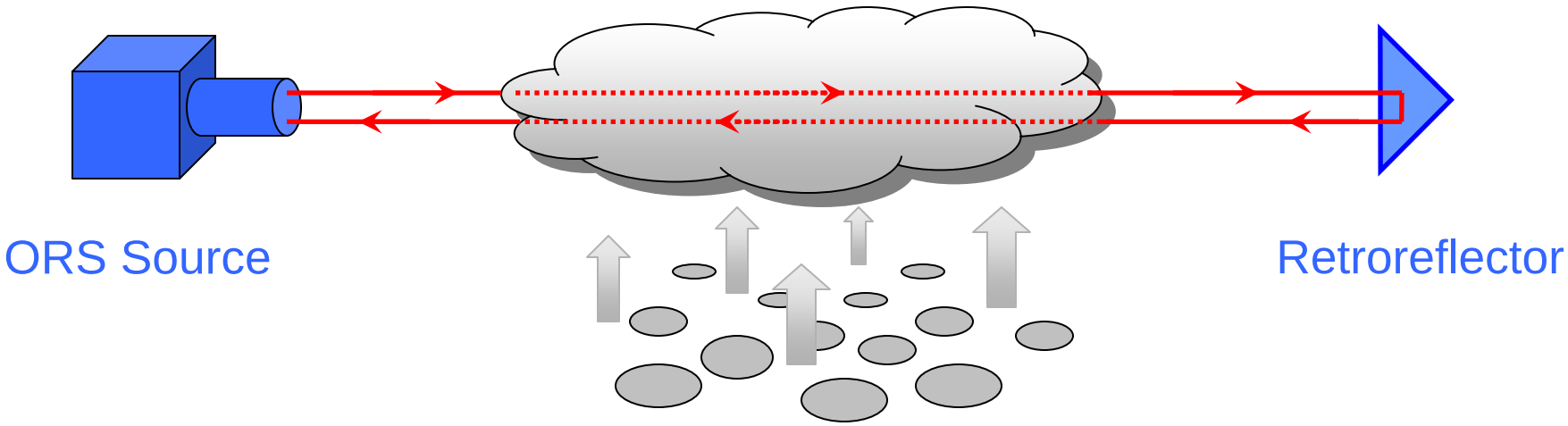
Using Tunable Diode Lasers to Measure Emissions from Animal Housing and Waste Lagoons

D. Bruce Harris

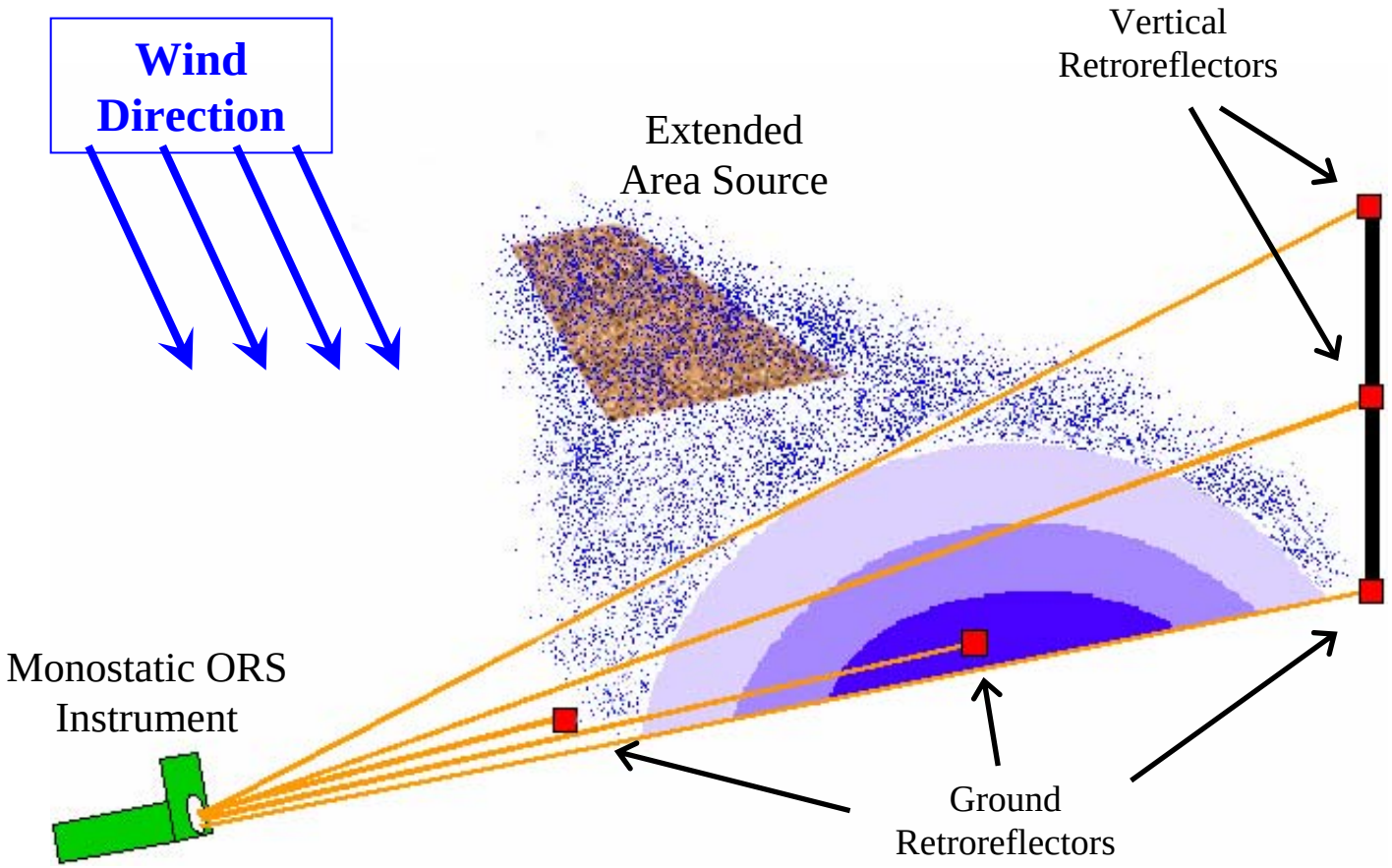
U. S. Environmental Protection Agency
Office of Research and Development
National Risk Management Research Laboratory
Air Pollution Prevention and Control Division
Research Triangle Park, NC

