Yale School of Forestry & Environmental Studies

Source or Sink?

Characterizing CH$_4$ flux in a Soybean and Corn Dominated Landscape

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Outline

- Objectives
- Background
- Methods
- Results
- Summary

Objectives

- To evaluate CO_2 and CH_4 fluxes from agricultural plants during the growing season (soybean and corn; aboveground and belowground section).

- To explore the impact of fertilization on CO_2 and CH_4 fluxes from agricultural fields.

Objectives (continued)

- To revise the current CH_4 inventory
- To build up a systematical method to research on gas inventory

Global CH$_4$ budget
(IPCC, 2001)

Sources		CH$_4$ (Tg CH$_4$ yr^{-1})
Natural	Wetland	92-237
	Termites	20-20
	Ocean	10-15
	Hydrates	5-1
Anthropogenic	Rice agriculture	
	Ruminant animals	80-115
	Energy	75-109
	Landfills	35-73
	Biomass burning	23-55
Total Sources		500-600
Sink	Troposphere OH	450-510
	Stratospheric loss	40-46
	soils	10-30

+ vegetation (10∼45%)?

A summary of observed CH$_4$ flux from Corn (*zea mays*)

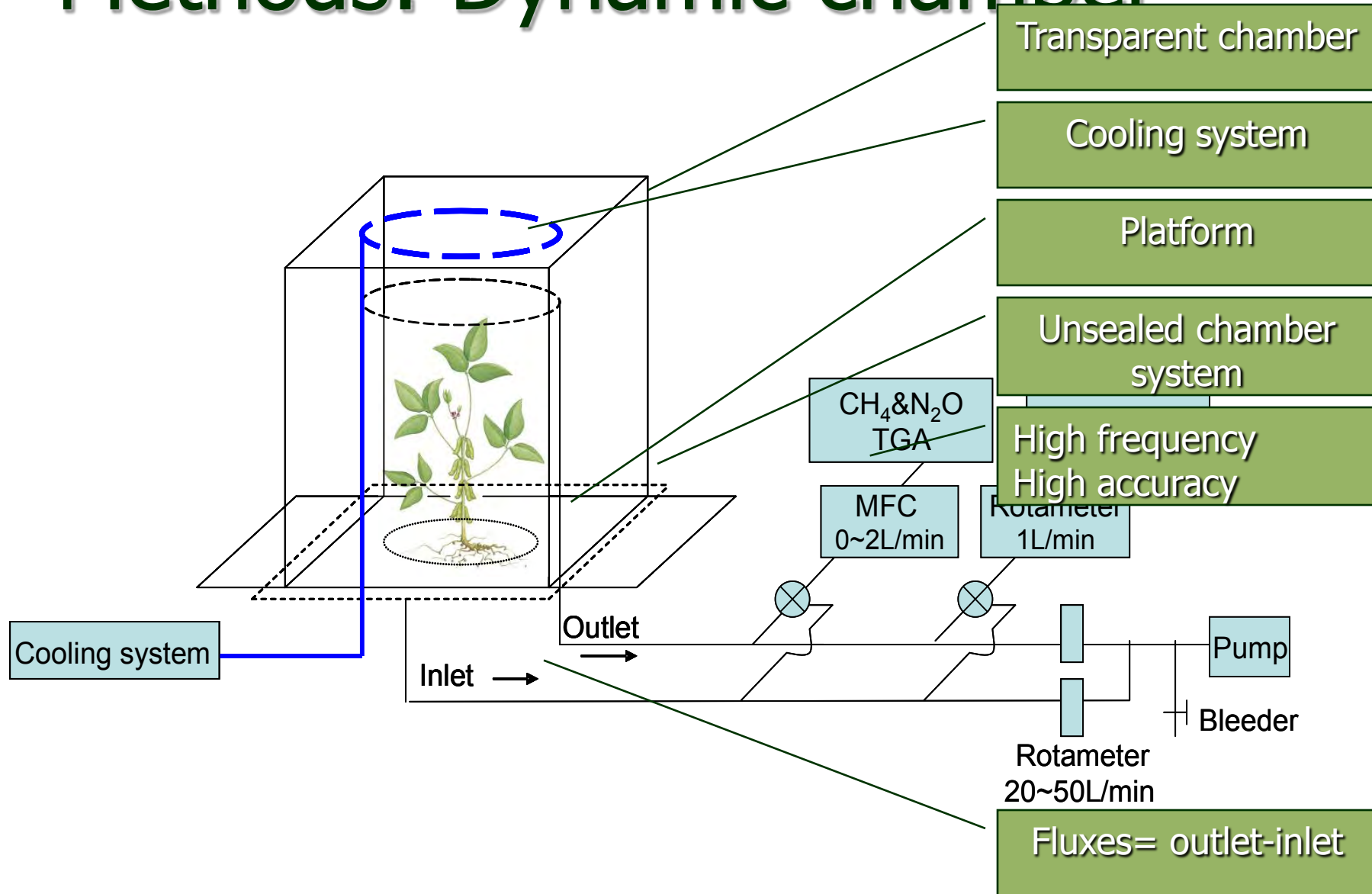| Reference	Method	Flow	Light	Temperature (°C)	Back ground concentration	Intact/detached	Result
Beerling et al., 2008	flow through cuvette; FID CH$_4$ sensing instrument	800ml min^{-1}	photosynthetically active radiation /dark	25	CH$_4$ (59ppbv), CO$_2$ (1000ppm) and high purity artificial air	intact	-20 ~ 20 CH$_4$ gdw^{-1} h^{-1}
Dueck et al., 2007	continuous-flow gas cuvettes; 13C-labelling approach	60-120 l h^{-1}	controlled light intensity (300/600 µmol m^{-2} s^{-1})	25/35	^{12}CH$_4$: 2100ppb ^{13}CH$_4$: 22ppb CO$_2$: 200~300ppm	intact	28±36 ng CH$_4$ gdw^{-1} h^{-1}
Kirschbaum and Walcroft, 2008	non-flow-through chamber	N/A	lighted by fluorescent lamps at the intensity of 5 µmol quanta m^{-2} s^{-1}	20 RH=100%	CH$_4$ free	intact	-0.25±1.1 ng CH$_4$ gdw^{-1} h^{-1}
Nisbet et al., 2009	non-flow-through Chamber (gas removed at 24 hr. and 48 hr.)	N/A	fluorescent, 180 µmol m^{-2} s^{-1}, photosynthetically active.	N/A	ambient CH$_4$ concentration(1984-2021ppb)	detached leaves	emission was negeligible
Keppler et al., 2006	incubation Chamber	N/A	direct sunlight	ambient temperature	CH$_4$ free	intact	374(198/598)ng CH$_4$ gdw^{-1} h^{-1}
			Dark	ambient temperature	CH$_4$ free	intact	119(30.7/207) ng CH$_4$ gdw^{-1} h^{-1}
Vigano et al., 2008	flow-through chamber(detection limit is about 2 ng gdw-1 h-1)	100-500 ml min^{-1}	UV radiation: 49 W m^{-2}	30	ambient CH$_4$ concentration or CH$_4$ free	detached (fresh)	50ng CH$_4$ gdw^{-1} h^{-1}
		100-500 ml min^{-1}	UV radiation: 49 W m^{-2}	30	ambient CH$_4$ concentration or CH$_4$ free	detached (dry)	26ng CH$_4$ gdw^{-1} h^{-1}

