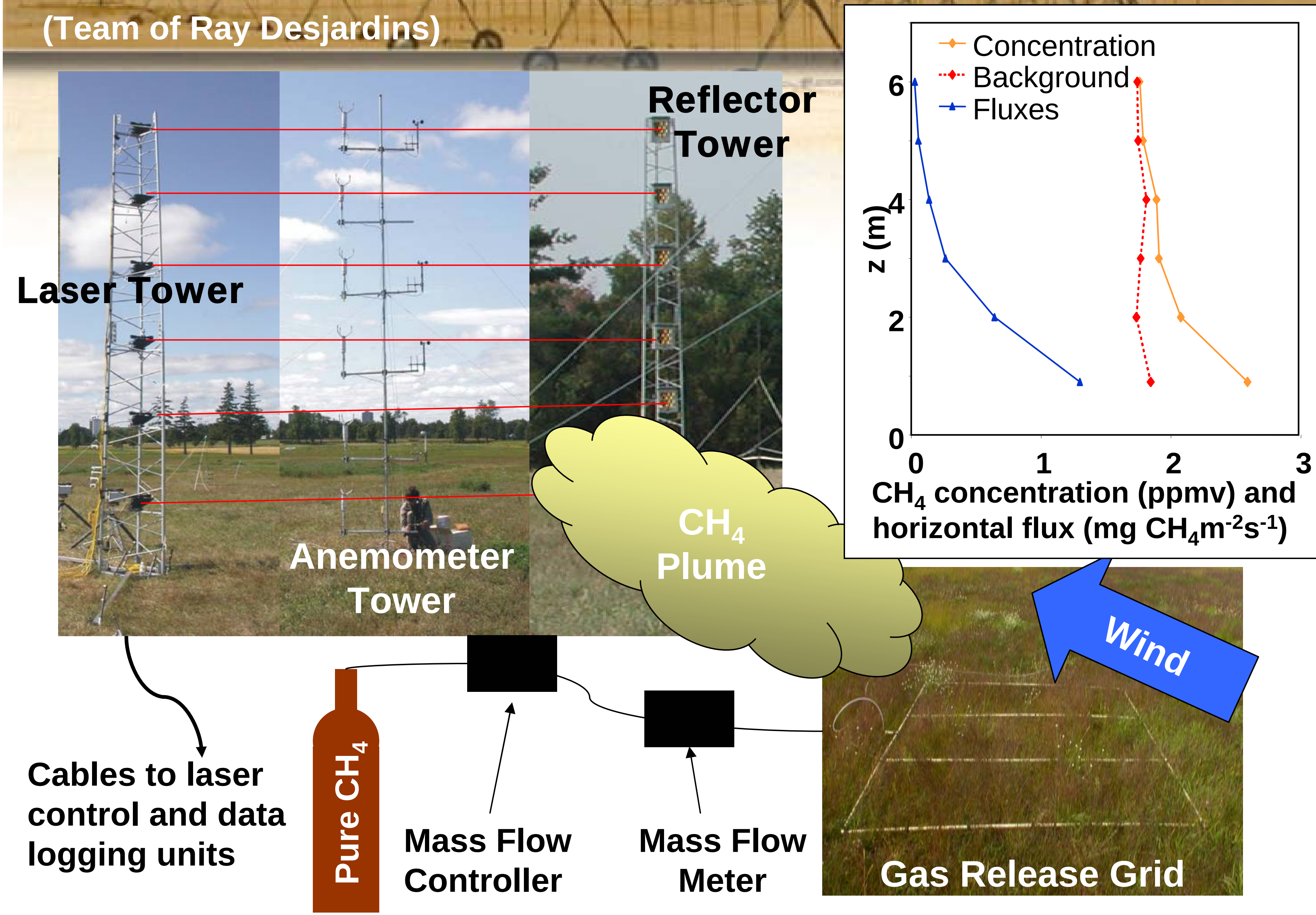
Portable Open Path Boreal Lasers

Reflector

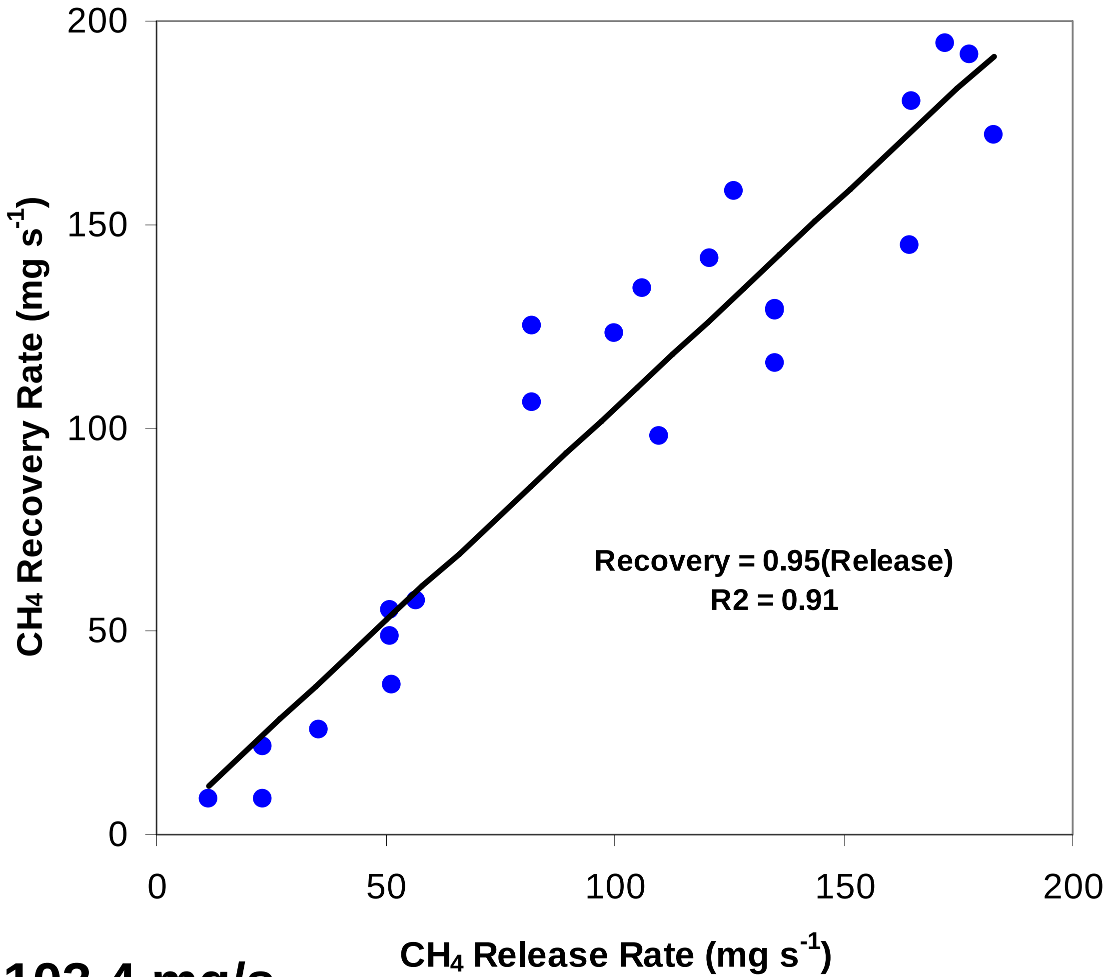
Sonic Anemometer

Instrumentation for the Mass Balance Technique, Methane

(Team of Ray Desjardins)



Recovery and Release Rates Of CH_4 (half hour averages)



Mean emission: 103.4 mg/s
Mean recovery: 109.0 mg/s

Desjardins, R.L., McBain, M.C., Kaharabata, S., Pattey, E., MacPherson, I., Worth, D., Srinivasan, R., Verge, X., and Gao, Z. 2007. Measuring methane emissions from agricultural sources. Int. J. Appl. Environ. Sci., in press.