Path-Integrated Optical Remote Sensing

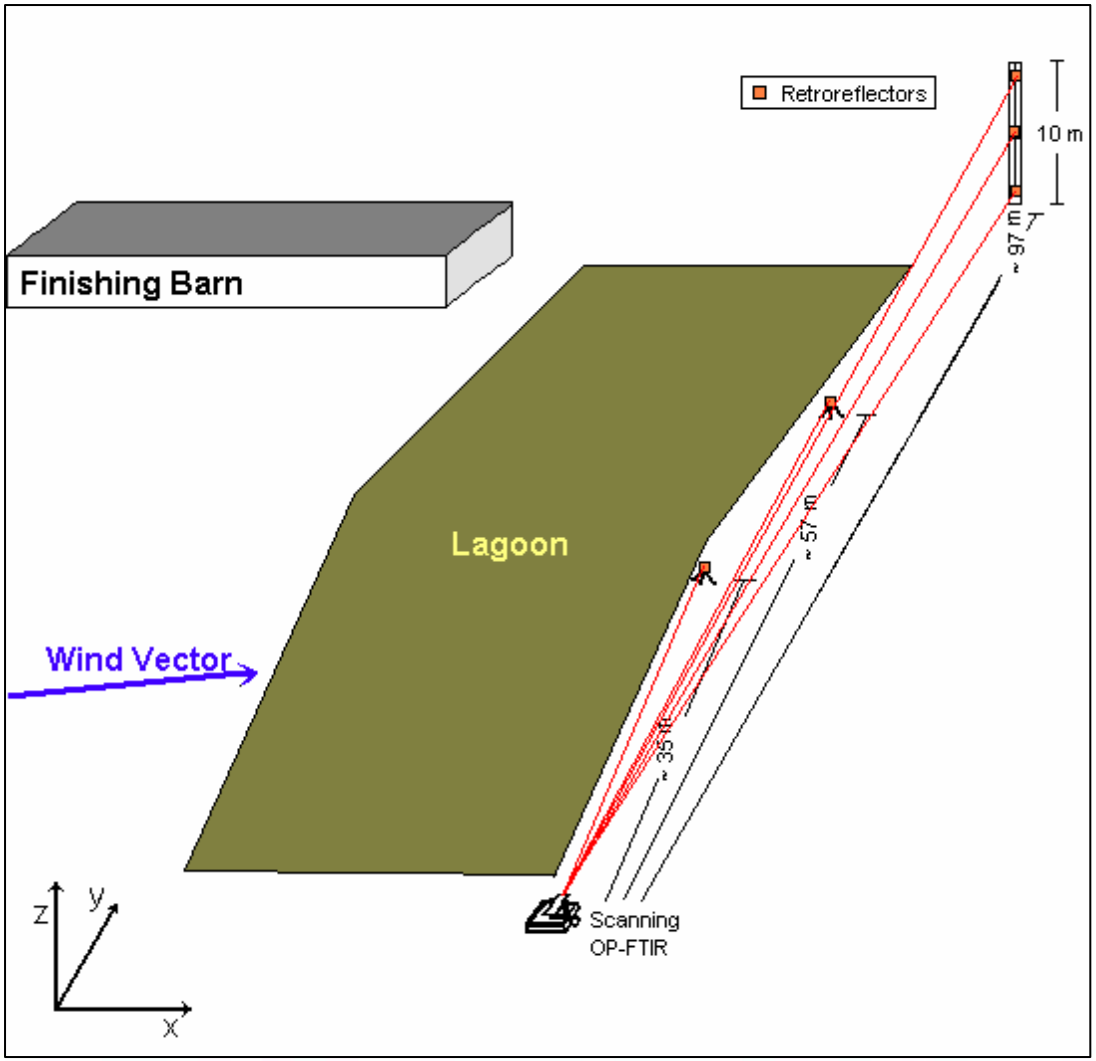


- OP-FTIR: Open-Path Fourier Transform Infrared
- OP-TDLAS: Open-Path Tunable Diode Laser Absorption Spectroscopy
- UV-DOAS: Ultraviolet Differential Optical Absorption Spectroscopy