Experiment artifacts

- Light condition
- Background CH_4 concentration
- Intact and detached plant
- Temperature and humidity

Methods: Dynamic chamber

Transparent chamber

Cooling system

Platform

Unsealed chamber system

High frequency High accuracy

CH$_4$&N$_2$O TGA

MFC 0~2L/min

Rotameter 1L/min

Cooling system

Outlet

Inlet

Pump

Bleeder

Rotameter 20~50L/min

Fluxes= outlet-inlet

Methods- Modified Bowen Ratio method

$$F_2 = F_1 \frac{\partial c_2 / \partial z}{\partial c_1 / \partial z}$$

- Assumption: all the scalar quantities were transferred indiscriminately.
- In the equation, F_2 is the flux of CH_4, F_1 is the flux of CO_2, $\partial c_2 / \partial z$ is the gradient of CH_4, and $\partial c_1 / \partial z$ is the gradient of CO_2. Here, the CO_2 flux was the average between close path eddy covariance systems on the two towers, one in corn field and in soybean field.

Research Site

- University of Minnesota Rosemount Research and Outreach Center
- Land cover types: within 5km, 32.5% for corn, 10.5% for soybean
- Soybean-corn rotation field
- Field management (fertilization, irrigation)
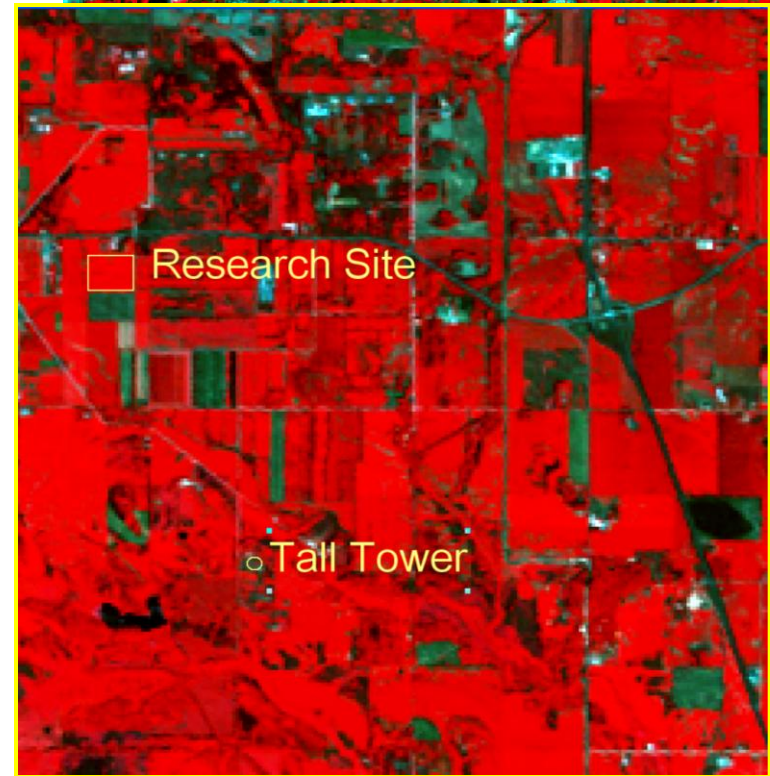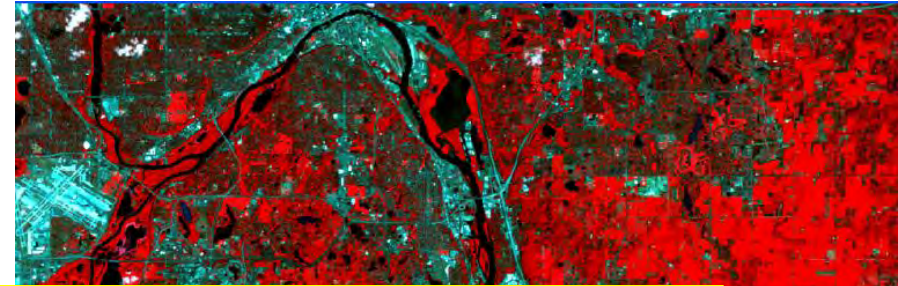
Methods: observation systems

