Comparison of active flux and passive concentration measurements of methane emissions from cattle

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Comparison of methods to determine methane emissions from dairy cows in farm conditions

P. Huhtanen,*[1] E. H. Cabezas-Garcia,* S. Utsumi,† and S. Zimmerman‡
*Department of Agricultural Research for Northern Sweden, Swedish University of Agricultural Sciences, SE-901 83 Umeå, Sweden
†Department Animal Science and Kellogg Biological Station, Michigan State University, Hickory Corners 49060
‡C-Lock Incorporated, Rapid City, SD 57702

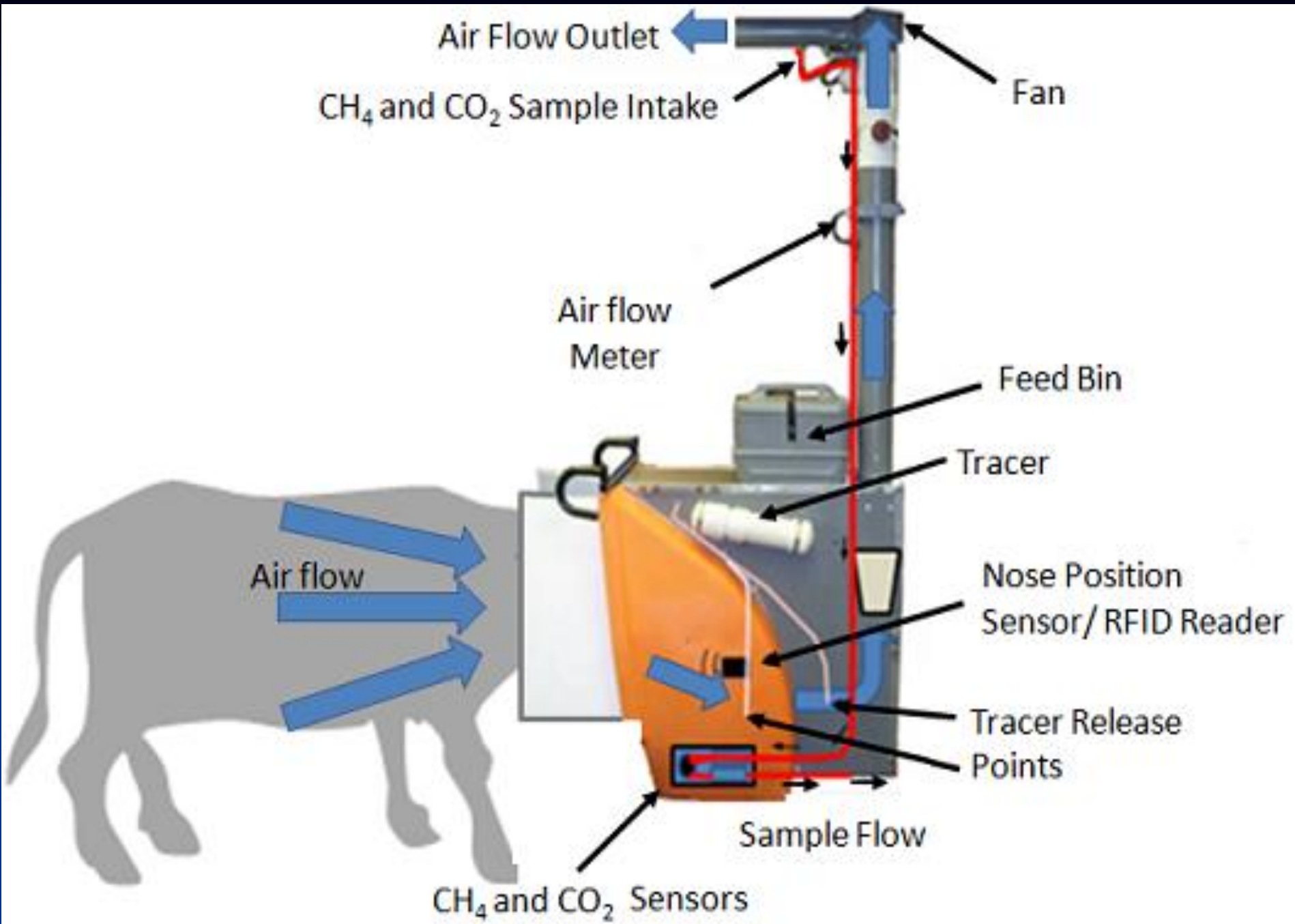
NJV Forage Research Centre, Umeå, 63°45´N, 20°17´E