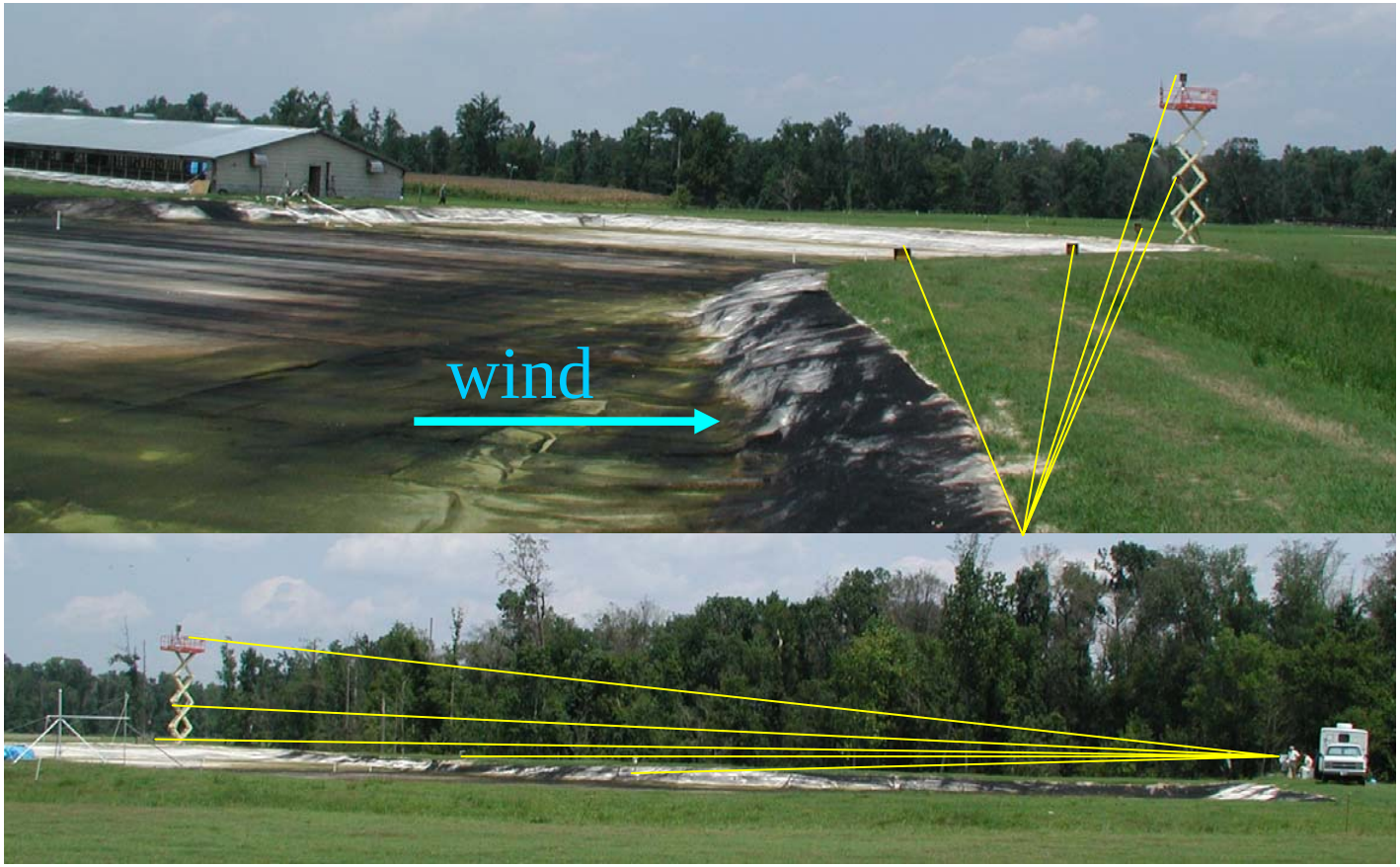
Vertical Radial Plume Mapping
Mass Emission Flux Measurement



Open-Path FTIR Measurement System for Hog Waste Lagoon



OP-FTIR Measurement Paths



CAFO Emission ORS Measurements

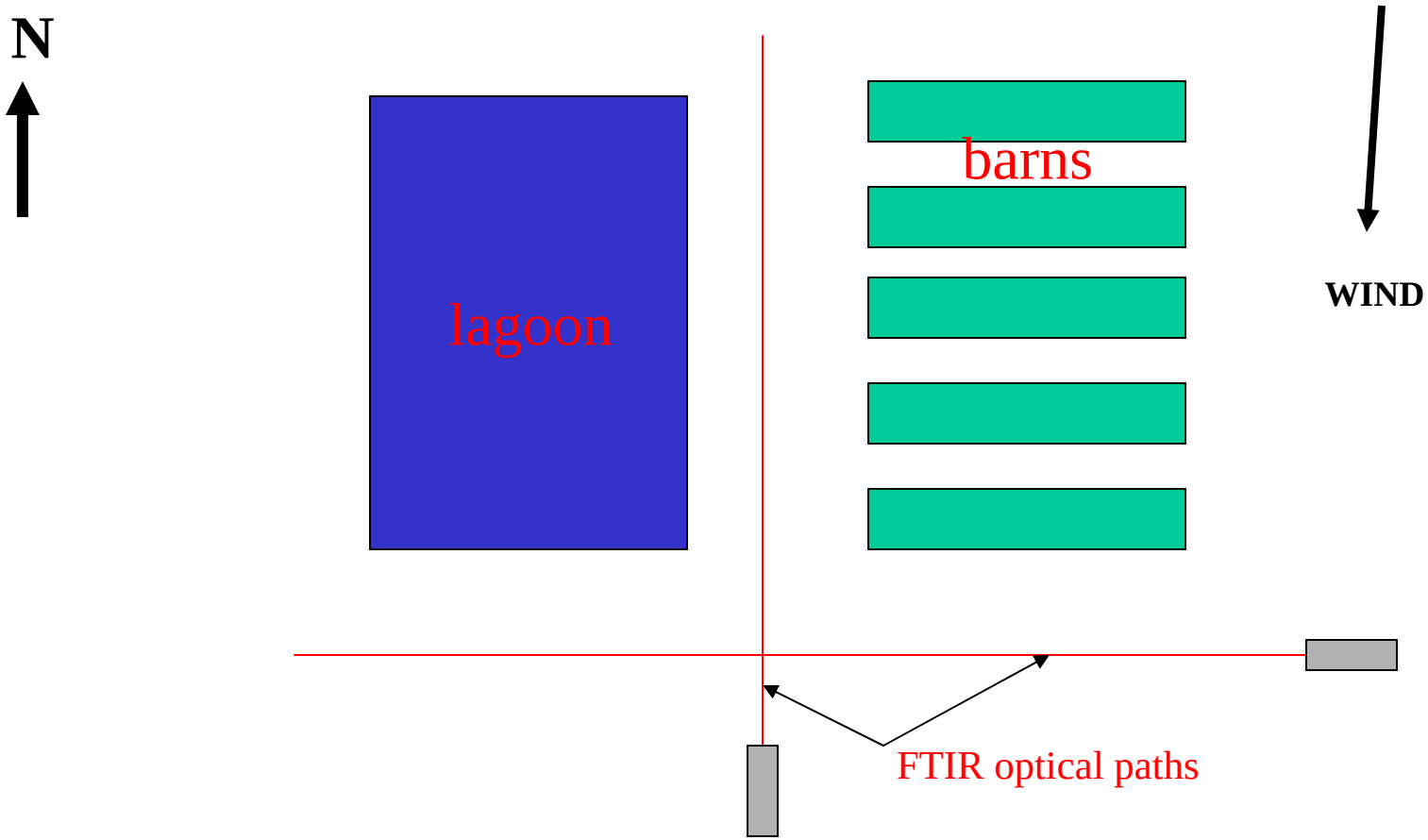
Vertical Radial Plume Mapping Mass Emission Flux