Results: chamber blank tests

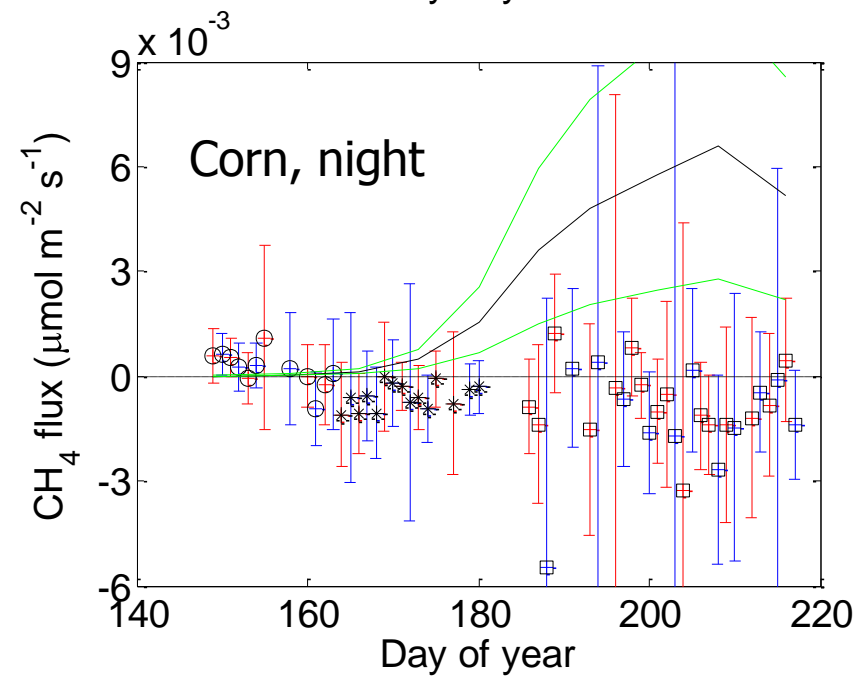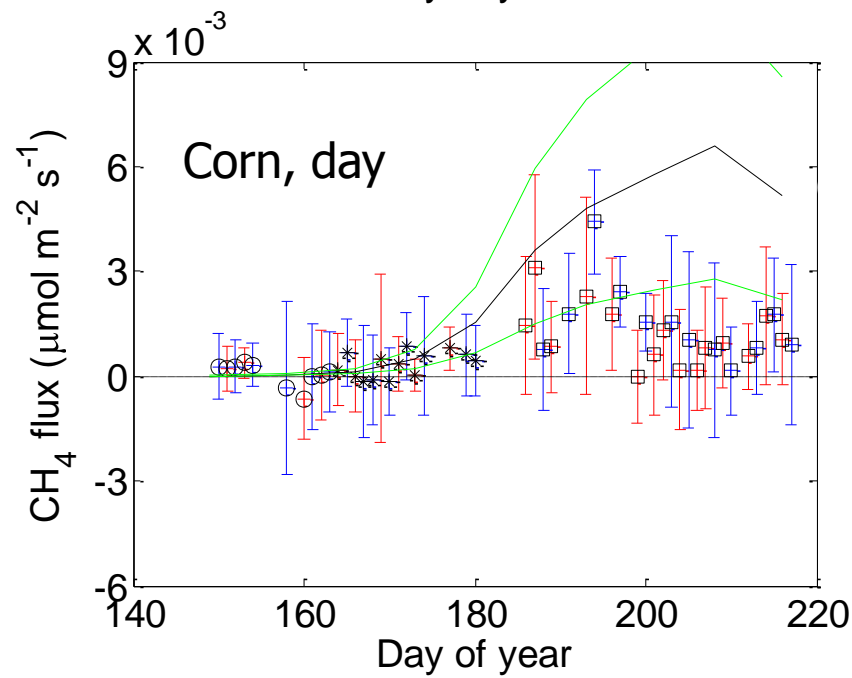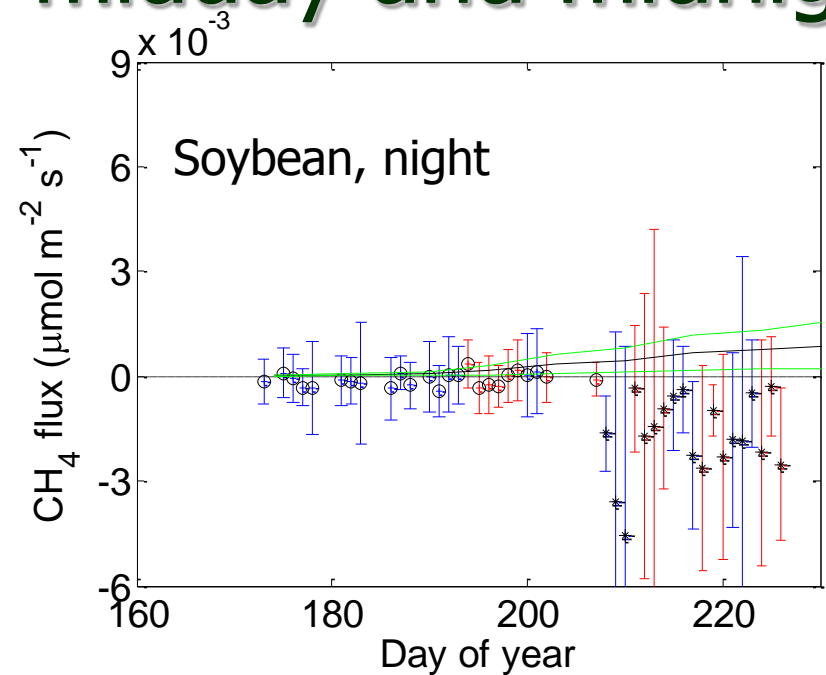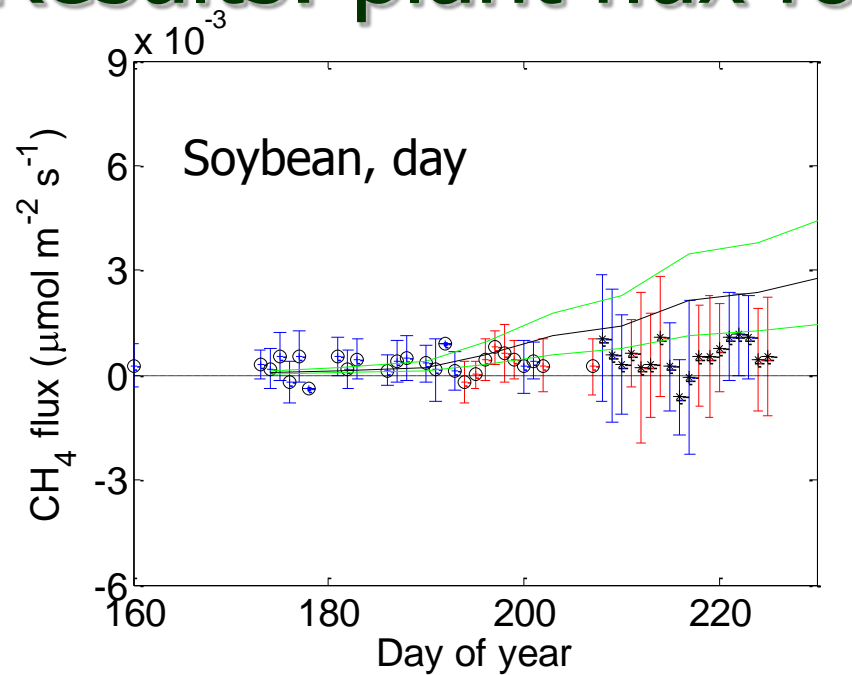| Chamber	CH$_4$ (μmol m^{-2} s^{-1})	CO$_2$ (μmol m^{-2} s^{-1})
Small	$1.68 \times 10^{-4} \pm 8.23 \times 10^{-5}$	-0.23 ± 0.06
Medium	$3.93 \times 10^{-5} \pm 4.44 \times 10^{-5}$	-0.23 ± 0.20
Big	$5.02 \times 10^{-4} \pm 4.60 \times 10^{-4}$	-1.00 ± 1.19

