

National Air Emissions Monitoring Study  
Update for the Dairy Industry



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Quality Laboratory



Agricultural and Biological  
Engineering



Purdue University

## National Air Emission Monitoring Study

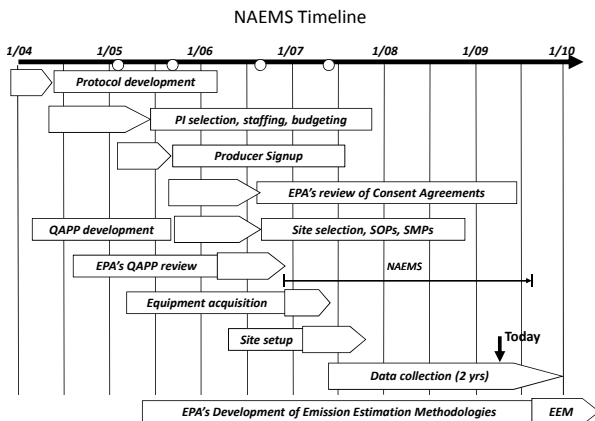
- Objective:
  - Collect quality-assured emission data from representative farms to generate a database from which emission prediction models can be developed:
    - Particulate Matter (PM<sub>10</sub>, PM<sub>2.5</sub> and TSP)
    - Ammonia
    - Hydrogen Sulfide
    - VOCs
- Quality Assurance Project Plan and Standard Operating Procedures

### Study Design

- > **Barns (38) monitored continuously**
  - > **Hydrogen sulfide** (pulsed fluorescence)
  - > **Ammonia** (photoacoustic spectroscopy)
  - > **Non-methane HC** (GC-FID)
  - > **Carbon dioxide** (photoacoustic spectroscopy)
  - > **TSP, PM<sub>2.5</sub>, PM<sub>10</sub>** (TEOM)
  - > **Barn airflow** (fan rpm, pressure, air speed, fan tester)
- > **Outdoor manure facilities (9) @ corral (1) tested every 3 mon.**
  - > **Hydrogen sulfide** (pulsed fluorescence with S-OP).
  - > **Ammonia** (TDLAS, photoacoustic spectroscopy)
  - > **VOC** (photoacoustic spectroscopy)
- > EPA-approved standard operating procedures

### National Air Emission Monitoring Study

- Barns
  - Project Director: Al Heber
  - Purdue Ag Air Quality Laboratory
    - Bill Bogan, Erin Cortus, Jiqin Ni, Teng Lim, Juan Carlos Ramirez, Yaomin Jin, and Kaiying Wang
  - Co-Principal Investigators:
    - Curt Gooch, Cornell University
    - Frank Mittlöhner and Ruihong Zhang, UCD
    - Larry Jacobson, University of Minnesota
    - Teng Lim and Jiqin Ni, Purdue University
    - Pius Ndegwa, Washington State University-Pullman
    - Wayne Robarge and Lingjuan Wang, NCSU
    - Ken Casey, Texas Ag Exp. Station, Texas A&M
    - Jacek Koziel and Steve Hoff, Iowa State University
- Open Sources
  - Richard Grant
  - Purdue Applied Meteorology Lab
    - Alfred Lawrence, Matt Boehme



### General Timeline

- 2004 Protocol Development
- 2005 PI Selection, Staffing, Budgeting at Purdue
- 2006 Site Selection, Quality Assurance Project Plan
- 2007 Setup of Barn and Open Source Emission Monitoring
- 2008 Data Collection, Analysis and Reporting
- 2009 Data Collection, Analysis and Reporting
- 2010 Prepare Final Report for EPA
- 2011 EPA Develops Emissions Estimating Methodologies

## Particulate Matter (PM)

- Real-time monitors
  - Inlet: Thermo FH62 C-14 Beta Attenuation
  - Exhaust: Thermo 1400a TEOM
- PM monitoring schedule
  - PM<sub>10</sub> most of the time
  - TSP every 8th week for one week
  - PM<sub>2.5</sub> during two 2-week periods.
- Sampling location near fan inlet