- Swine Lagoon and Whole Farm Capture
- NH_3 from Lagoon Spraying Operation

Open Path-Tunable Diode Laser Absoption Spectroscopy Barn Measurements

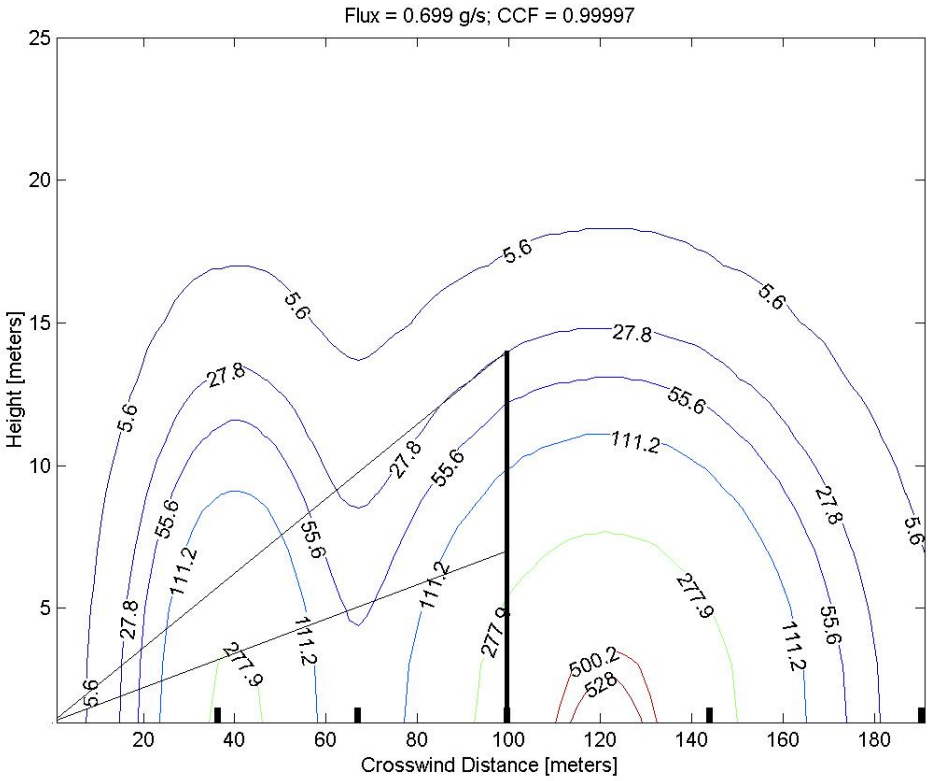
- NH_3 from Mechanically Ventilated Poultry
- Naturally Ventilated Poultry and Swine

Swine Production Facility



Swine Operation with OP-FTIR / VRPM

Swine Operation with OP-FTIR / VRPM Downwind of Barns and Lagoon



- Can resolve multiple plumes.
- Shown are plumes from 5 naturally ventilated barns to left and a lagoon to right.
- Real time software displays total flux as collected.