Introduction

- Online methods
  - Measurements of CH_4 during visits to automatic milking systems or concentrate feeders
  - Methane emission index (Garnsworthy et al.)
  - CO_2 tracer method (Madsen et al.)
    - CH_4 Flux = $CO_2 \times CH_4 / CO_2$
    - CO_2 a tracer based on estimated heat production

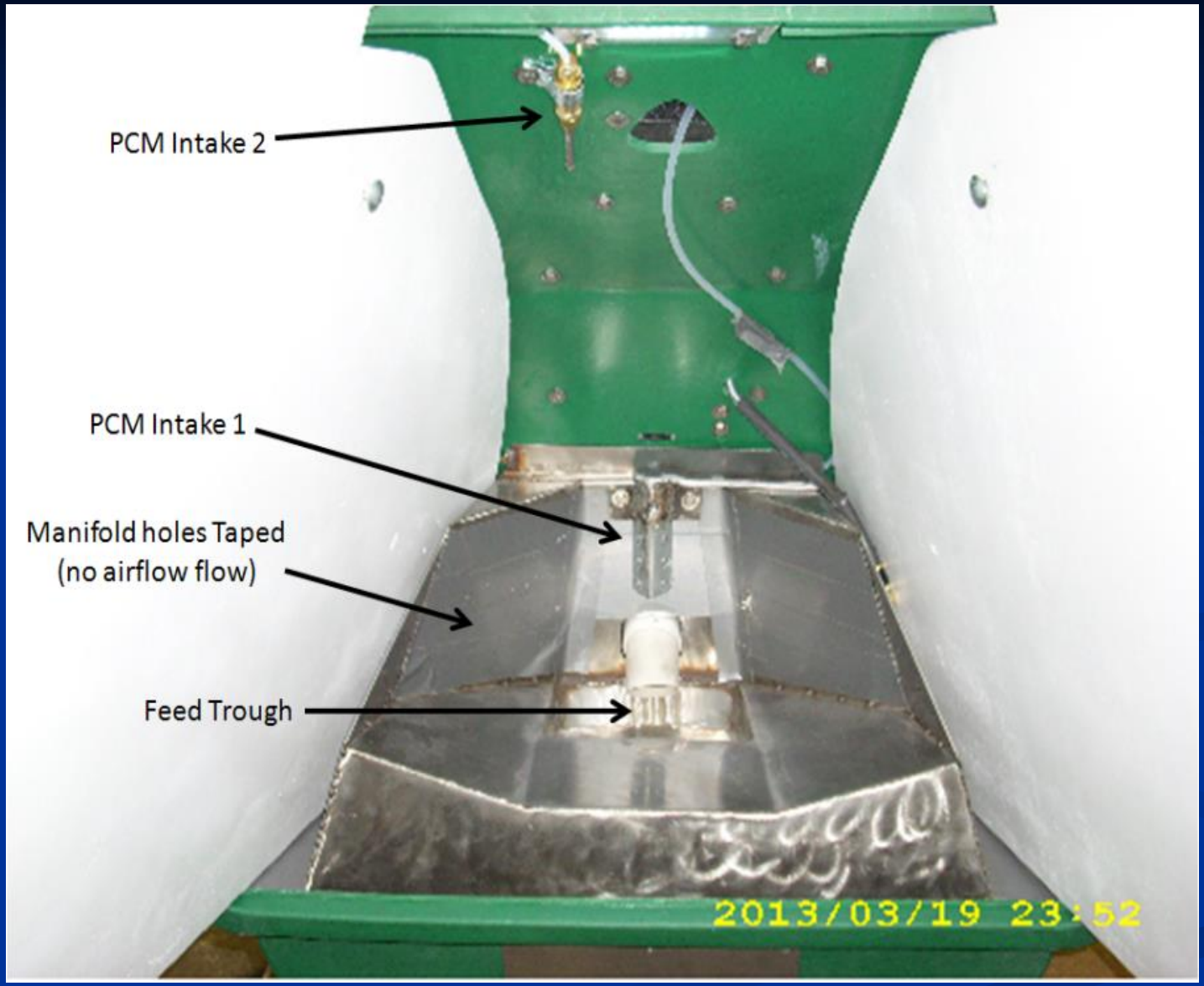
GreenFeed

- Flux method
- CH_4 flux = Concentration × Air flow
- Air flow 25-30 L/s
- Head sensors; if head position is not correct the data is filtered out
- Cows visit three to five times each day by programming the food reward
- SLU experiences:
  - Mean production about 450 g/d; between cow CV 11-12% for CH_4 /DMI 8-10%; CH4-$_4$/GE ~ 6.5%; High repeatability (0.70 – 0.75)
  - Consistent ranking for low and high emitters