## Gas Measurements

- NH<sub>3</sub>, CO<sub>2</sub>: Innova 1412 Multigas analyzer
- H<sub>2</sub>S: TFS 450i pulsed-fluorescence analyzer
- VOC: TFS 55C GC-FID - CH<sub>4</sub> / Non-CH<sub>4</sub>
- Environics 4040 6-port single-gas diluter

## Barn Ventilation Airflow

- Spot measurements
  - FANS: A portable fan tester.
  - Traverse with portable anemometer.
- Continuous measurements
  - Air velocity: bi-directional impeller.
  - Fan speed (magnetic Hall-effect detectors)
  - Fan operation status
    - Current switches
    - Vibration sensors
    - Fan stage monitoring at relays
- Air velocity at NV barns
  - 3-D sonic anemometers.
  - Wind speed and direction

## Other Measured Variables

- Outdoor temperature and humidity
- Indoor temperature and humidity
- Wind direction and speed
- Solar radiation
- Pit flushing and feeding operation
- Animal and worker activity
- Differential pressure
- Animal inventory
- Feed consumption
- Milk and egg production

## Manure Analysis

- pH, total solids, ash, total N, NH<sub>3</sub>-N
- Total N will be used in conjunction with total N in feed, bedding, milk, and eggs to calculate N mass balance.
- Ash-balance will be used at some sites to estimate manure volumes, and will be validated at sites where manure volume is measured directly (e.g., deep pits).

## Final Data Processing

- Facilitated with CAPECAB, a powerful custom data analysis program.
- Hourly and daily means of emission rates are submitted to U.S. EPA.

## Overview of QAQC Program

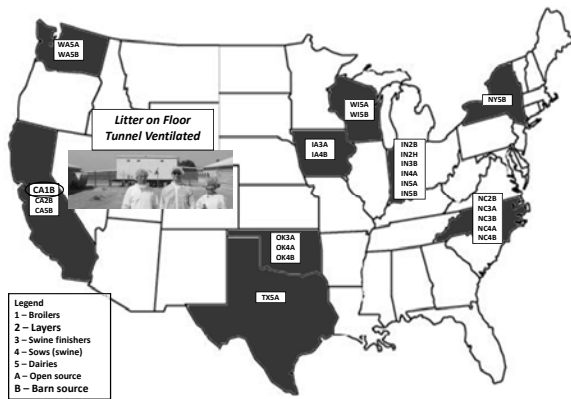
- Calibration of Equipment (Dilutors, Flow meters, Psychrometers).
- Daily inspection of data and feedback to the site engineer and site's Principal Investigator.
- Technical support (SOPs, guidance documentation, Repair/Maintenance troubleshooting assistance).
- Maintenance schedule
- Spare parts available.

Summary of NAEMS Sites

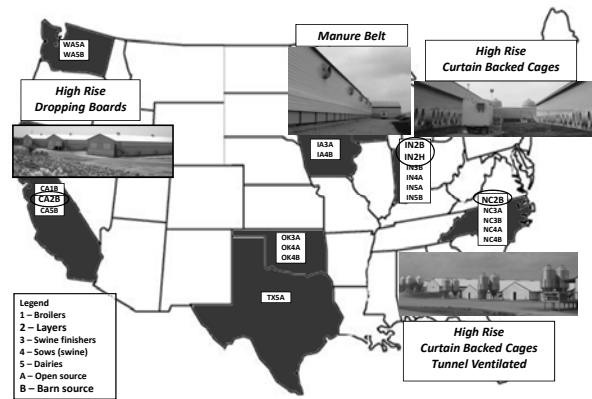
Species	Barns per Site			Total number		Number of Area Sites			
	2-b	3-b	4-b	Sites	Barns	Corrals	Lagoons	Basins	Total
Swine	0	4	1	5	16	0	5	1	6
Dairy	3	2	0	5	12	1	3	0	4
Layers	2	0	1	3	8	0	0	0	0
Broilers	1	0	0	1	2	0	0	0	0
<b>Total</b>	<b>6</b>	<b>6</b>	<b>2</b>	<b>14</b>	<b>38</b>	<b>1</b>	<b>8</b>	<b>1</b>	<b>10</b>