OP-TDLAS Measurements of Naturally Ventilated Animal Houses

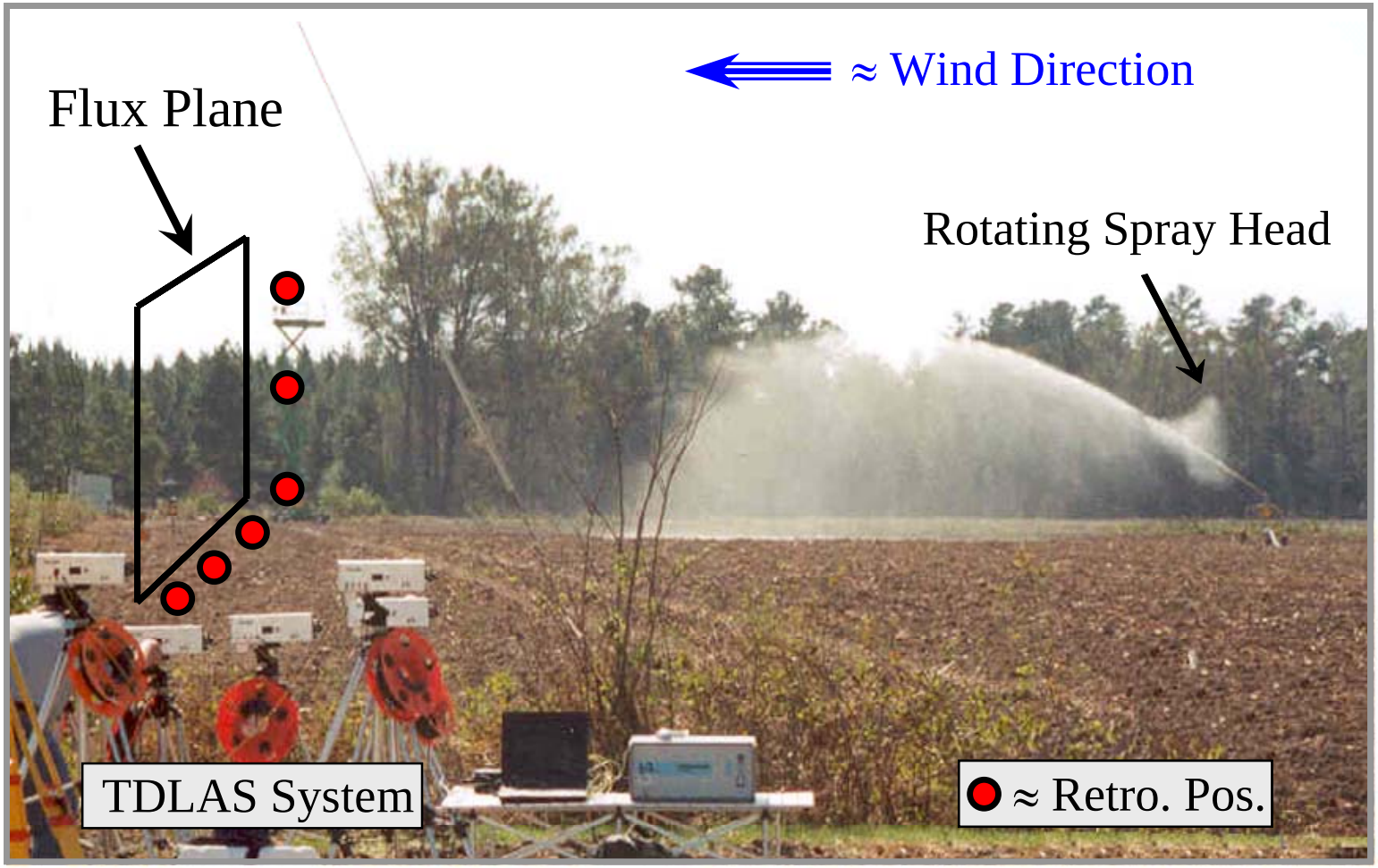
Naturally Ventilated Swine Barn Gas Concentrations – Inlet and Exhaust

	Barn 2 Side 1 Mid	Barn 2 Side 2 Low	Barn 2 Side 2 Mid	Barn 2 Side 2 High
Methane (ppm)	2.06	2.37	2.26	2.29
Ammonia (ppm)	0.09	0.66	0.51	0.39

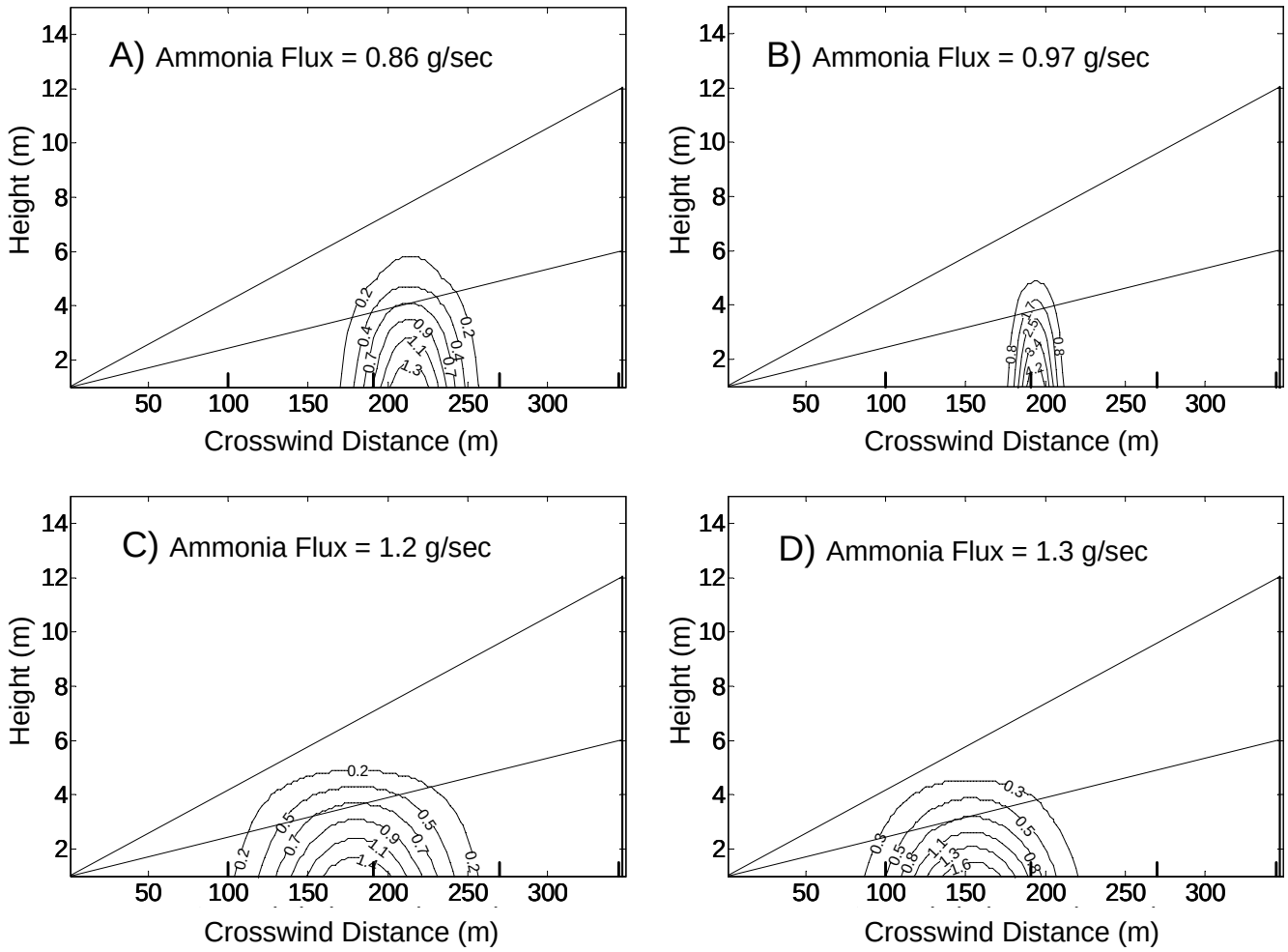
Ammonia Emissions from Lagoon Spraying Operation