Specs of Close –Path Tunable Diode Laser

- Lead salt diode as a source of narrow bandwidth infrared radiation
- Selection of an infrared line with minimal interference from other molecules by mapping the laser over a range of temperature
- Fast-response: 10 Hz
- Close-path offer high precision and resolution needed for diffuse source/sink studies
- Optical path length configuration: single-pass vs multiple-pass
- Increase in path length is often associated with increase in noise
- Reference gas to determine the sample gas concentration, by ratioing the sample and reference signals
- Cryo-cooling of the laser using either a compressor or LN_2
- A vaccum pump is used to maintain constant flow rate and pressure (~50-75 mbar)


Larger Dewar for more than
48 h refilling period
=>vibration-free environment
Sampling cell of 1.5m long
CAUTION
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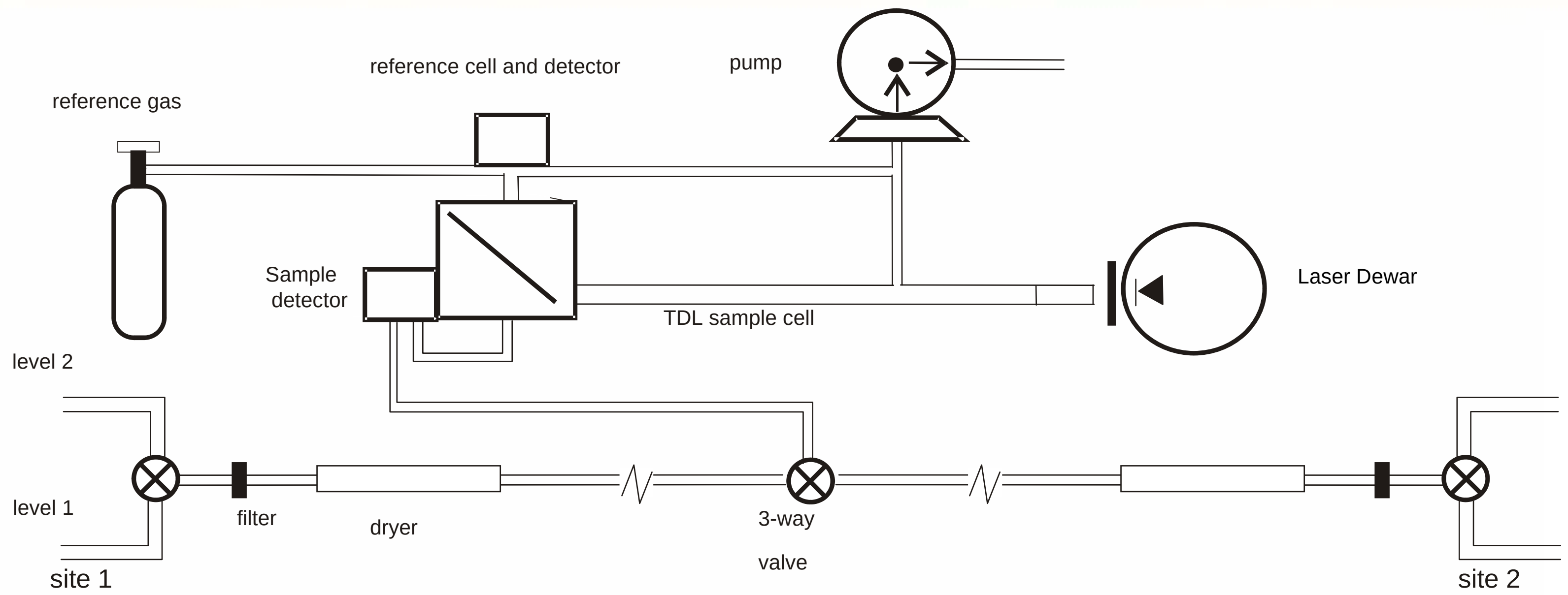
Agroalimentaire

TDL configuration for EC, FG & NBL



GRADIENT FLUX RESOLUTION USING SINGLE-PATH TDL

- 30-min 2-level TDL gradient resolution:

  N_2O (1ppbv noise over 10s): 16 pptv

  CH_4 (7ppbv noise over 10s): 113pptv

- 30-min Flux-Gradient resolution:

  [z_o=0.1 m s^{-1}; u_*=0.2 m s^{-1}; d=0.66m; z_2=3.25m; z_1=2.25 m]

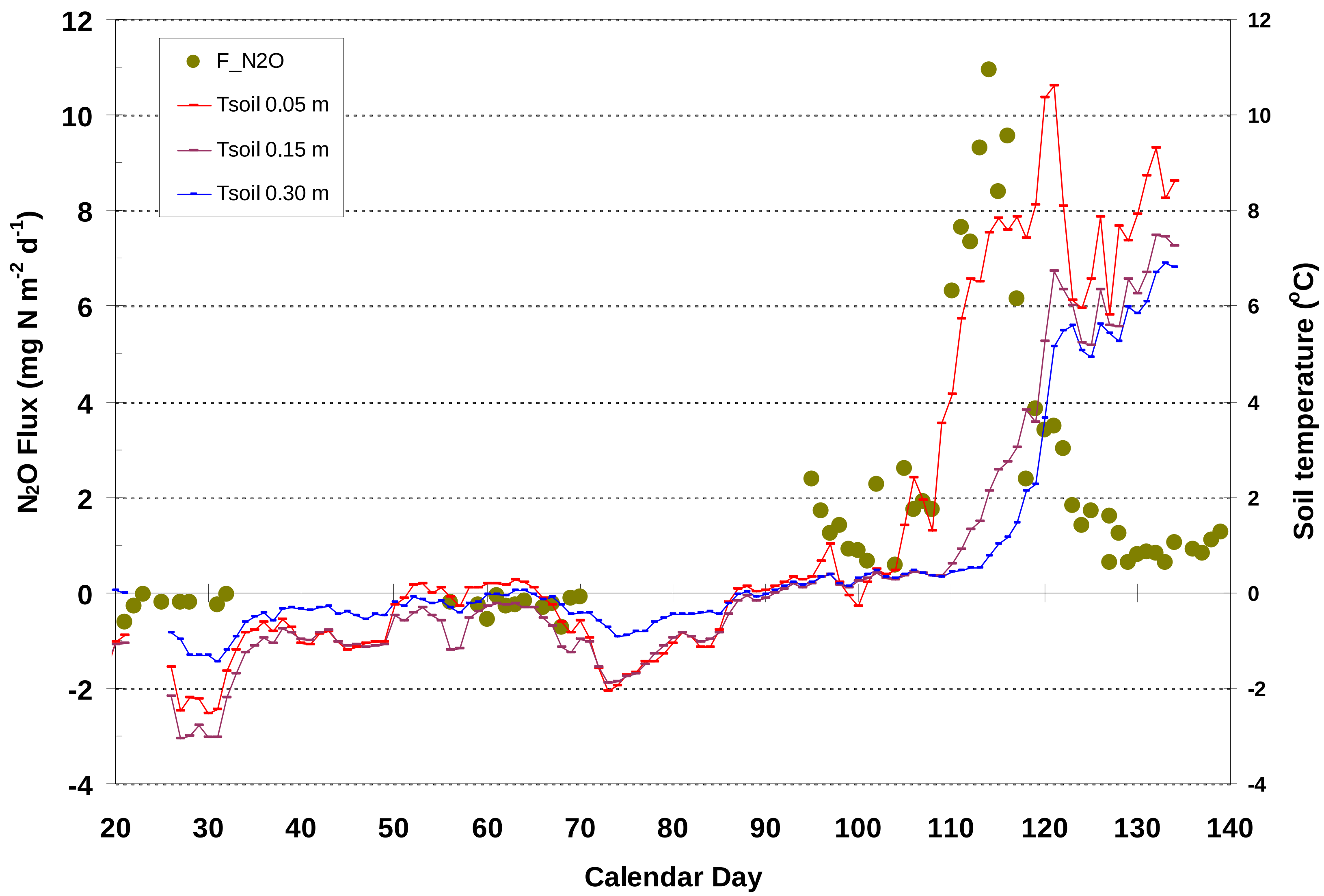
  $F(N_2O) \approx$ 7.7 ng N_2O m^{-2} s^{-1}

Pattey, E., Edwards, G., Strachan, I.B., Desjardins, R.L., Kaharabata, S. and Wagner Riddle C., 2006. Towards standards for measuring greenhouse gas flux from agricultural fields using instrumented towers. Can. J. Soil Sci. 86: 373-400.