Air Flow Outlet
CH_4 and CO_2 Sample Intake
Fan
Air flow
Meter
Feed Bin
Tracer
Air flow
Nose Position
Sensor/ RFID Reader
Tracer Release
Points
Sample Flow
CH_4 and CO_2 Sensors

Objectives

- To compare to compare active gas capture (AGC) = GreenFeed setup ("flux") and passive concentration measurement (PCM) method = setup of methods based on concentration and gas ratio measurements ("sniffer")


PCM Intake 2
PCM Intake 1
Manifold holes Taped
(no airflow flow)
Feed Trough
2013/03/19 23:52

Material and methods

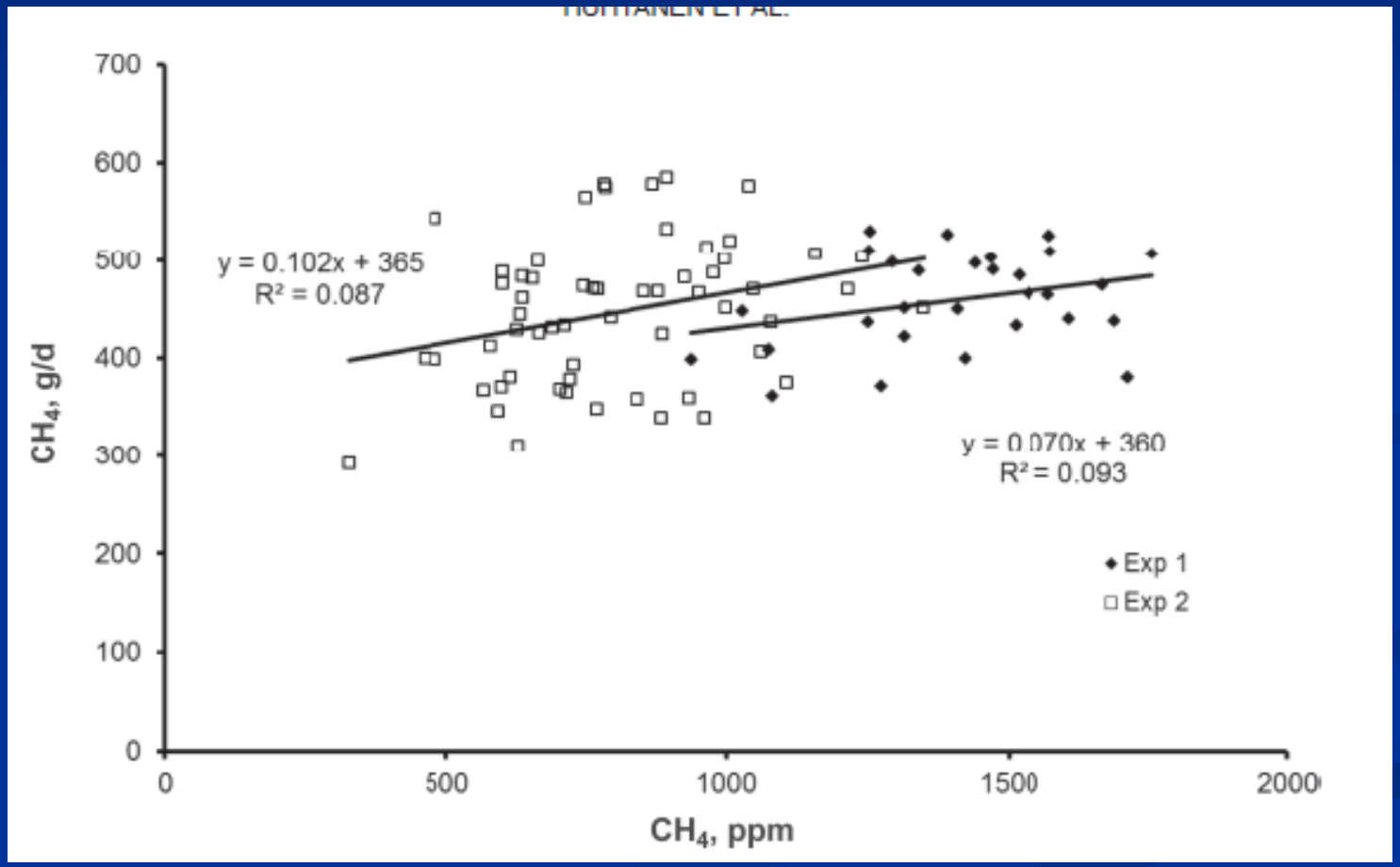
- Five 10 day periods (AGC – PCM – AGC – PCM – AGC) during a change-over feeding experiment investigating the effects of forage type (grass vs. grass/red clover) and protein supplementation
- Total mixed ration (forage: concentrate 60:40)
- Automatic feeding 5 times/day
- The cows were programmed to visit every 7 h
- 8 drops of concentrates every 40 s
- Mixed model analysis; cow observation unit
- Repeatability (R) was calculated as $R = \delta^2_{Animal} / (\delta^2_{Animal} + \delta^2_{Residual})$