NAEMS QAQC

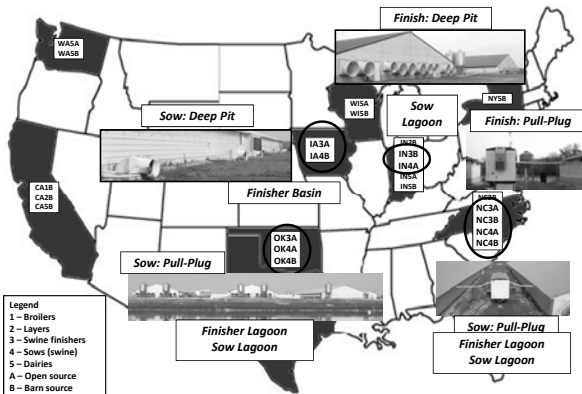
NAEMS Broiler Site



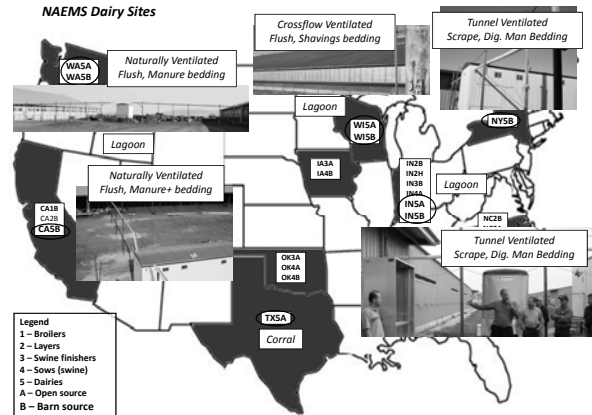
NAEMS Layer Sites



NAEMS Swine Barn Sites



NAEMS Dairy Sites



## Dairy Sites

SMP #	Site Type	Ventilation Type	# of Units Measured	Manure Collection	Manure Storage <sup>1</sup>	Bedding Type <sup>2</sup>	PJ
<b>Northeast</b>							
NY5B	Freestall	MV	2 <sup>3</sup>	Scrape	Dig./SS/Basin	SDS	Gooch
<b>Midwest</b>							
IN5B	Freestall	MV	2	Scrape	Dig./SS/Basin	SDS	Lim
W5B	Freestall	MV	3 <sup>3</sup>	Flush	<u>SP/Basin</u>	<u>Mattress/shavings</u>	Jacobson
<b>West</b>							
CASB	<u>Open Freestall</u> <sup>4</sup>	NV	2	Flush	<u>SP/Basin</u>	<u>Soil/MS/Almond shells</u>	Mitloehner
WASB <sup>1</sup>	<u>Open Freestall</u> <sup>4</sup>	NV	2	Flush	<u>SP/SS/Basin</u>	MS	Ndegwa

<sup>1</sup>Barn sites that also have measured area sources, which are described in the open-source QAPP

<sup>2</sup>Cattle are free to walk from open freestall barn into dry lots between the barns.

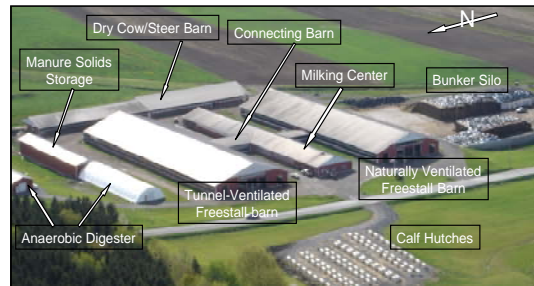
<sup>3</sup>Monitored units include the milking center.