Traveling Spray Head - 644 litters/min Lagoon Effluent

OP-TDLAS VRPM Mass Emission Flux Measurement



VRPM Results for Lagoon Spraying Operation



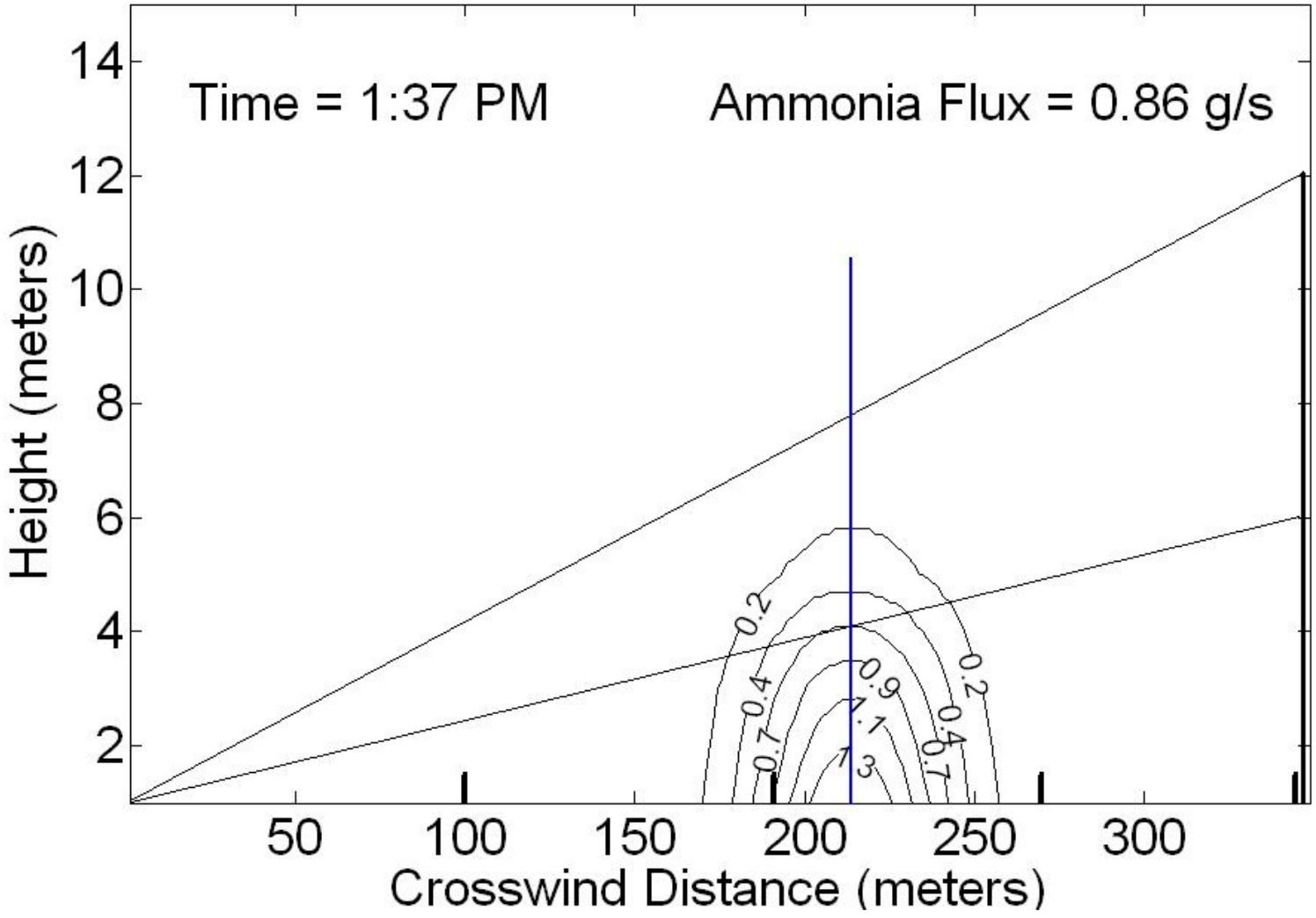
Four consecutive 38-minute observation periods