Data description

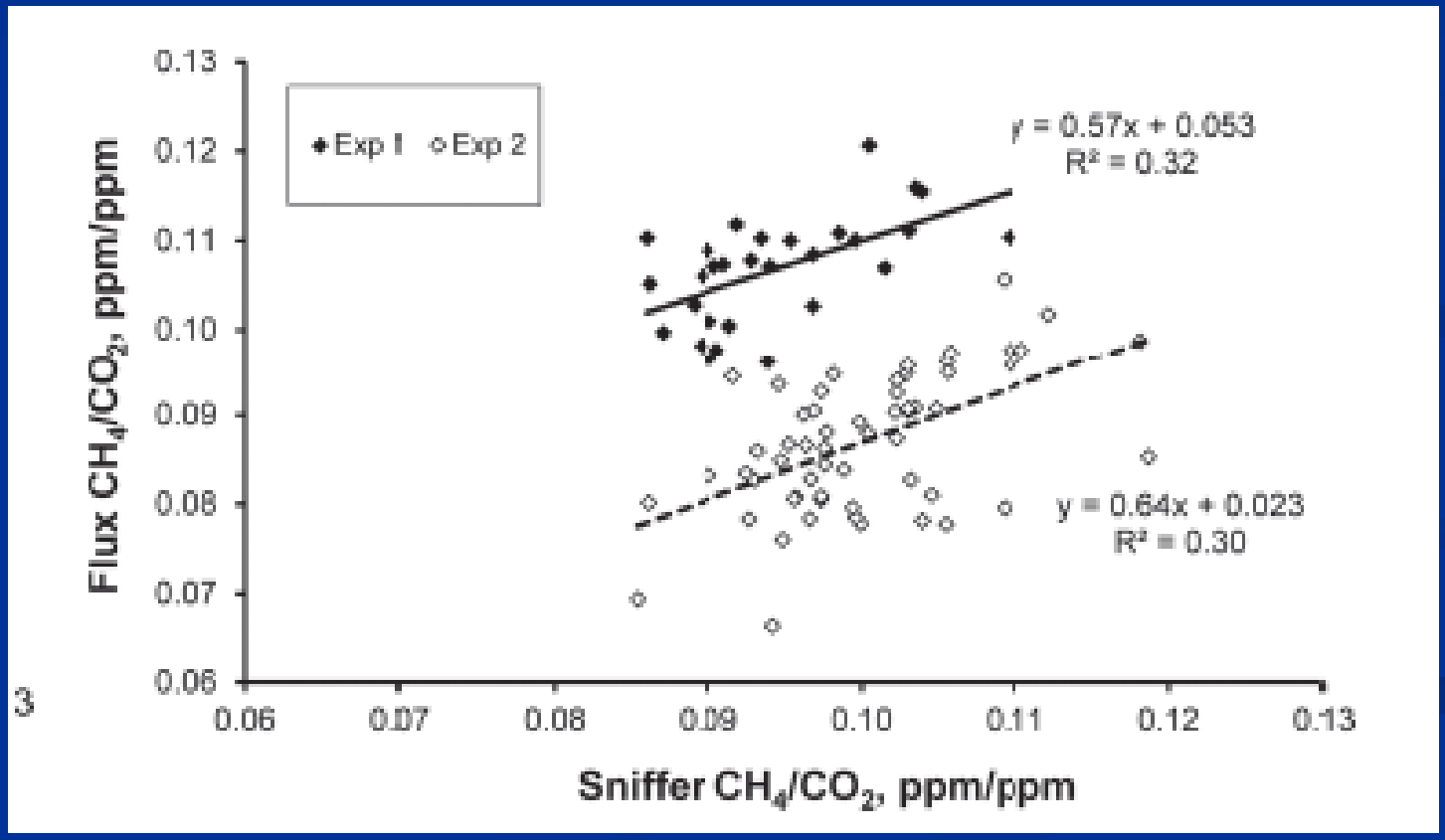
System	Item	CH_4[a] (g/d)	CO_2[a] (g/d)	CH_4/CO_2 vol/vol	Visits (number)
AGC	N	75	75	75	
	Mean	453	11619	0.107	
	SD	50	850	0.0069	
	CV	0.110	0.073	0.064	
	Repeatability	0.74	0.84	0.62	0.50
PCM	N	57	57	57	
	Mean	1405	14924	0.094	
	SD	247	2340	0.0062	
	CV	0.176	0.157	0.066	
	Repeatability	0.72	0.87	0.57	0.68