<sup>4</sup>SP = settling pond

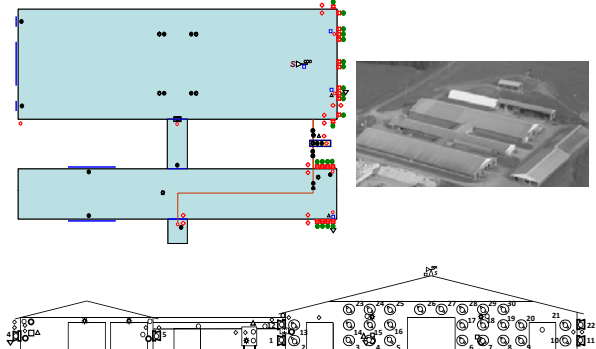
<sup>5</sup>MS = Manure solids; SDS = Separated digested solids

Open source sites include the underlined basins, a basin at another IN site, and a dairy corral in TX.

## New York Dairy Site (NY5B)

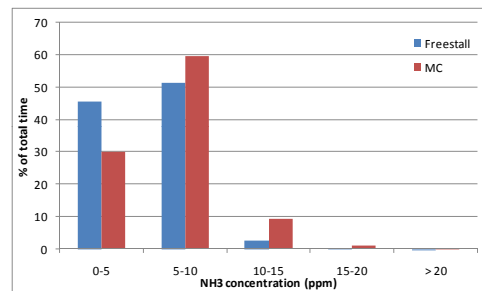


New York Dairy Site NY5B



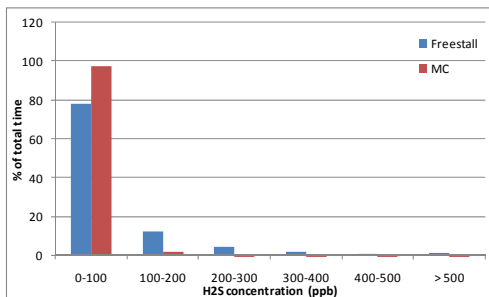
## Exhaust NH<sub>3</sub> Concentrations at NY5B

Nov 2007 – June 2008



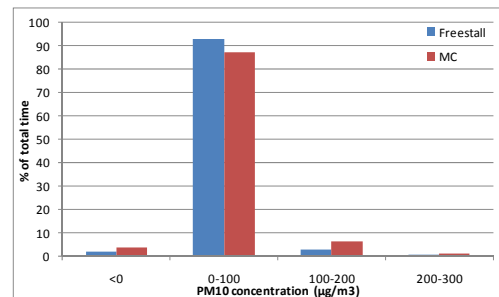
## Exhaust H<sub>2</sub>S Concentrations at NY5B

Nov 2007 – June 2008

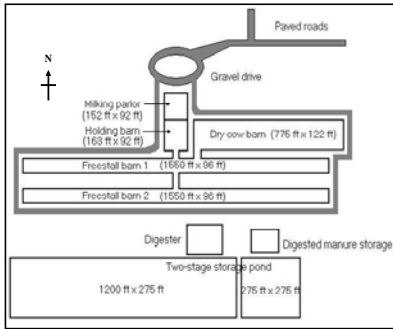


## Exhaust PM<sub>10</sub> concentrations at NY5B

Nov 2007 – June 2008



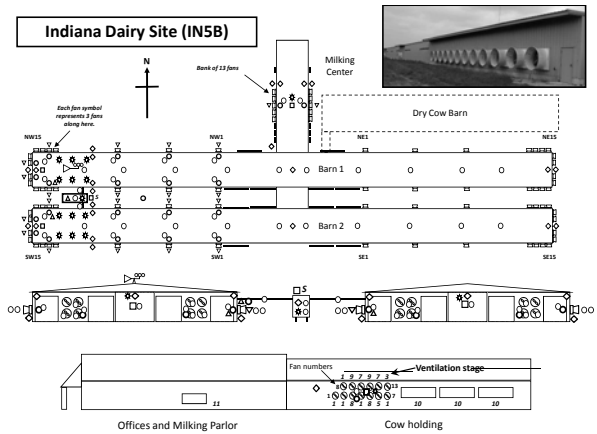
## Indiana Dairy Site (INSB)