Flux-Gradient technique

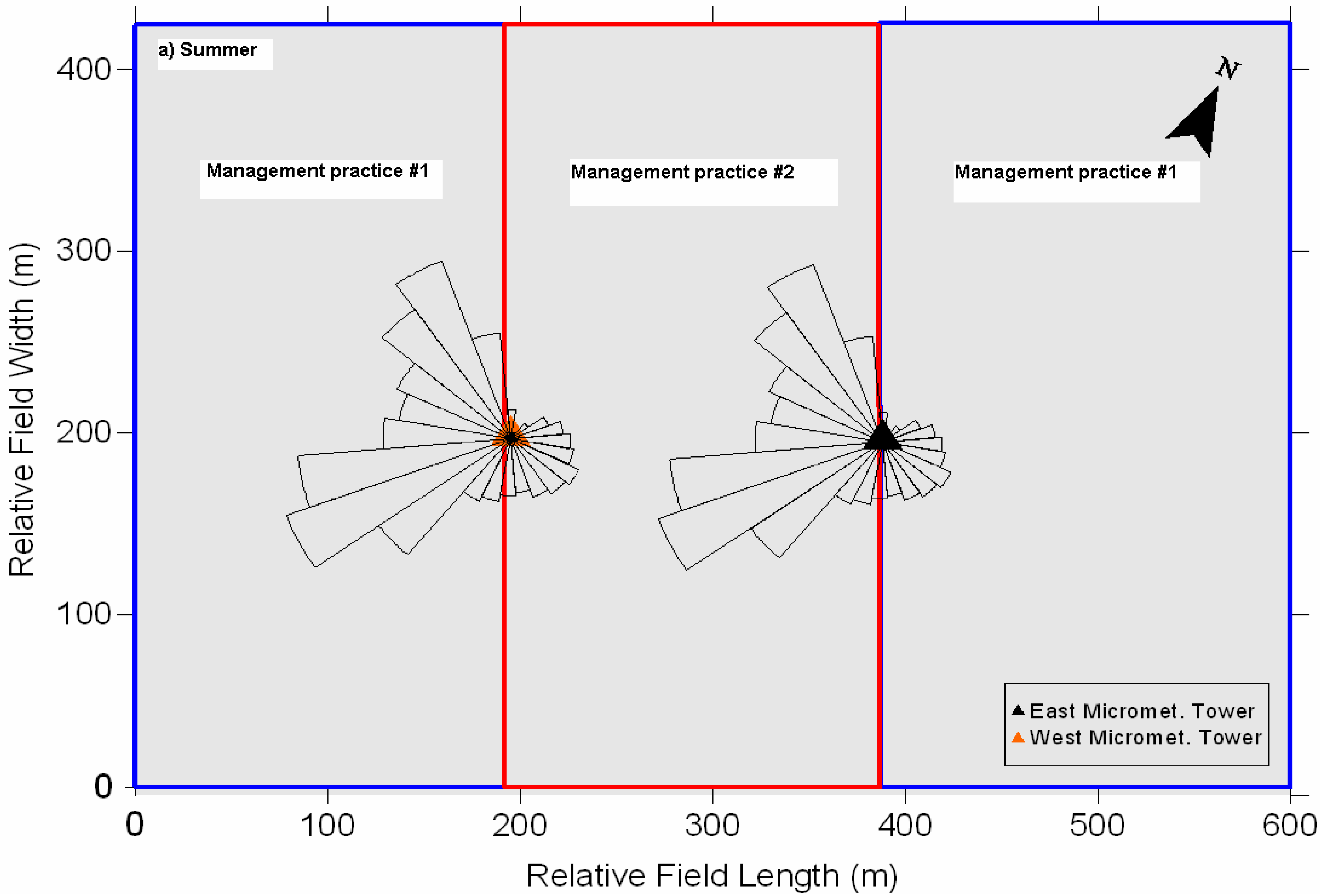
- Performed over agricultural fields (in the inertial sublayer)
- Concentration is measured sequentially at a fast-rate, typically 5-10 s, with data omitted during gradient valve switching
- N_2O fluxes need to be measured during rainy conditions and spring thaw, where the technique is quite robust
- Easier to monitor several sites