[a] Flux (g/d) for AGC and concentration (ppm) for PCM

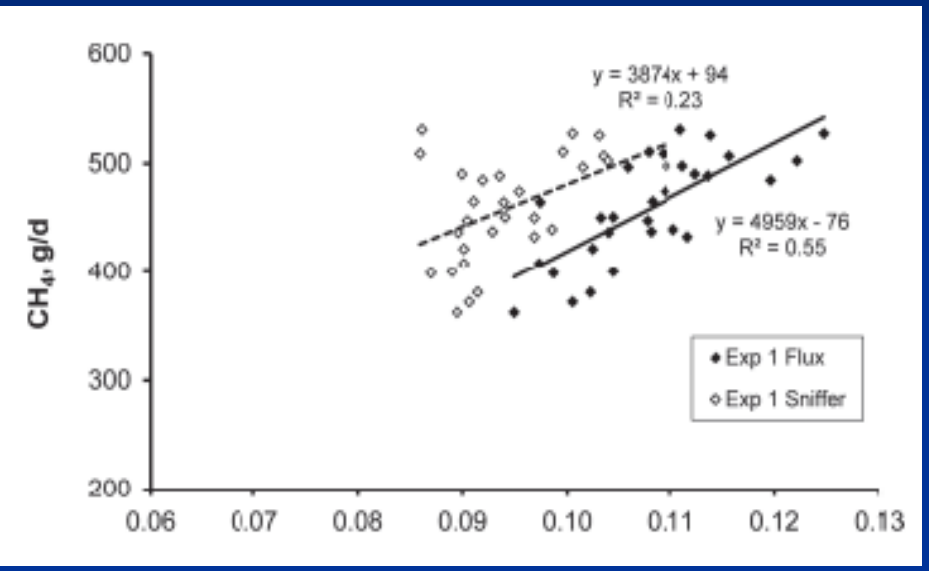
Relationship between CH_4 concentration (Sniffer) and CH_4 flux