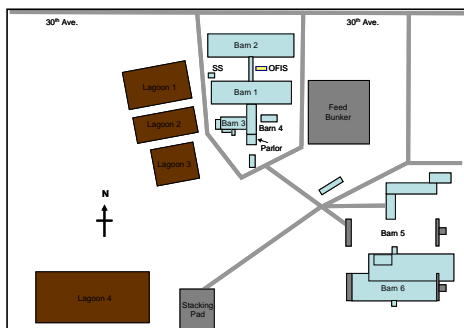
Continuous emissions will be measured in the tunnel-ventilated freestall barns 1 and 2, and in the milking center.



## Indiana Dairy Site (INSB)



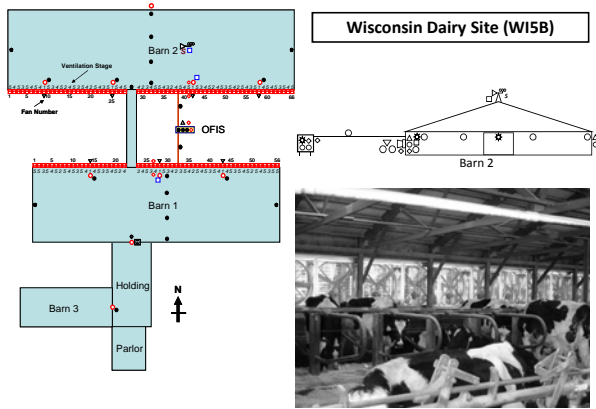
## Wisconsin Dairy Site (WISB)



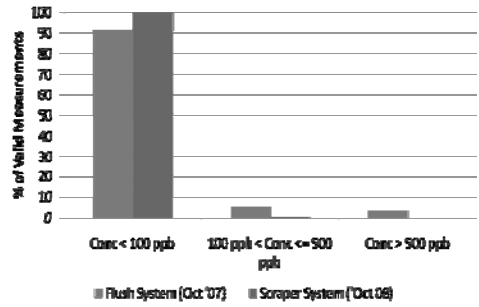
Ground layout of the Wisconsin Dairy Site.

## Wisconsin Dairy Site (WISB)

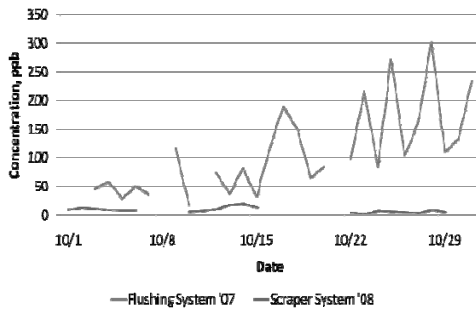




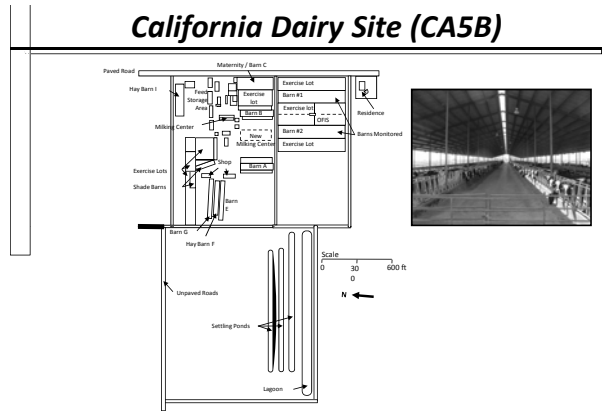
H<sub>2</sub>S Concentrations at WISB



Daily Mean H<sub>2</sub>S in One WISB Barn Related to Manure Removal System

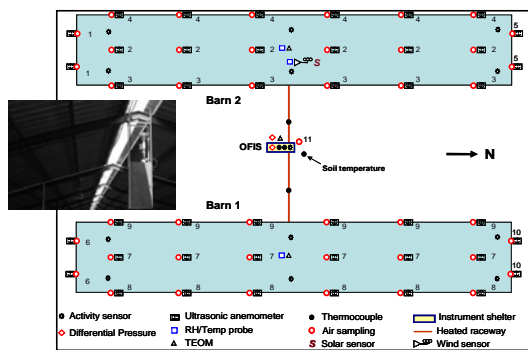


California Dairy Site (CA5B)



Ground layout of the California Dairy Site.