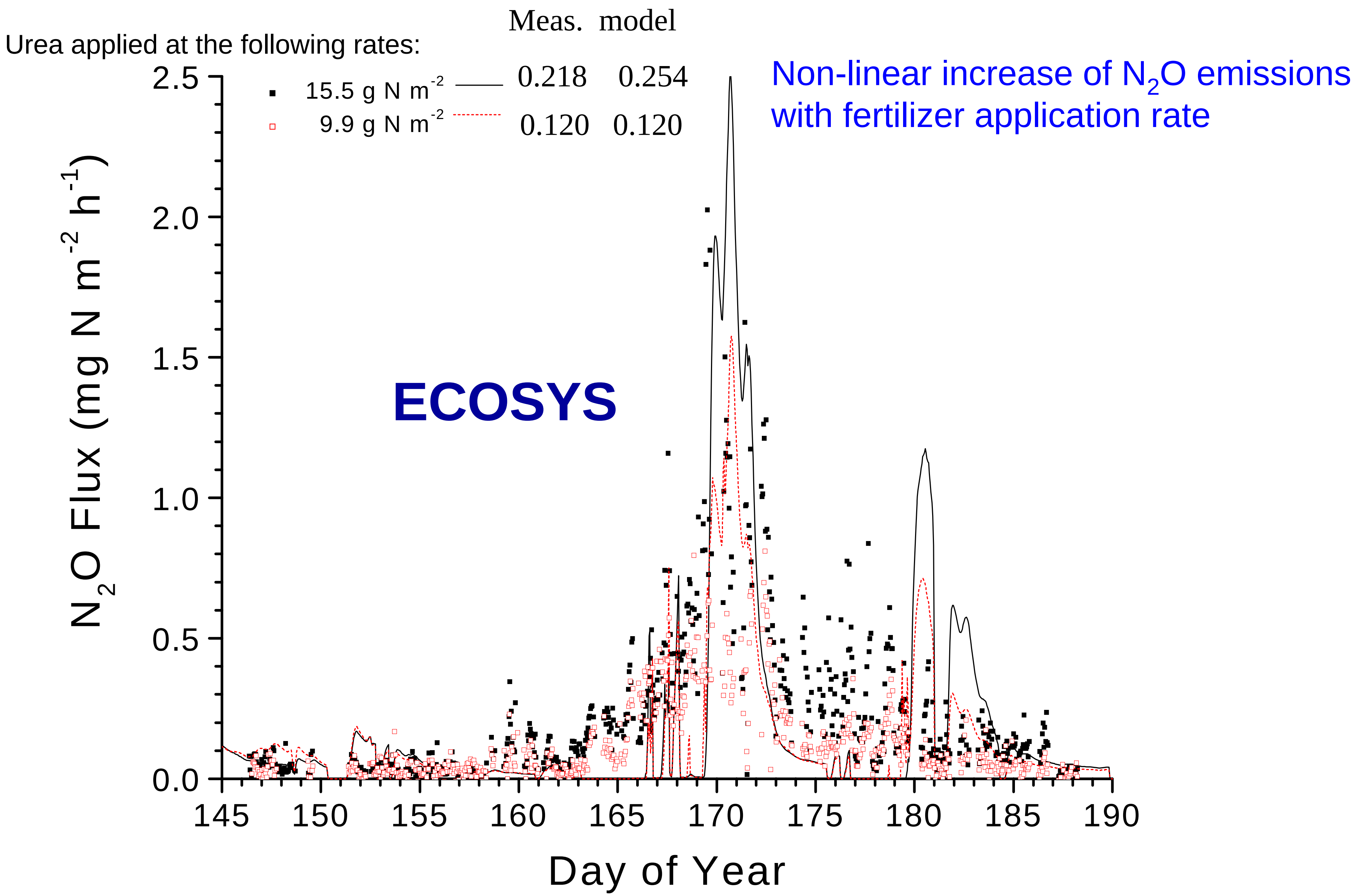
Permanent Site, Ottawa - Snowmelt 1997



SETUP FOR QUANTIFYING N_2O FLUXES FOR TWO MANAGEMENT PRACTICES

1 TDL connected to 2 micromet. towers

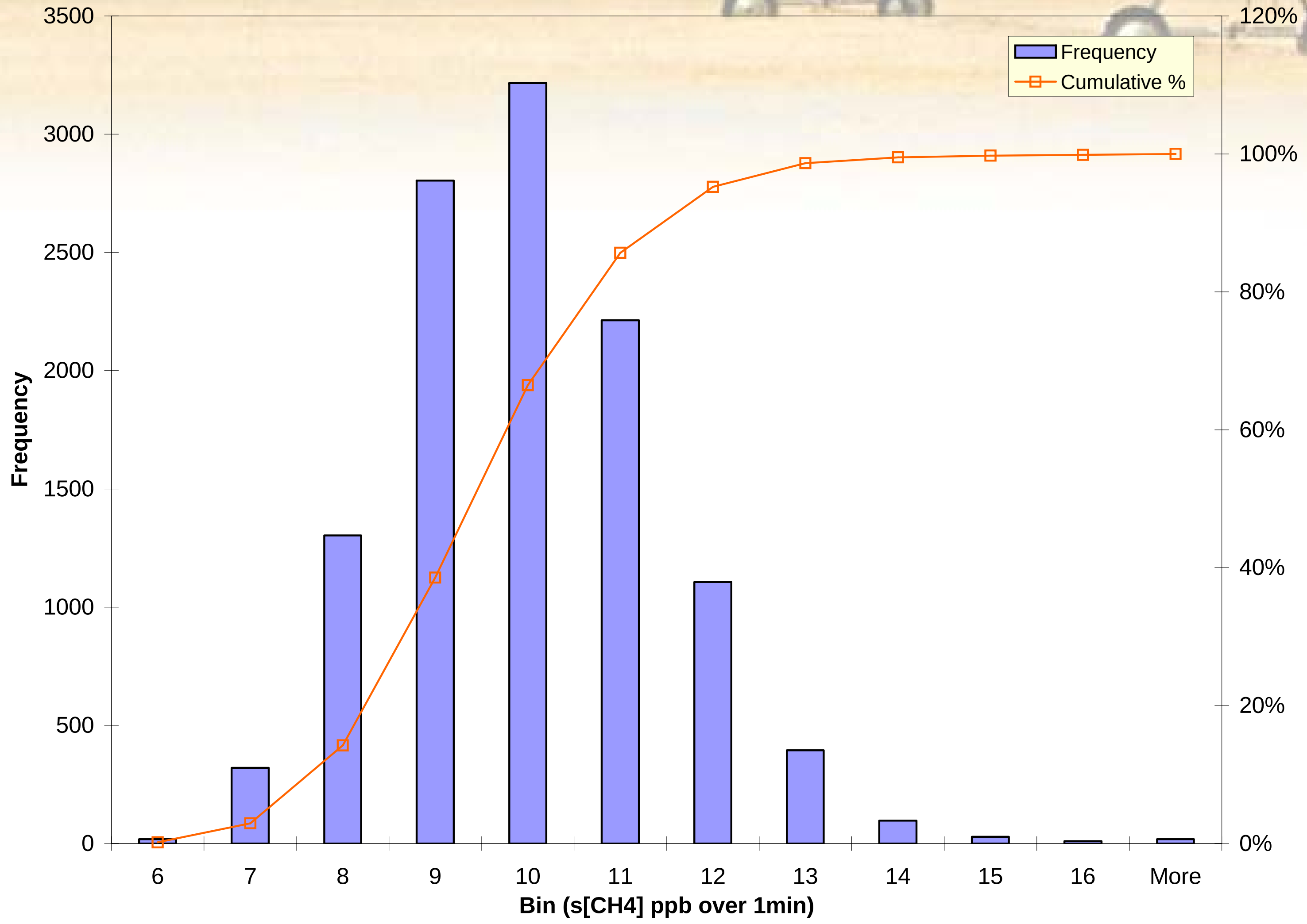




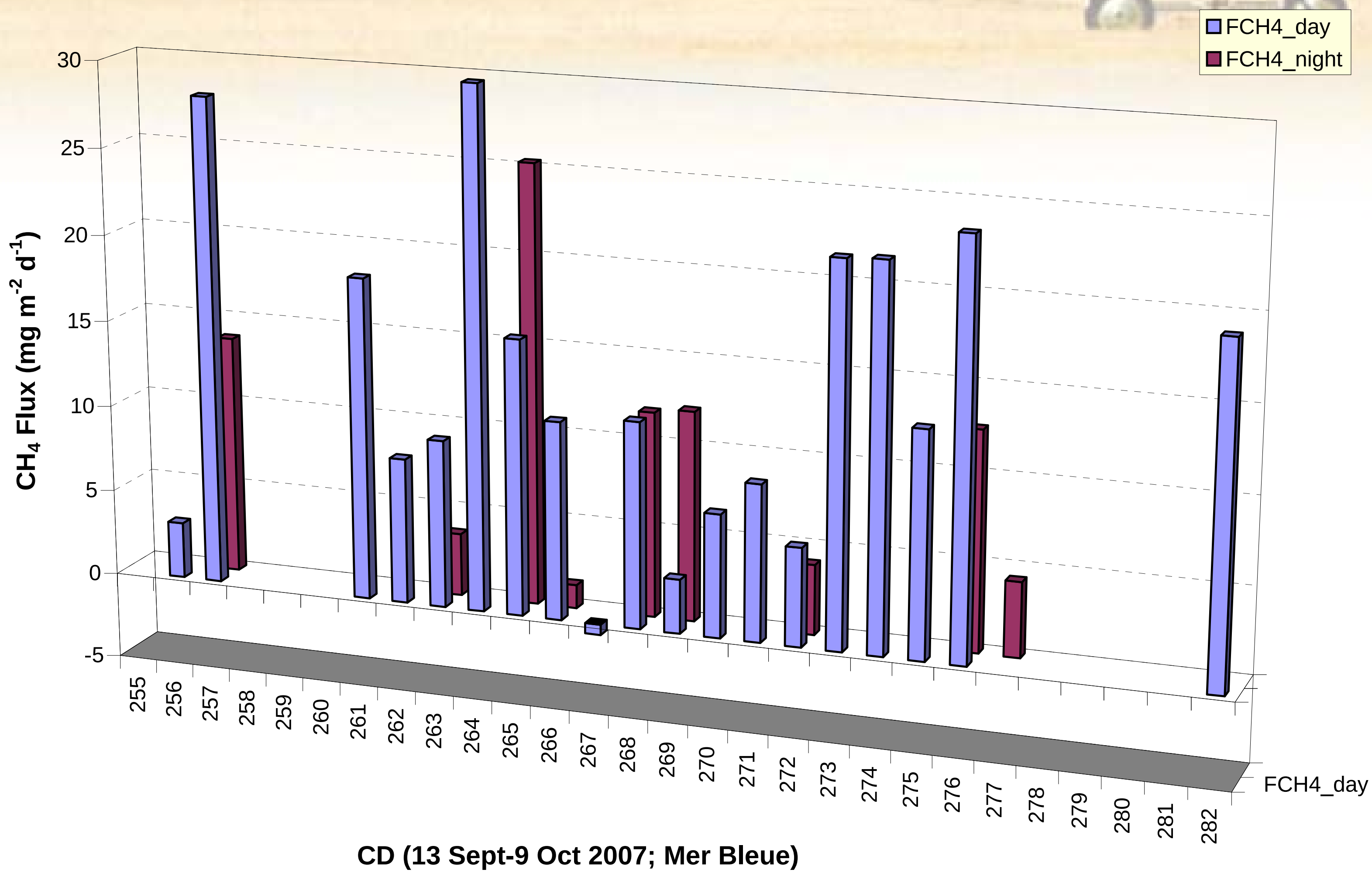
Grant, R. and Pattey, E., 2003. Modelling variability in N_2O emissions from fertilized agricultural fields. Soil Biology and Biochemistry:35(2): 225-243.