VRPM Results for Lagoon Spraying Operation

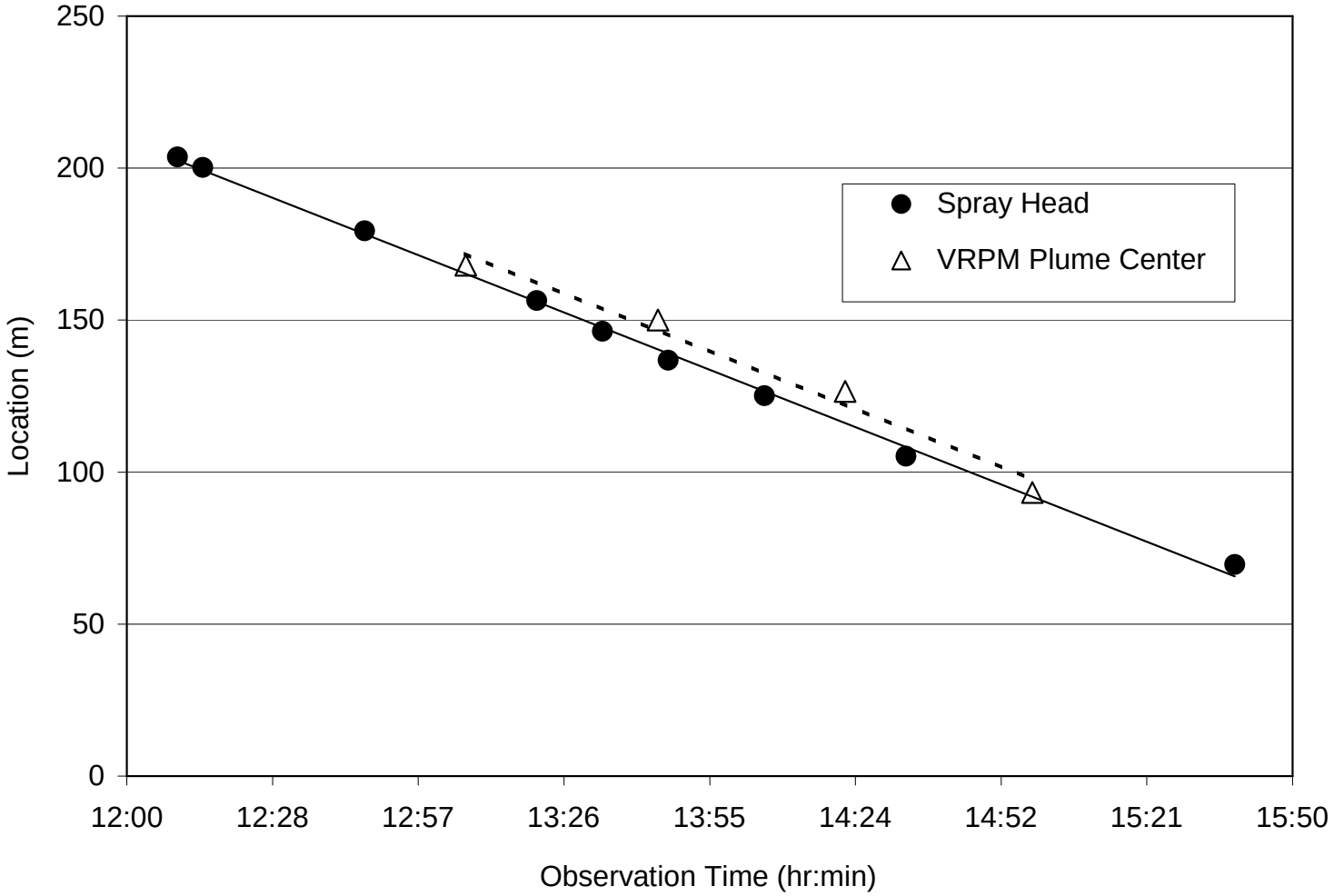
Time Period	Emission Flux (g/sec)	Wind Speed (m/sec)	Wind Direction (deg.)	Concordance Correlation Factor
1	0.86	4.6	45.5	0.979
2	0.97	4.4	47.2	0.983
3	1.2	4.1	46.8	0.989
4	1.3	4.3	35.3	0.990
Average (Periods 1-4)	1.08	4.4	43.7	0.985
Standard Deviation (Periods 1-4)	0.23	0.6	13.9	0.011

Four consecutive 38-minute observation periods

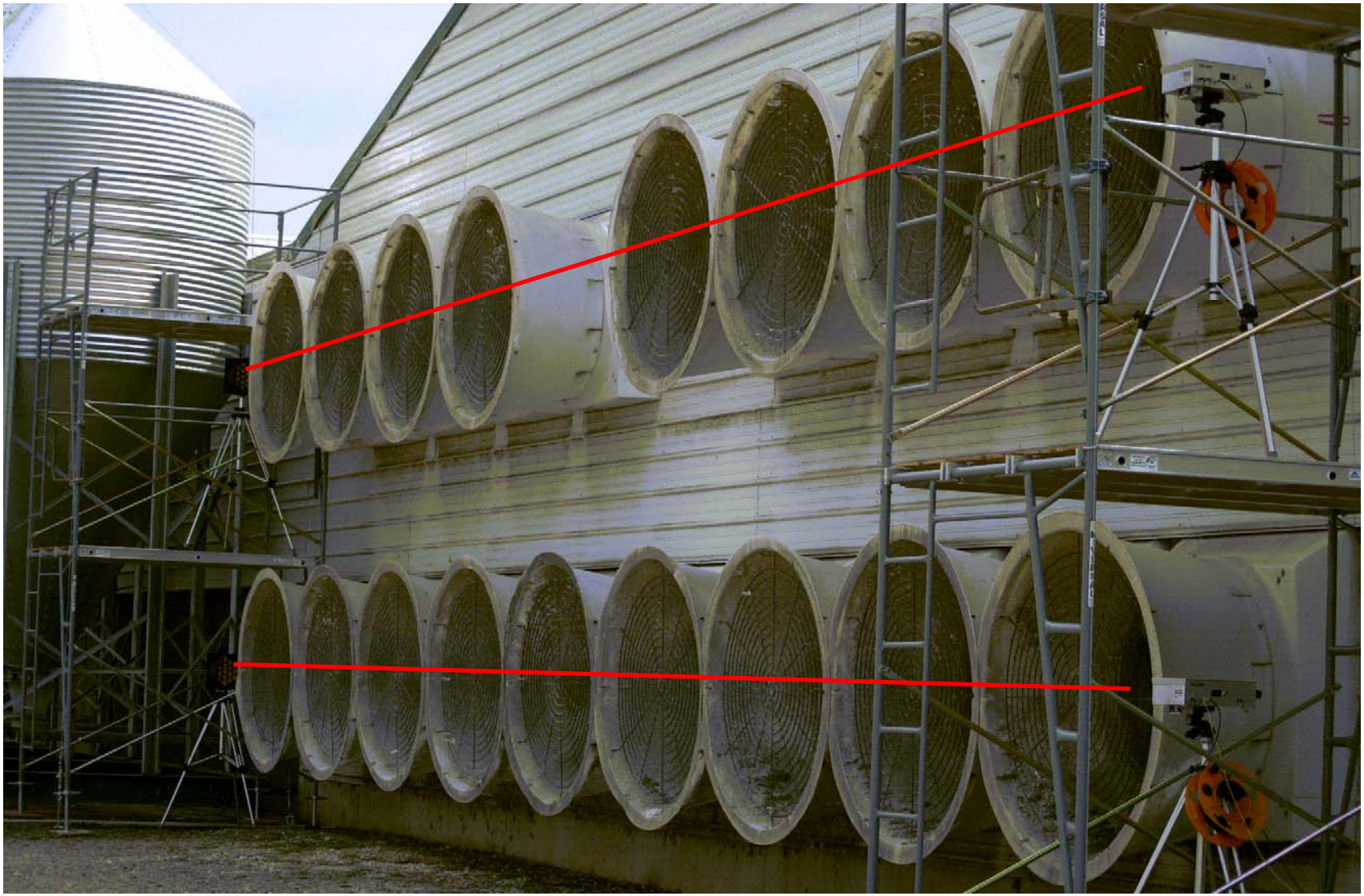
Ammonia Emissions from Lagoon Spraying Operation