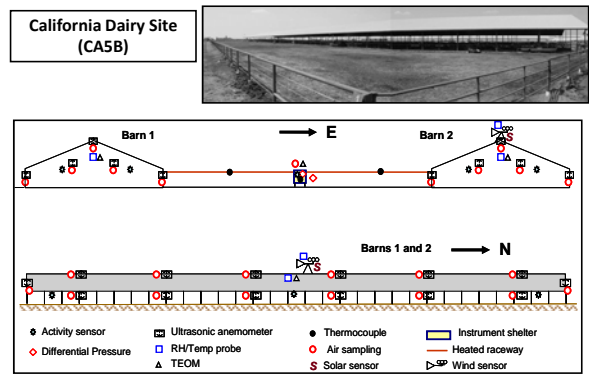
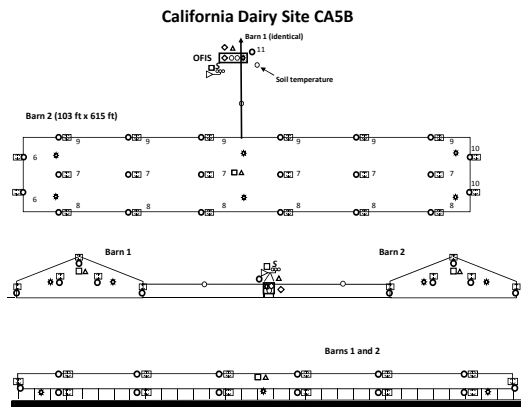
California Dairy Site (CA5B)



Site monitoring plan for continuous air emission testing.

CA5B

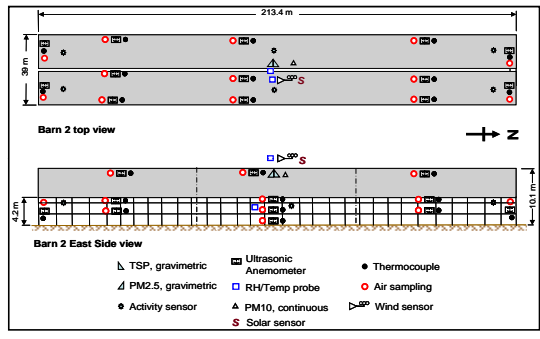




**Washington Dairy Site (WA5B)**



**Washington Dairy Site (WA5B)**



### Uniqueness of the NAEMS

- Pollutants (PM<sub>2.5</sub>, PM<sub>10</sub>, TSP, NH<sub>3</sub>, H<sub>2</sub>S, CO<sub>2</sub>, CH<sub>4</sub>, VOC)
  - Add-on studies measure GHG, odor and airborne pathogens.
- 24-months of continuous monitoring
- 38 livestock & poultry barns tested with same protocols
- Quality assurance/quality control (raising the bar)
  - Oversight by the U.S. EPA OAQPS in Raleigh, NC
  - Quality Assurance Project Plan (Category 1)
    - 57 standard operating procedures (SOPs)
    - 15 site monitoring plans (SMPs)
  - On-site audits
- Novel methods
  - NV barn airflows measured with 3-D sonics.
  - Fan operation measured with vibration sensors.
  - Custom data acquisition/processing systems