Methane Fluxes at Mer Bleue using EC technique (coll. Elyn Humphreys, Carleton U. and CCP)

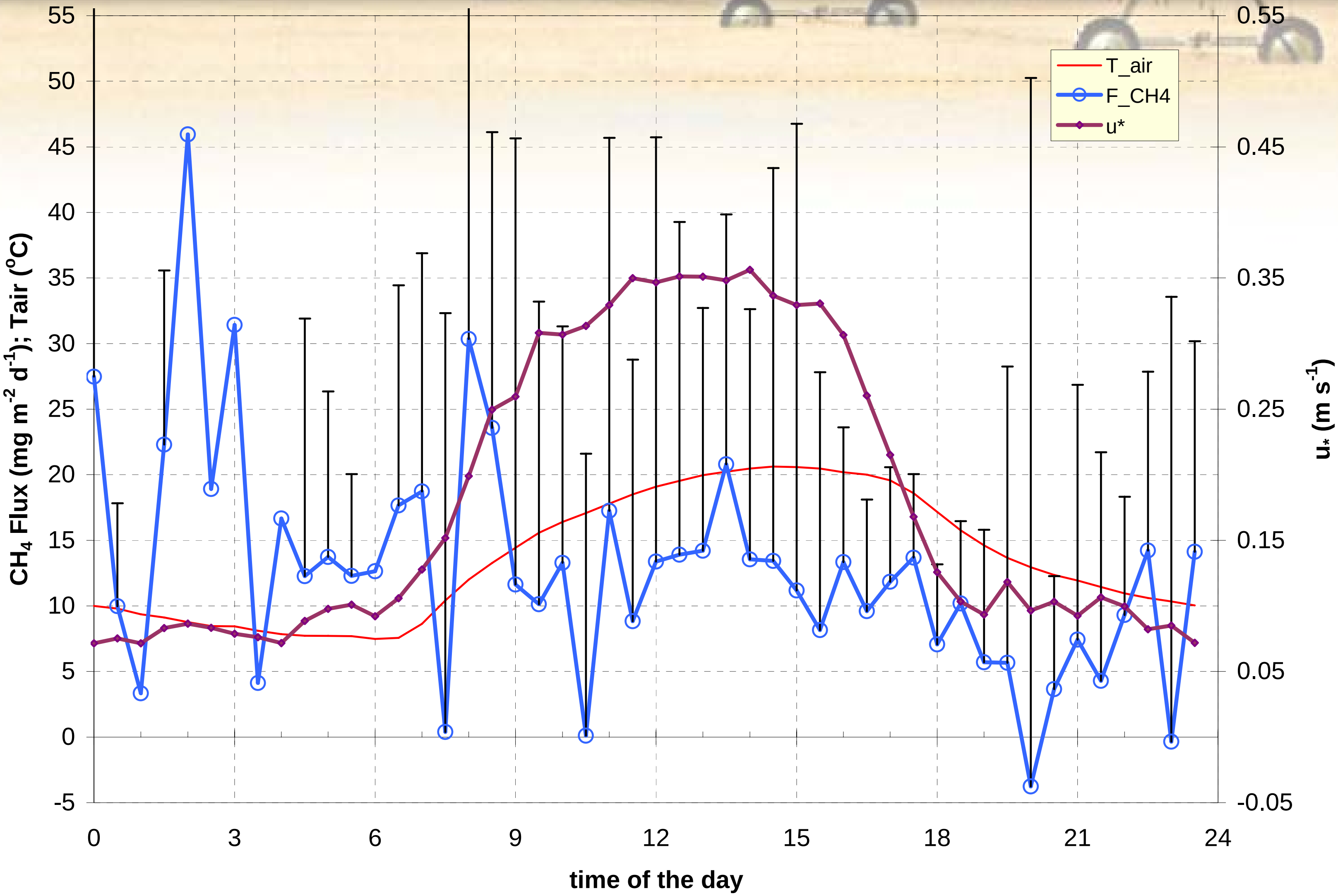
1-min standard deviation of daytime CH4 at Mer Bleue from Sept 13-October 9 2007



30-min daytime and nighttime CH_4 Fluxes at Mer Bleue from 13 Sept - 9 Oct 2007



Diurnal course of EC Methane flux at Mer Bleue



Comparison with other daytime CH_4 Flux measurements at Mer Bleue

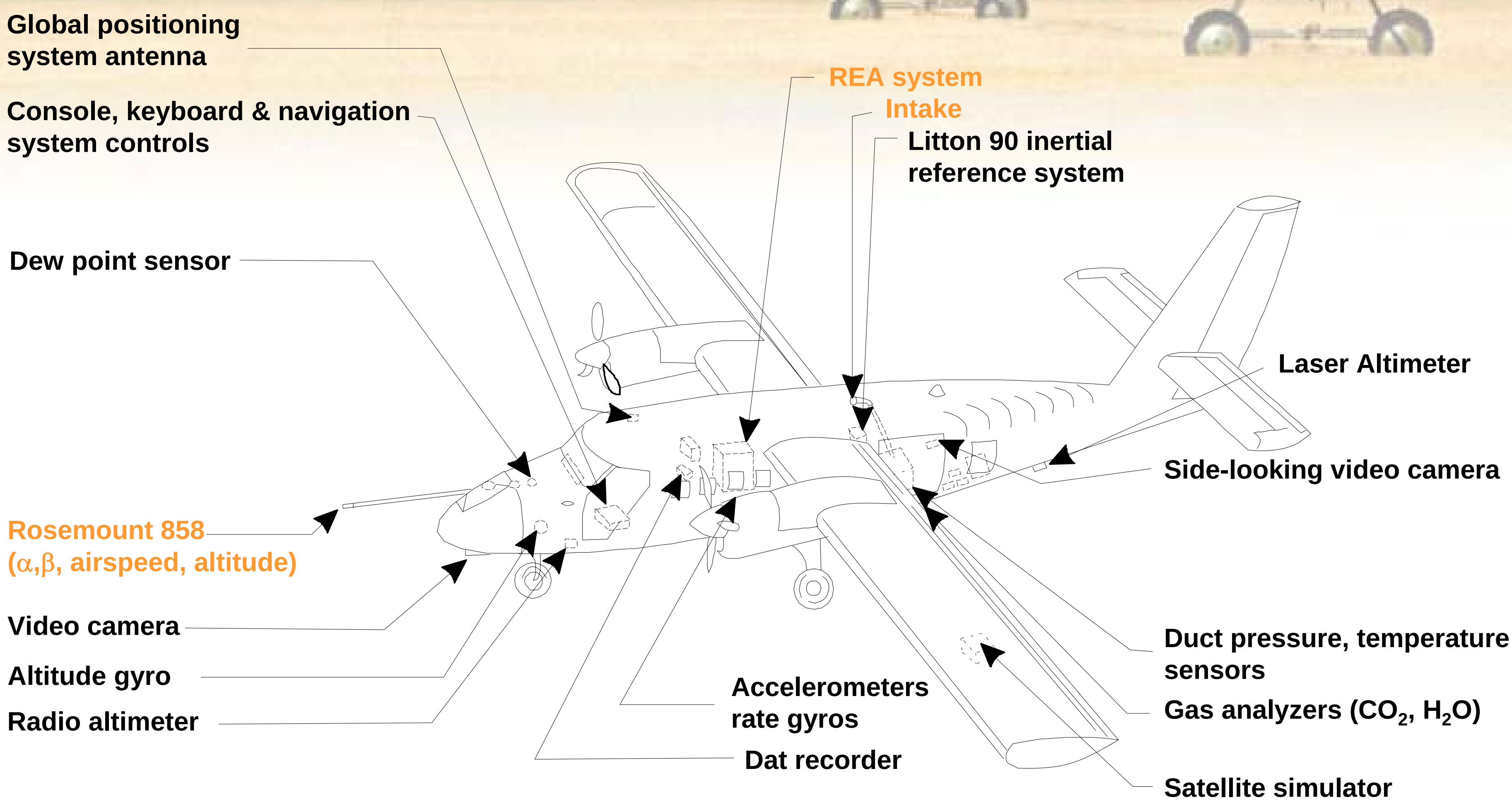
Aircraft –based CH_4 Flux using REA on 28 Aug 2003