Results: daily averaged plant flux
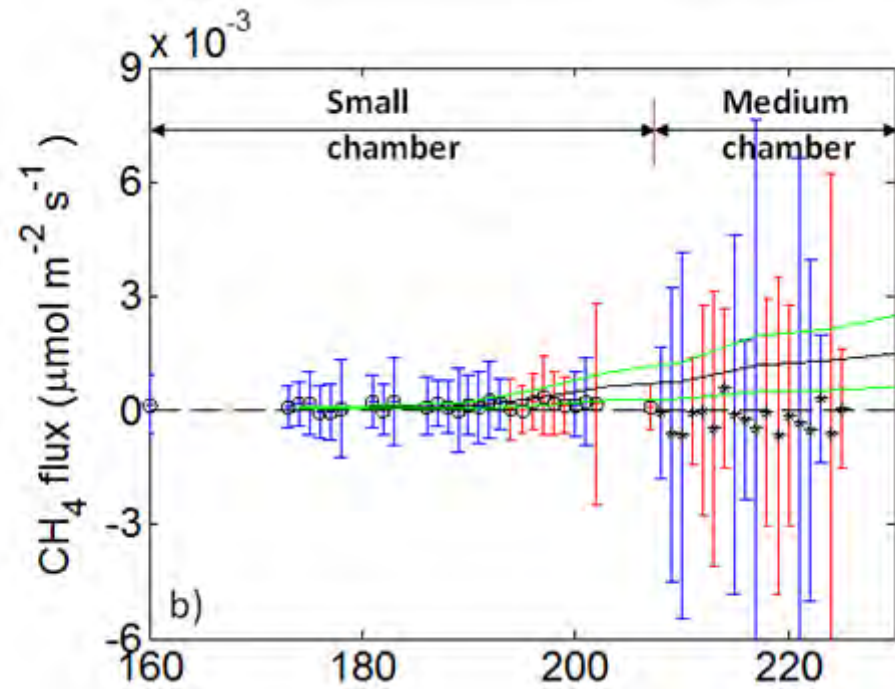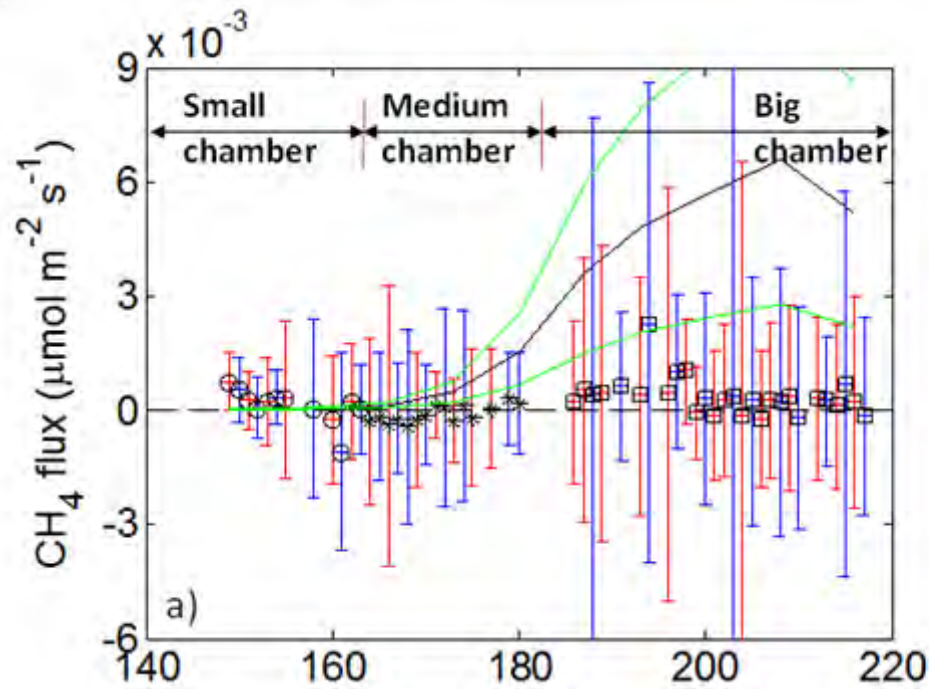
Results: plant flux through the growing season
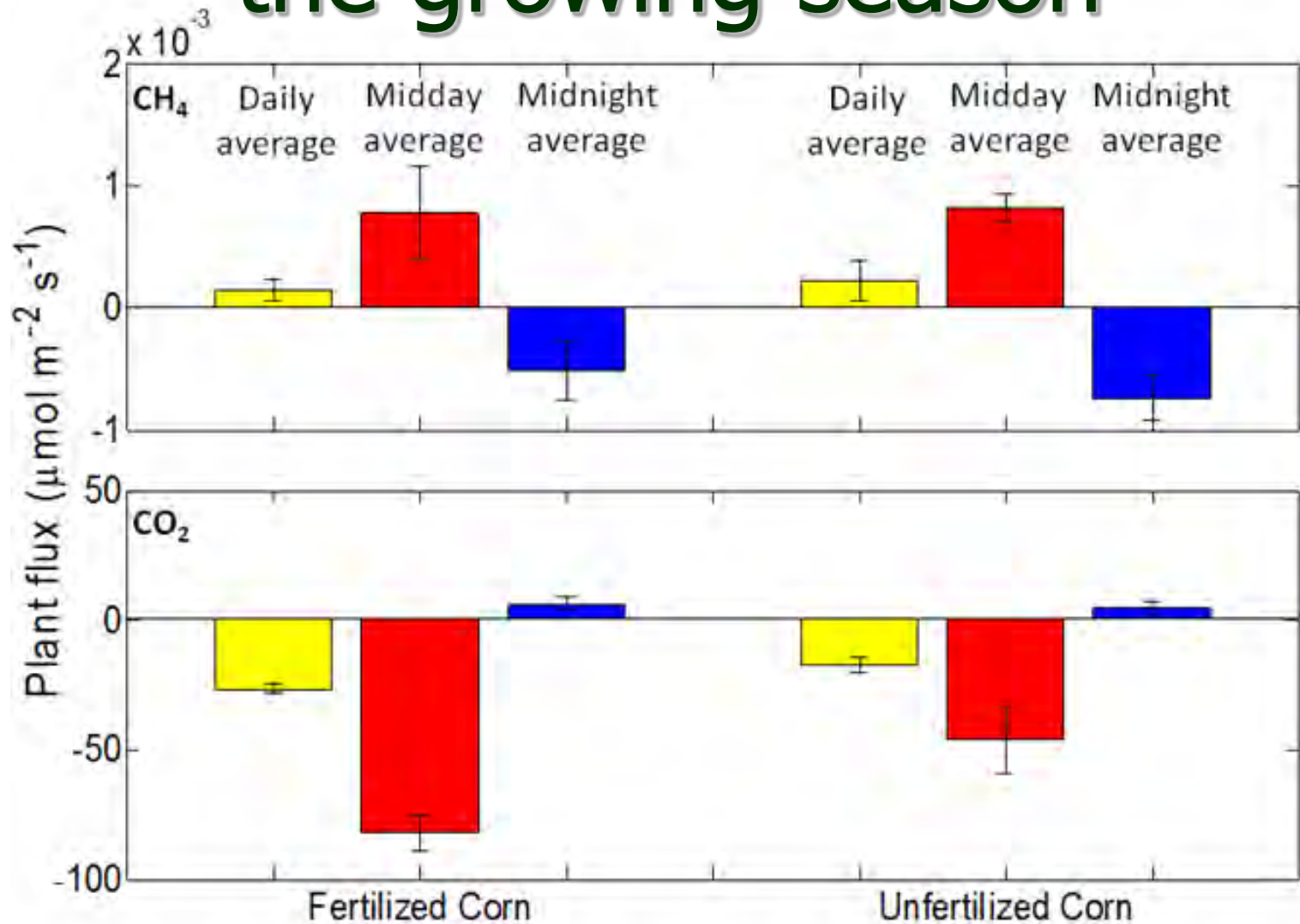
Results: plant flux for midday and midnight