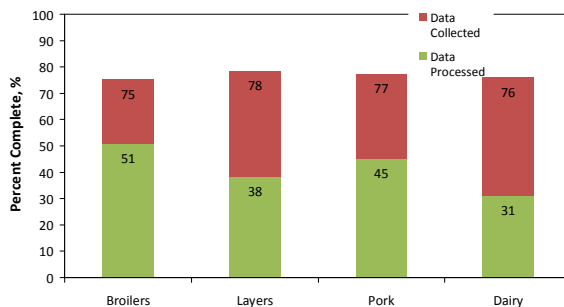
### Some Process Variables

- Facility design and management
- Operating techniques
- Weather
- Animal inventory and activities
- Ventilation = f (weather, animals)
- Manure pH, NH<sub>3</sub>-N, mc and flows.
- Nutrient inputs
- Production of milk, eggs, and/or meat.
- Losses in manure, mortalities

## Data for Process-Based Modeling

- Measurement/documentation of most process variables affecting emissions.
  - Effect of flushing
  - Effect of animal activity
  - Effect of light
- Dynamic emissions (min, hr, daily)
- Integrated long-term results

## Data Processing Update



## Site Milestones (dairy in yellow)

Site	Day 1	Last Day	Audit	Sensors	EPA Audit	DA
CA1B	9/28/07	9/27/09	9/5/07	125	6/4/08	EC
CA2B	10/17/07	10/16/09	10/30/07	104	3/21/09	EC
IN2B	11/2/07	11/1/09	1/15/08	297	9/26/07	LC
IN2H	5/9/07	5/8/09	1/16/08	169	9/26/07	BB
NC2B	9/24/07	9/23/09	9/12/07	140	10/28/08	KW
IN3B	7/13/07	7/12/09	8/24/07	154	9/27/07	YJ
NC3B	11/30/07	11/29/09	11/14/07	98	1/21/09	KW
NC4B	12/14/07	12/13/09	1/30/07	85	1/20/09	KW
IA4B	7/19/07	7/18/09	8/30/07	147	8/7/08	EC
OK4B	7/20/07	7/19/09	8/16/07	121	9/17/08	EC
CA5B	9/27/07	9/26/09	9/6/07	239	6/3/08	KW
IN5B	8/24/07	8/23/09	9/15/07	186	9/25/07	YJ
NY5B	10/24/07	10/23/09	11/13/07	107	6/25/08	BB
WA5B	9/28/07	9/27/09	10/31/07	214	3/19/09	JR
WI5B	9/12/07	9/12/09	8/29/07	121	8/5/08	EC

## Progress Update

- Open-source monitoring completion: 08/09
- Emission monitoring continuing at all barn sites with a total of 2,307 sensors.
- Ultimate Data Quantity (UDQ): 10950 site-days.
- 77% of UDQ has been collected and stored.
- 39% of UDQ has been processed and is under internal review by site PIs and Purdue team.
- VOC initial characterization completed.
- Barn-source monitoring completion: 12/09.
- NAEMS web site: [www.naems.info](http://www.naems.info).

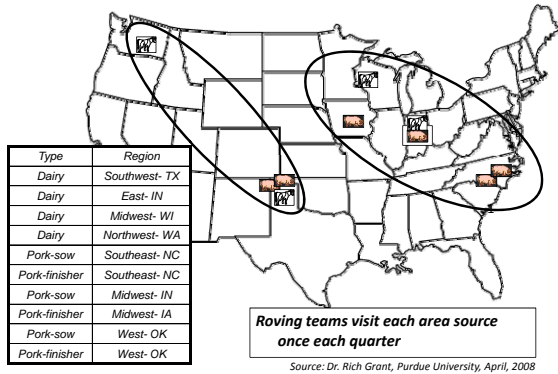
## Simultaneous Studies

PI	Topic/Sponsor	Site(s)
Ni	Air emissions (USDA-NRI)	IN2B
Koziel	GHG (ISU)	IA4B
Zhang	GHG emissions (Foster Farms)	CA1B
Wang	PM size distribution (USDA-NRI)	NC2B
Jacobson	Odor emissions (USDA NRI)	IA&OK4B, IN&WI5B
Jacobson	GHG emissions (University of Minnesota)	WI5B
Lim	Dairy Odor Setback Model (Purdue Ag)	IN5B
Ndegwa	Bioaerosols (PNASH)	WA5B
Heber	GHG (DMI)	Dairy sites