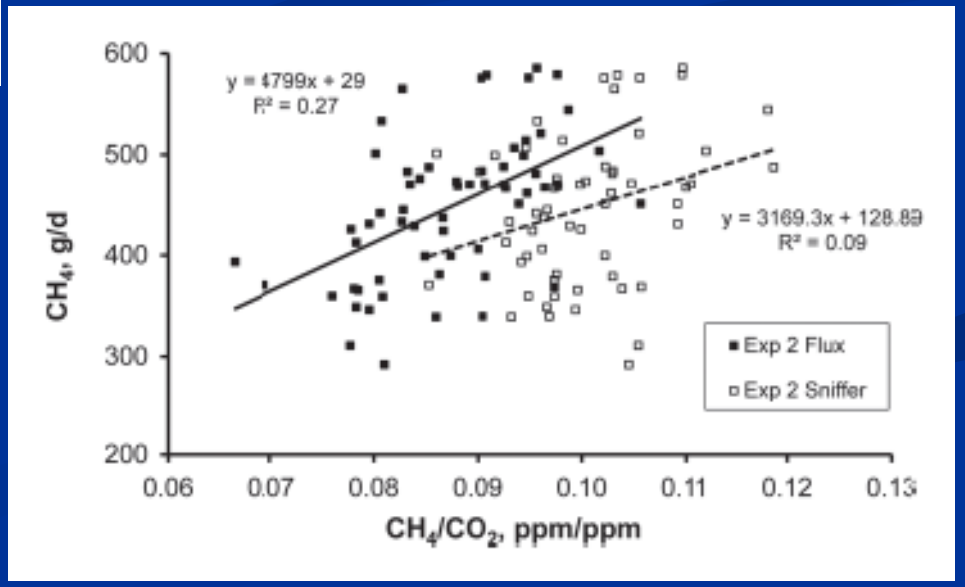


Relationship between the methods in CH_4/CO_2 ratio



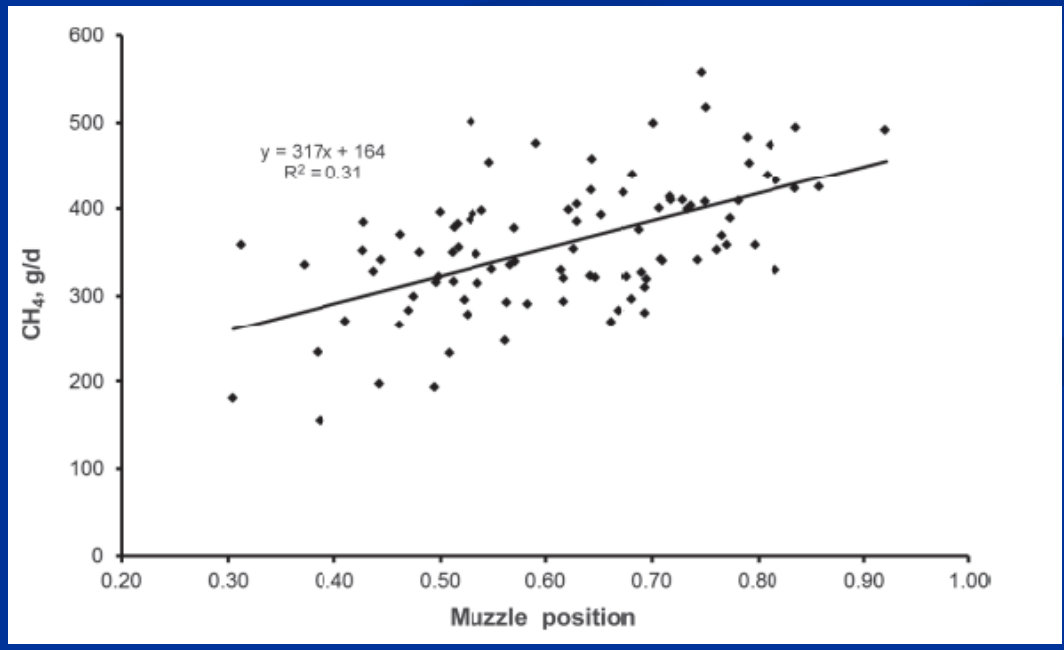
Relationship between the methods in CH_4/CO_2 ratio