CH$_4$ flux vs. CO$_2$ flux and environment parameters

P-value	Incoming Solar radiation	Air Temperature	Soil moisture	Soil Temperature	Day time CO$_2$ flux (photosynthesis)	Night time CO$_2$flux (respiration)
Daytime CH$_4$ flux from corn	(+) p = 0.00383	(+) p = 0.0348	(-) p =0.00541	(+) p =0.035	(-) p =0.0058	N/A
Nighttime CH$_4$ flux form corn	Not Related	(-) p = 0.0127	Not Related	Not Related	N/A	(-) p=0.133
Daytime CH$_4$ flux from soybean	(+) p= 0.084	Not related	Not related	Not related	(-) p=0.079	N/A
Nighttime CH$_4$ flux form soybean	Not related	Not related	(+) p=0.05	Not related	N/A	(-) p<1×10^{-7}

# Results: CO_2 flux vs CH_4 flux on plant scale
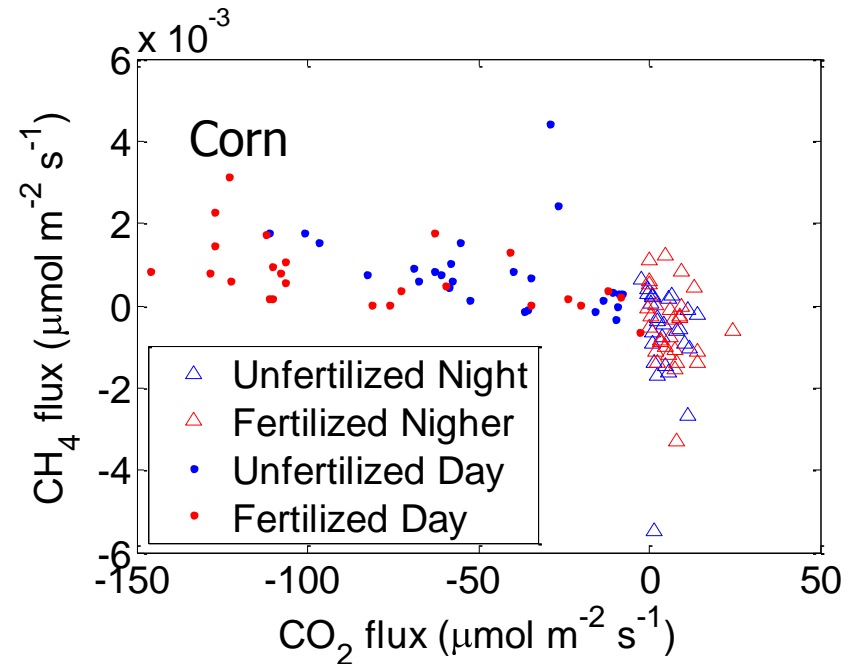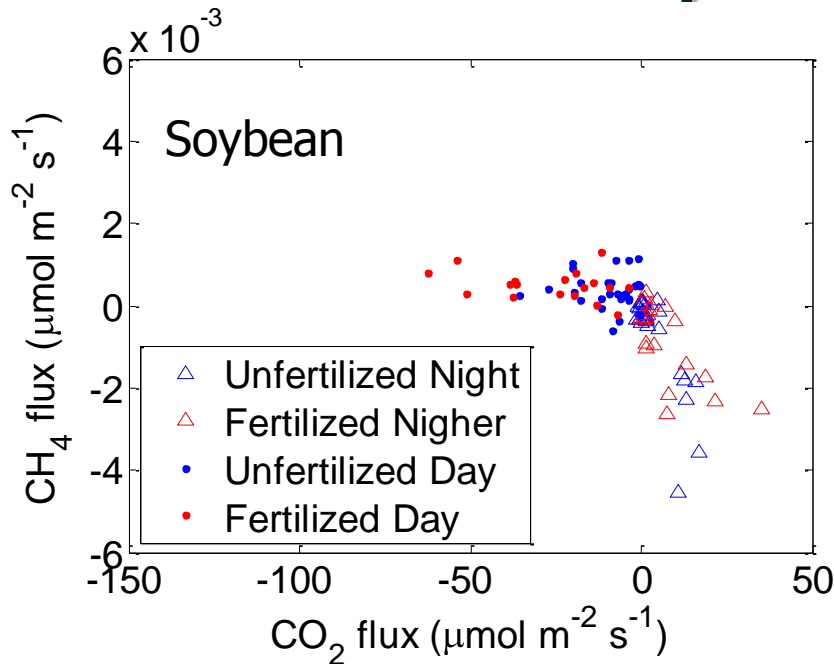
Relation between CO_2 flux and CH_4 flux from plants: red dot – daytime average flux from fertilized plant; blue dot – daytime average flux from unfertilized plant; red triangle – night time average flux from fertilized plant; blue triangle– night time average flux from unfertilized plant.

Result: CH$_4$ production and consumption

| CH4	Day time	Night time
production	UV radiation	Diffusion
consumption	Methanotrophy / CO2 respiration	Methanotrophy / CO2 respiration

Results: Regional scale flux
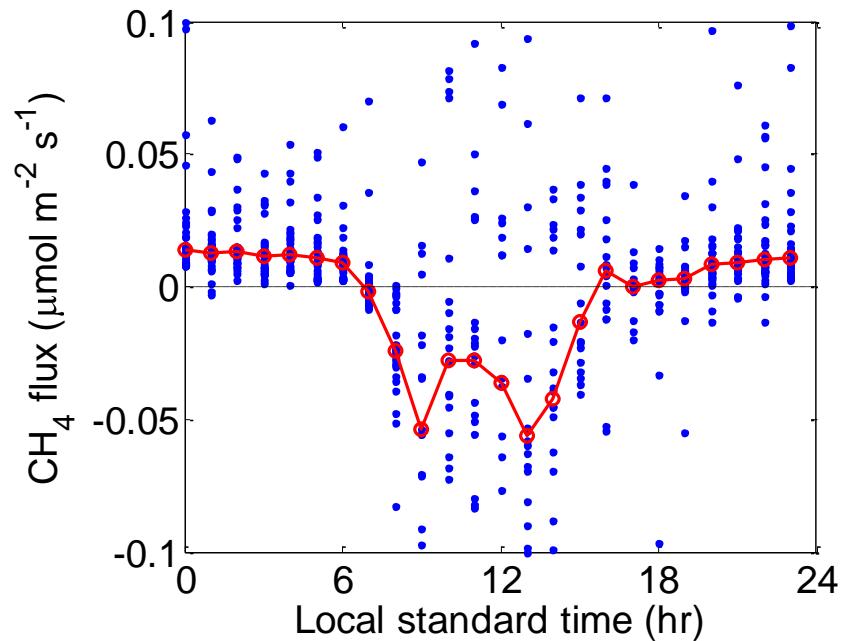
Ensemble diurnal variation of CH_4 fluxes calculated from the tall tower gradient measurement, August 2009: blue dot – hourly flux value; red circle – median value for each hour of the day

Nigh time flux

- CO$_2$ gradient and H$_2$O gradient correlated
- CO$_2$ gradient vs CH$_4$ gradient on regional scale
- Diurnal pattern of CH$_4$ concentration