Coll: Ian MacPherson (NRC) & Ray Desjardins (AAFC)

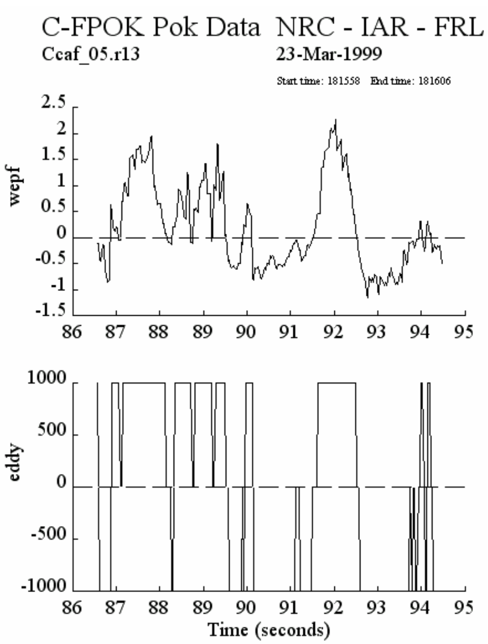
3 flights 40-m above ground; U_*~0.4 m s^{-1} Tsurf ~ 21^{o}C :

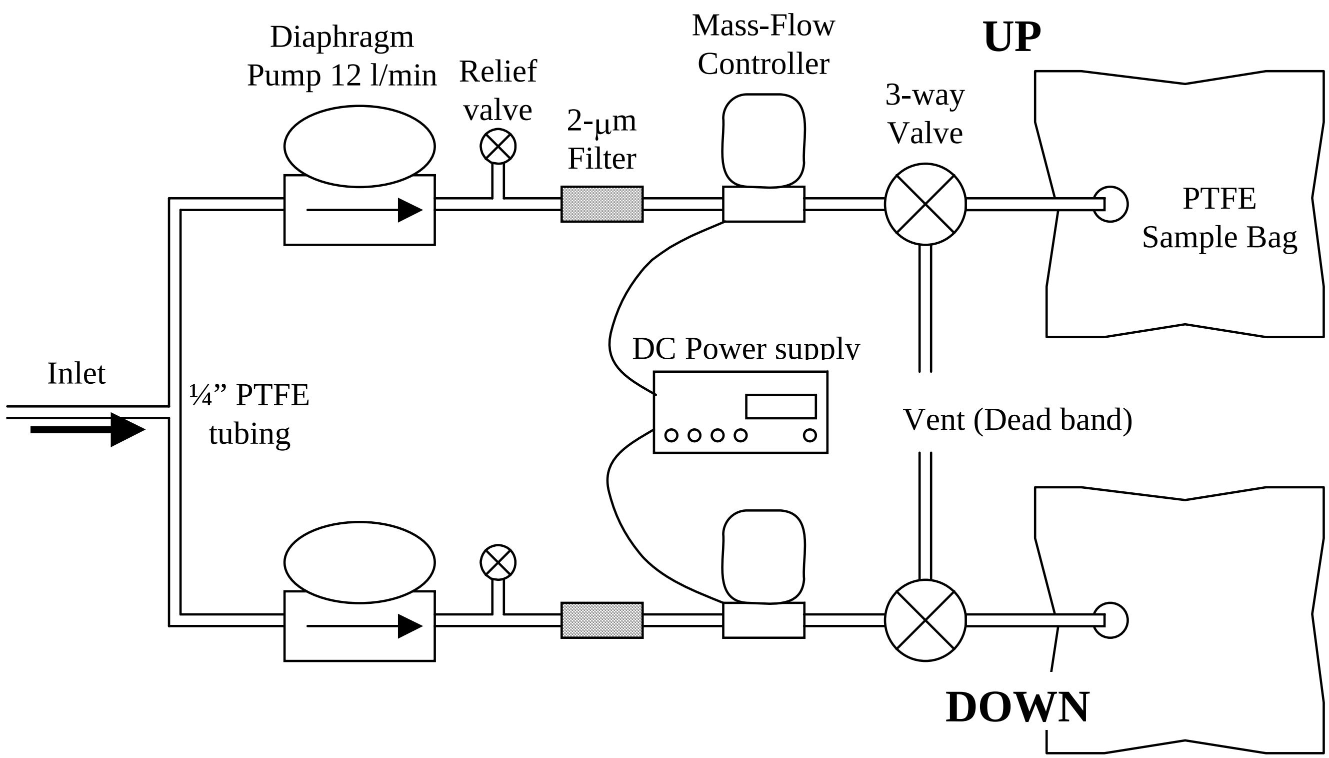
CH_4 Fluxes ($mg\ m^{-2}\ d^{-1}$)
12.6
48.8
24.0