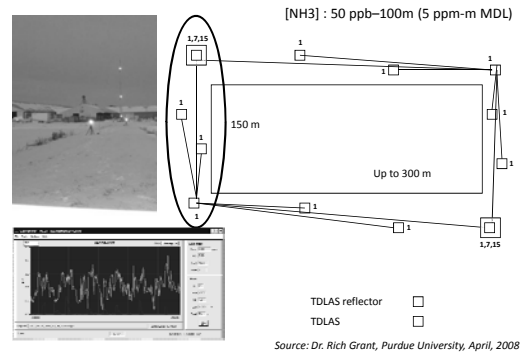
## Open Sources



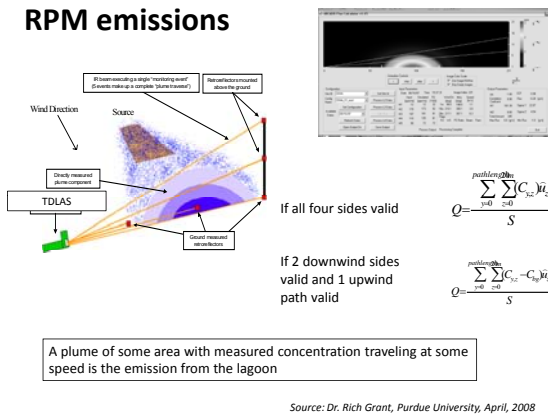
### Open Source Measurement Sites (Dr. Rich Grant)



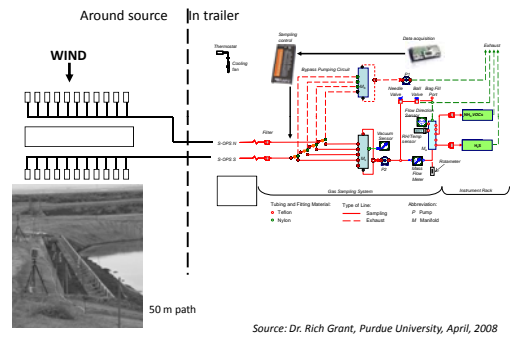
### NH<sub>3</sub> Measurements: TDLAS



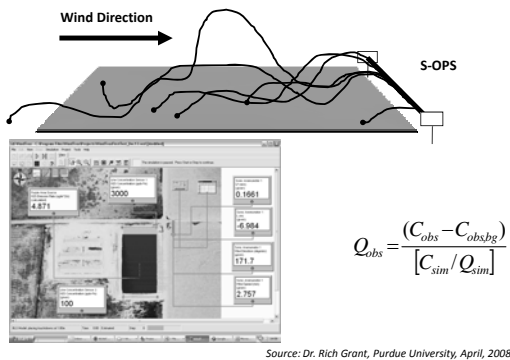
### RPM emissions



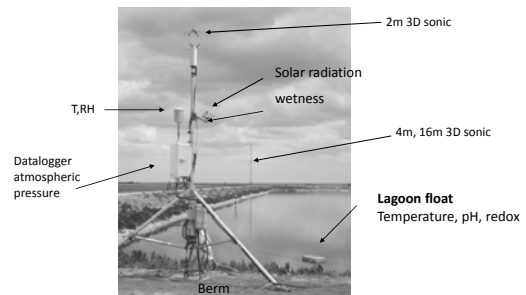
### S-OPS/ Gas sampling system



### bLS emissions



### Meteorological and lagoon measurements



## What Comes After NAEMS?

- Continued measurements using NAEMS infrastructure and expertise.
- Source emission model development.

**Check out [www.AqAirQuality.com](http://www.AqAirQuality.com)  
and [www.naems.info](http://www.naems.info)**