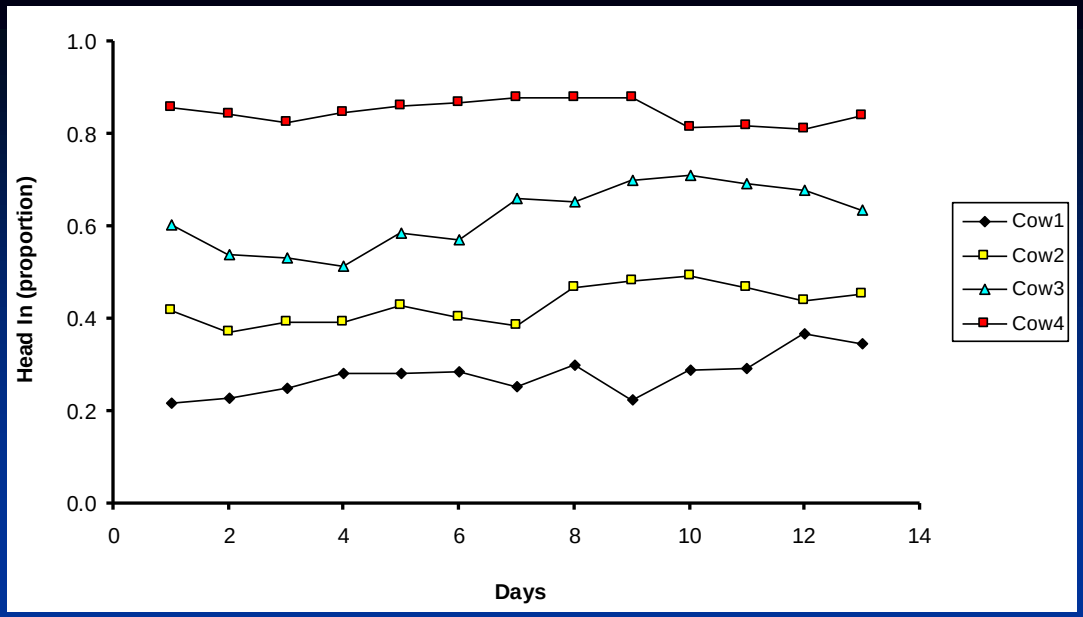


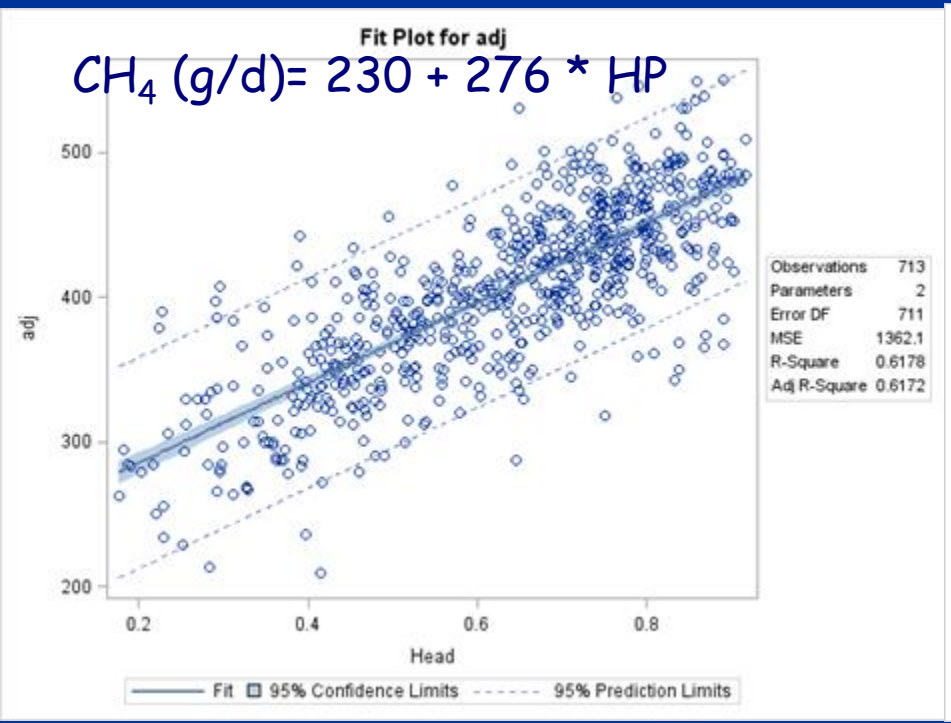


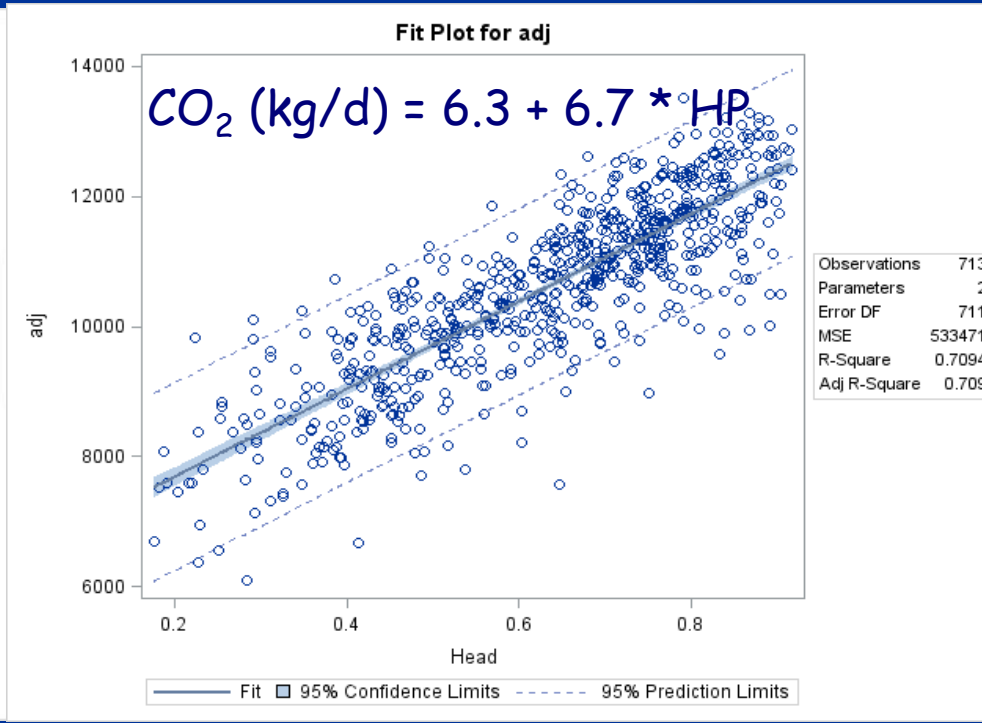
Effects of muzzle position

- High repeatability of muzzle position
  - 0.74 for cow/day data
  - 0.82 for cow/period data




Head In (proportion)
1.0
0.8
0.6
0.4
0.2
0.0
0
2
4
6
8
10
12
14
Days
Cow1
Cow2
Cow3
Cow4


Fit Plot for adj
CH_4 (g/d)= 230 + 276 * HP
adj
500
400
300
200
0.2
0.4
0.6
0.8
Head
Observations 713
Parameters 2
Error DF 711
MSE 1362.1
R-Square 0.6178
Adj R-Square 0.6172
Fit
95% Confidence Limits
95% Prediction Limits


Fit Plot for adj
CO_2 (kg/d) = 6.3 + 6.7 * HP
adj
14000
12000
10000
8000
6000
0.2
0.4
0.6
0.8
Head
Observations 713
Parameters 2
Error DF 711
MSE 533471
R-Square 0.7094
Adj R-Square 0.709
Fit
95% Confidence Limits
95% Prediction Limits

Problems related to CO_2 tracer method

- High CH_4 / CO_2 can result from
  - Increased CH_4 production
  - Increased intake (all incremental DMI produce CH_4, but only part CO_2 – more to milk, body)
  - Improved feed efficiency (less CO_2 produced per unit of intake)
- Low CH_4 / CO_2
  - Mobilization of body tissues (produce CO_2, but not CH_4)
  - Low intake
  - Low feed efficiency

Data from respiration studies in cows fed mainly grass silage-based diets (Yan et al., 2010)

Table 1. Summary statistics for animal and dietary variables used in model development