# Results: CO_2 gradient vs CH_4 gradient on regional scale
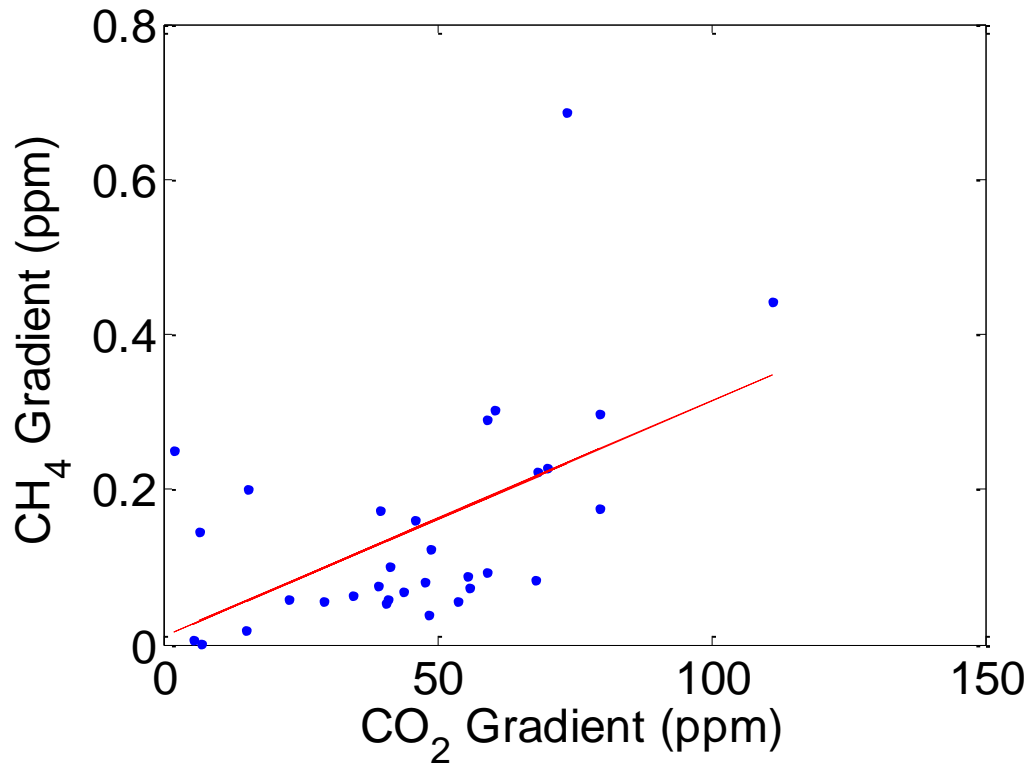
Linear relationship between the night CH_4 and CO_2 gradients, August 2009. The results of the linear regression are shown. Each data point represents the block average between 2300-0400 LST.