AIRCRAFT-BASED MEASUREMENTS

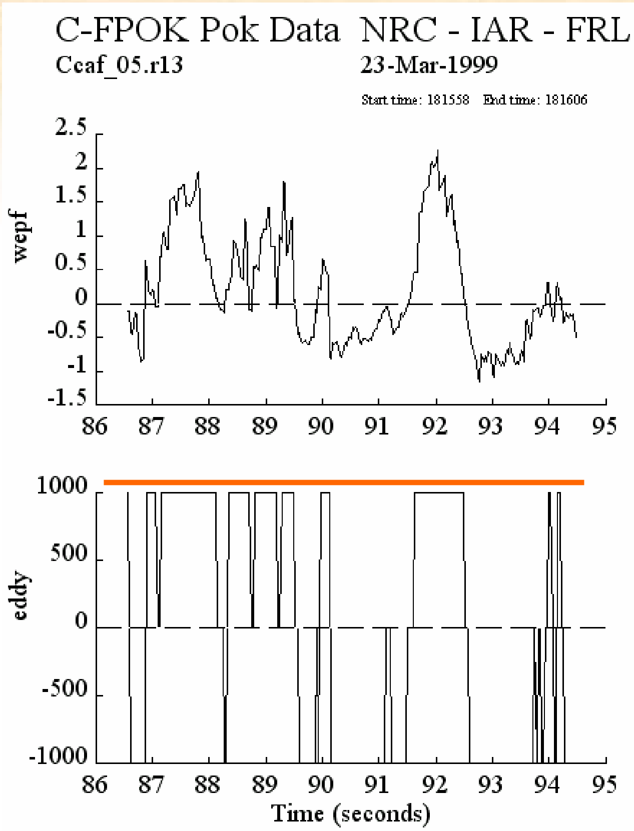


THE REA SAMPLING SYSTEM & TDL

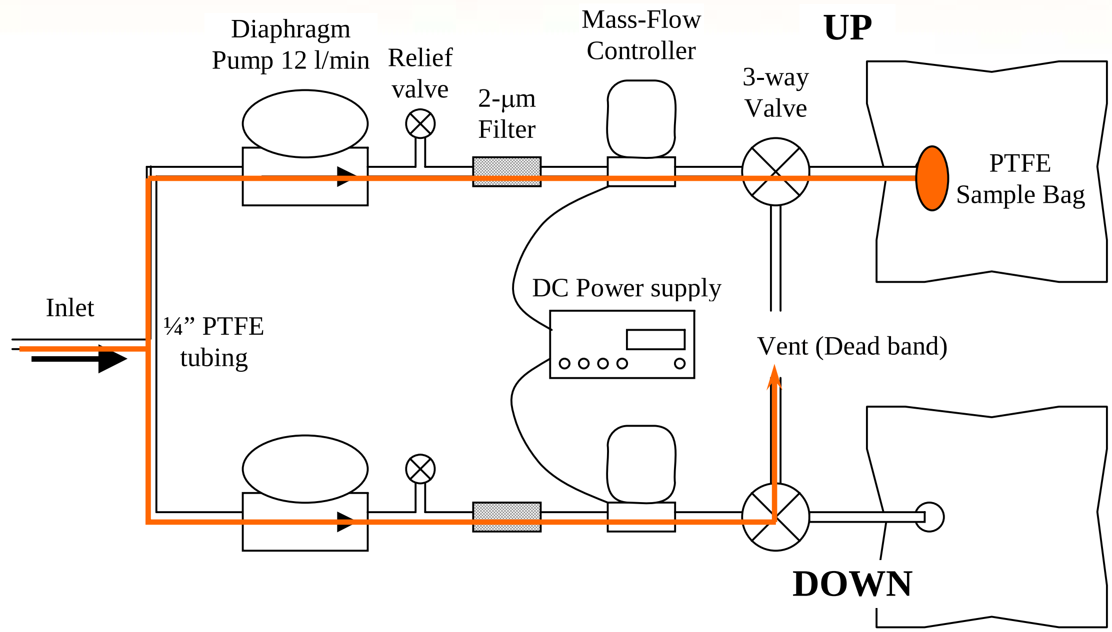




Up Gust

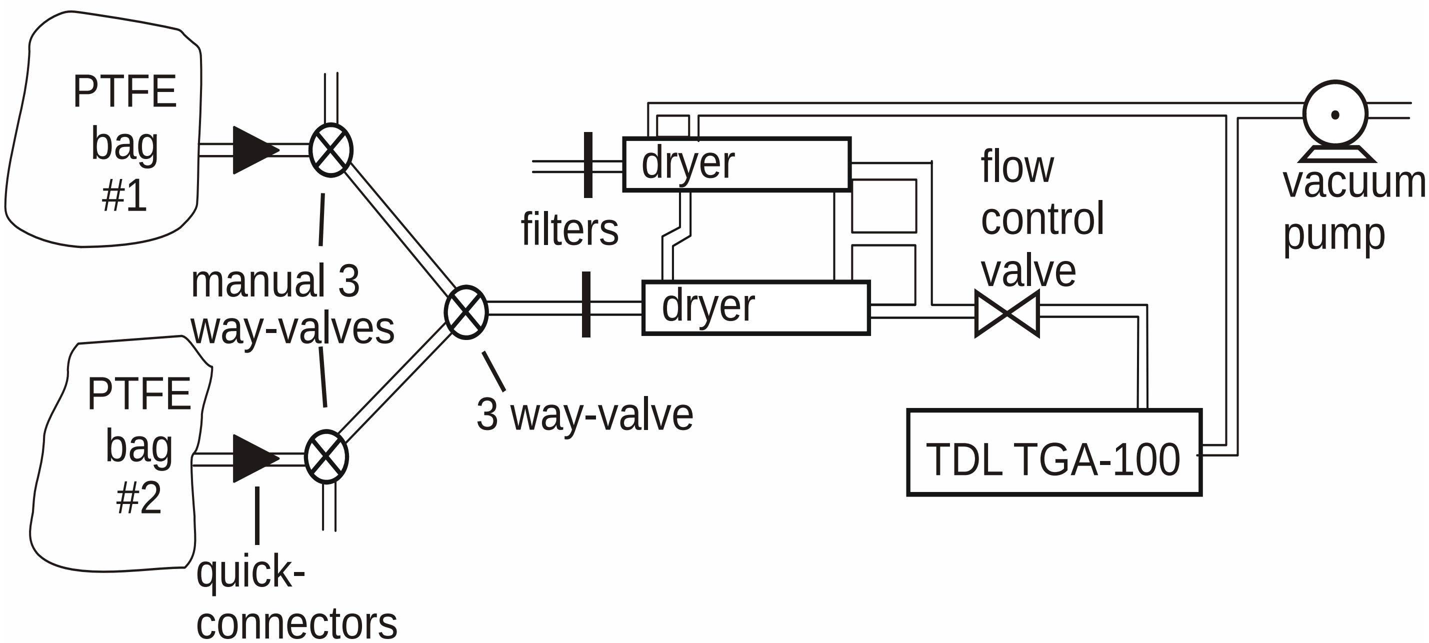


C-FPOK Pok Data
NRC - IAR - FRL
Ccaf_05.r13
23-Mar-1999
Start time: 181558 End time: 181606
wepf
eddy
Time (seconds)



Diaphragm Pump 12 l/min
Relief valve
2-µm Filter
Mass-Flow Controller
3-way Valve
UP
PTFE Sample Bag
DC Power supply
Inlet
¼" PTFE tubing
Vent (Dead band)
DOWN