Variable	Mean	SD	Minimum	Maximum
Animal and dietary data				
Live weight (kg)	543	66.8	379	733
BCS[1]	2.57	0.285	1.75	3.75
DMI (kg/d)	16.8	31.3	7.5	25.0
Milk yield (kg/d)	22.6	6.75	3.2	49.1
Forage proportion (g/kg of DM)	540	191.5	181	1,000
CP (g/kg of DM)	178	25.3	113	250
Ash (g/kg of DM)	81	10.2	57	113
ADF (g/kg of DM)	240	43.8	169	362
NDF (g/kg of DM)	420	73.9	265	604
Gross energy (MJ/kg of DM)	18.4	0.53	16.6	19.8
Energy intake and output data (MJ/d)				
Gross energy intake	309	59.0	137	461
Fecal energy	75	17.6	26	133
Urinary energy	11	3.8	2	28
Methane energy	21	3.6	11	32
Heat production	126	19.8	79	187
Milk energy	73	20.9	11	141
Energy balance	3	22.4	−88	71

CV = 3.6/21 = 17.1%

[1]The BCS of each cow was determined using the method described by Mulvanny (1977), with 5 categories from 1 (very thin) to 5 (very fat).

Conclusions

- Sniffer concentration poorly correlated to CH_4 flux measured by the Flux method despite high repeatability of the data
- High repeatability can reflect more repeatability of head position in Sniffer systems
  - Low emitters can be cows that keep their head longer distance from gas sampling tube
- Low CH_4 / CO_2 with tracer method can result from
  - Low CH_4 emissions
  - Low feed efficiency (Increased CO_2 at given production)
  - Low CH_4 / CO_2 can be due negative energy balance (CO_2 produced from body tissues)


Thank you for your attention – questions…