Result: diurnal pattern of CH$_4$ concentration
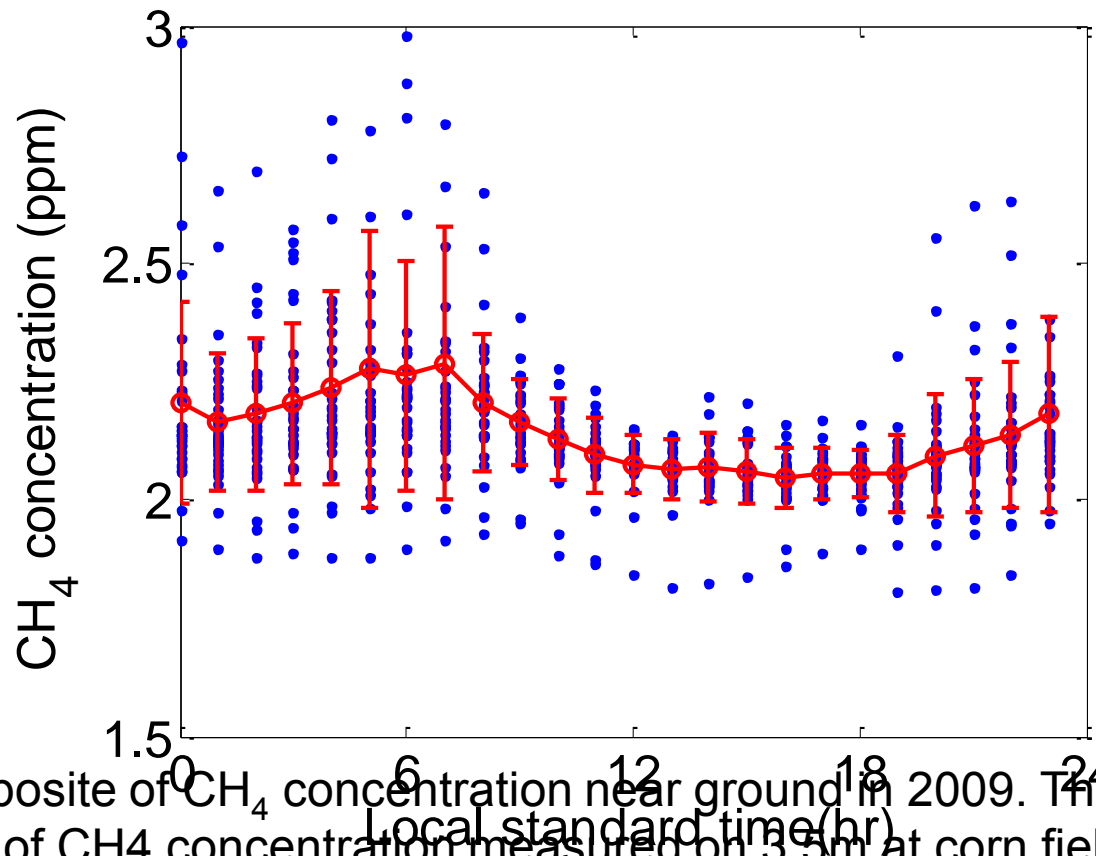
Diurnal composite of CH$_4$ concentration near ground in 2009. The blue dots are a combination of CH4 concentration measured on 3.5m at corn field during DOY 218~227 and on 3m at tall tower during 233~273. The red line is the mean value of all the concentration on each hour, and the error bars are the standard deviation.
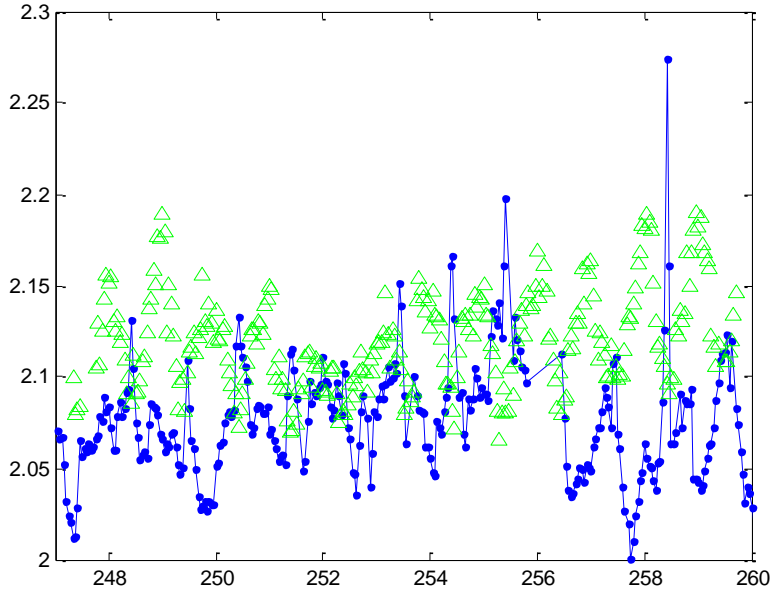
STILT model
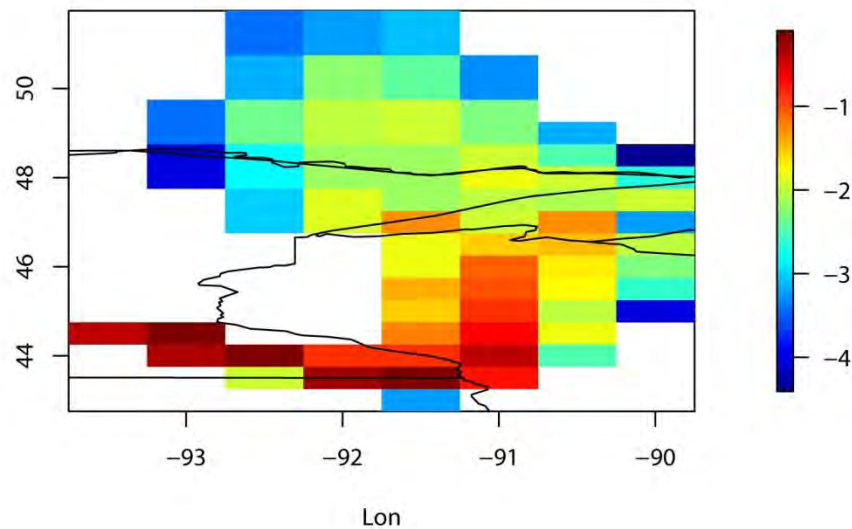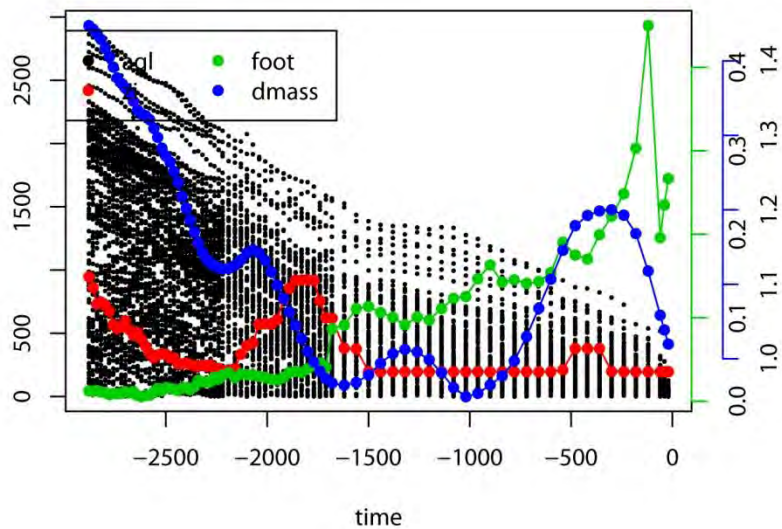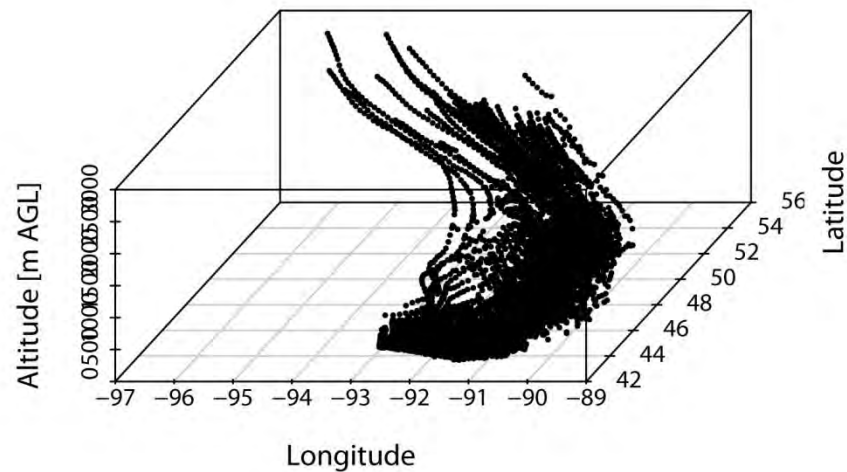
Observe vs. modeled

CH4Flux=0.02;

CCH4 at 3m(r) and 200m(b)

CH4Flux=-0.04;

CH_4 from observation(200m,b) and modeling(g)

Summary

Method	Target	DayCH$_4$	NightCH$_4$
Chamber	Corn (unfer)	$+0.8 \times 10^{-3}$	-0.7×10^{-3}
	Corn (fer)	$+0.8 \times 10^{-3}$	-0.5×10^{-3}
	Soybean (unfer)	$+0.2 \times 10^{-3}$	-0.1×10^{-3}
	Soybean (fer)	$+0.3 \times 10^{-3}$	-0.2×10^{-3}
Tall tower	Landscape (corn/soybean/soil/industry/landfill…)	-0.04	0.02

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