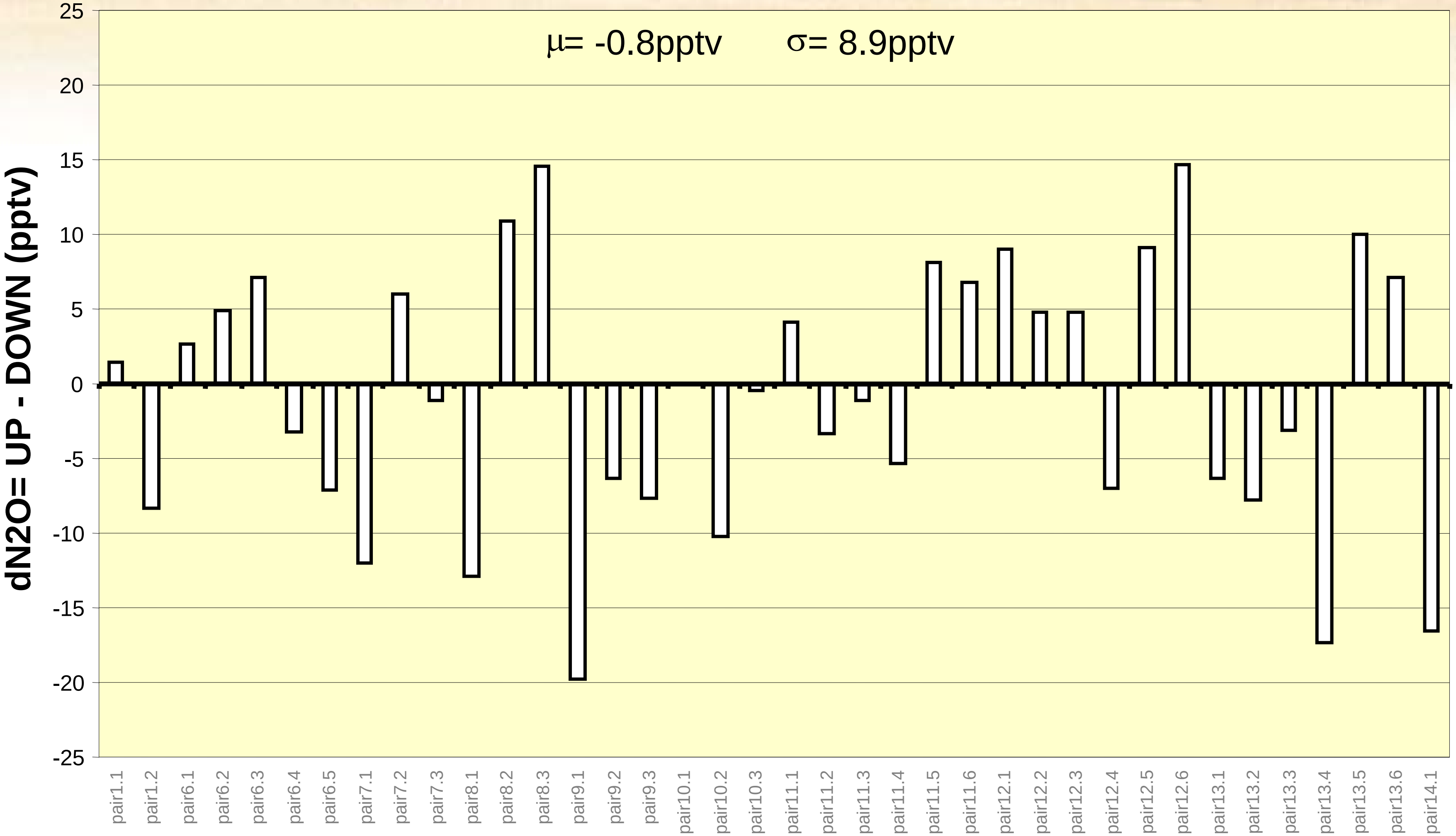
TDL configuration for REA technique



Pattey, E. Strachan, I.B., Desjardins, R.L., Edwards, G.C., Dow, D., and MacPherson, I.J. 2006. Application of a tunable diode laser to the measurement of CH_4 and N_2O fluxes from field to landscape scale using several micrometeorological techniques. *Agric. For. Meteorol*.136: 222-236.

BAG ANALYSIS SYSTEM

Detection limits of Laser/PTFE bags



(bags filled with the same (ambient) air through REA system with new KNF pumps (NO23 ANI) at 12 L/min)

Detection Limits of Aircraft-based REA System for Greenhouse Gases

CH_4 (mg CH_4 m^{-2} d^{-1})

ΔCH_4 (ppb)	σ_w = 0.3 m s^{-1}	σ_w = 0.9 m s^{-1}
0.5 (GC)	**5.2**	**15.6**
0.1 (TDL)	**1.0**	**3.1**

N_2O (ng N_2O m^{-2} s^{-1})

ΔN_2O (ppb)	σ_w = 0.3 m s^{-1}	σ_w = 0.9 m s^{-1}
0.1 (GC)	**32**	**96**
0.01 (TDL)	**3.2**	**9.6**

Aircraft/Chamber in Western Canada, Saskatoon, Spring 2002

Coll: Dan Pennock, Ray Desjardins, Ian MacPherson,

Laird Study Township: Land Use

31: C, P/W / G, G/C	32: G, G / G/C, G	33: G, G / C, P/G	34: P, G / C, (P)	35: G, C / C, G	36: P/G, G / C, G
30: G, C / C, P	29: G, G / G/C, G	28: G, G / G, G	27: G, (P) / G, G	26: G, P / C/G, G	25: G, G / P, P
19: F, P / G, P	20: G, G / G, G	21: C, C / (C), (P)	22: G, G / (C), (C)	23: P/G, C/F / P/G, P	24: G, G / G, C
18: G, G / G, G	17: G, G / C, C	16: G, G / G, C	15: G, P / G, C/G	14: G, G / P, G	13: P, (G) / (G), (C)
7: G, P / P, G	8: G, G / G, G	9: G, C / G, P	10: G, C / G, F/G	11: F, F / C/G, C	12: C, C / G, G
6: P, P / (P), P	5: G, G / C, G	4: G, G / (G), G	3: F/G, P/G / G/F, G	2: (G), G / G, G/C	1: G, P / G, F

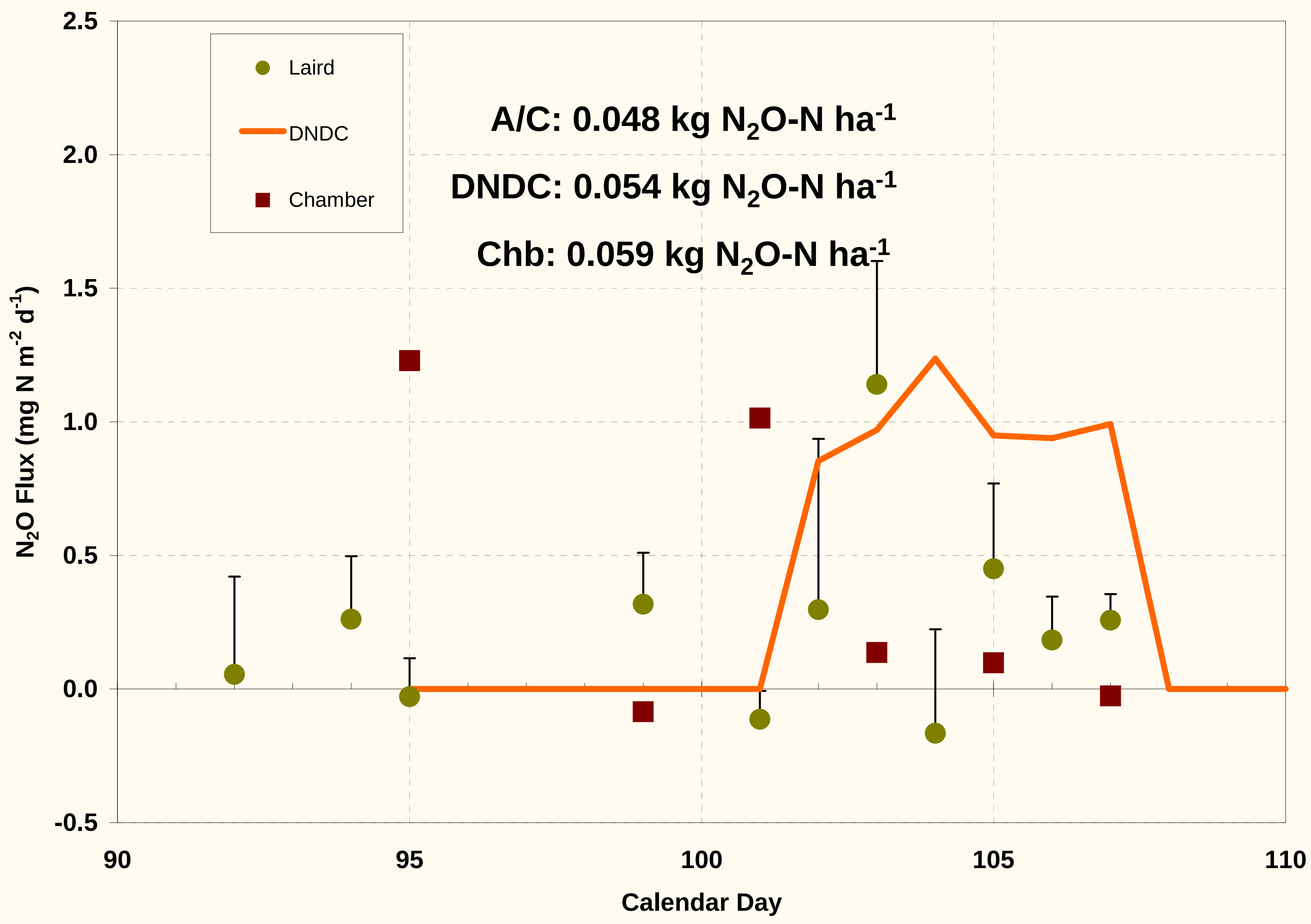
Township 43, Range 4,
West of the Third Meridian

0 meters 1600

C Canola
G Grain
P Pulse
F Forage/Pasture

O **Sampled Quarter-section**

Spring thaw N_2O emissions in Western Canada – DNDC Model



Pattey E., Edwards, G.C., Desjardins, R.L., Pennock, D., Smith W., Grant B., MacPherson, J.I., 2007. Tools for quantifying N_2O emissions from Agroecosystems. *Agric. For. Meteorol.*142(2-4): 103-119

Thank You

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