Surveyed Spray Head Position Vs. Calculated VRPM Plume Position Shows Source can Be Located with Downwind Data

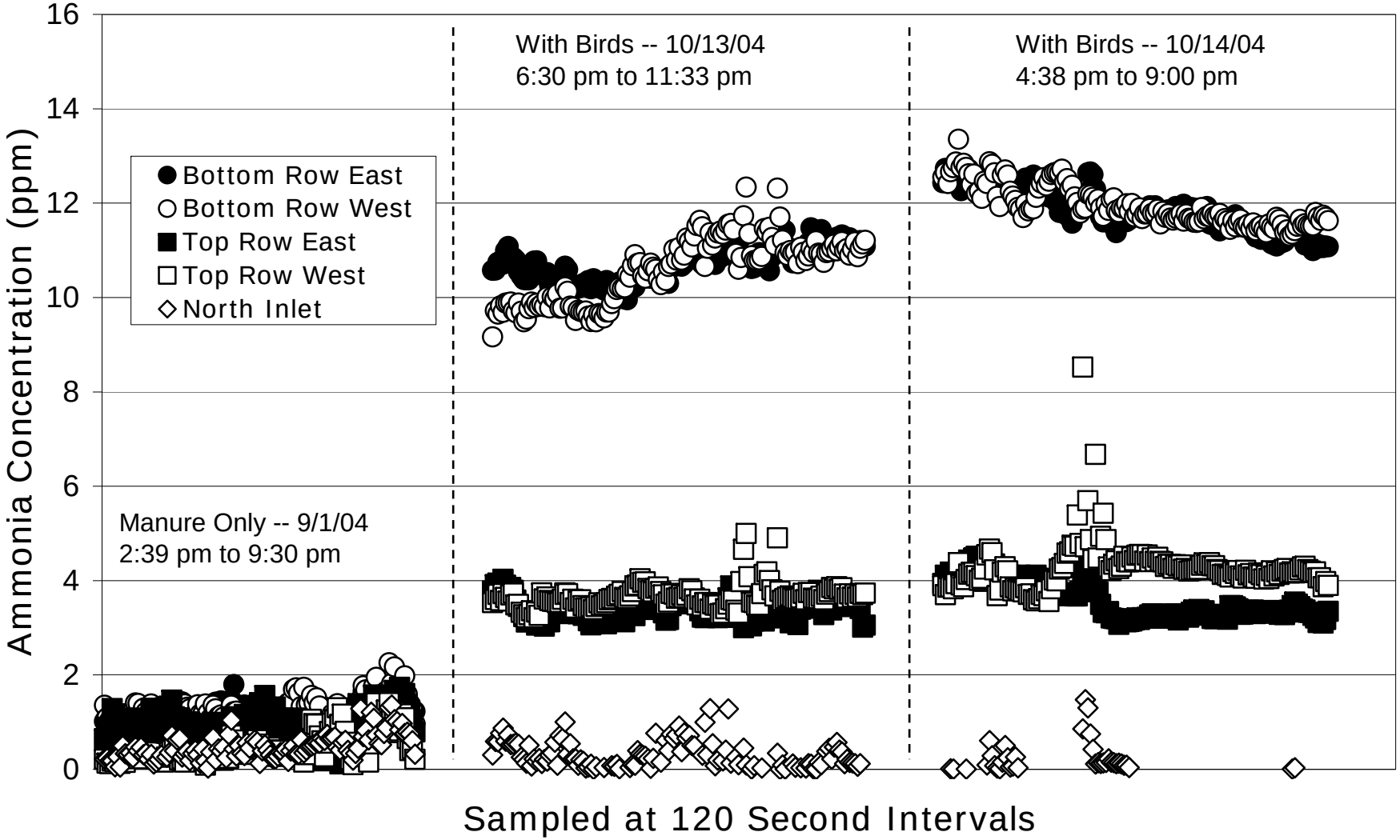


Cross Fan Measurements



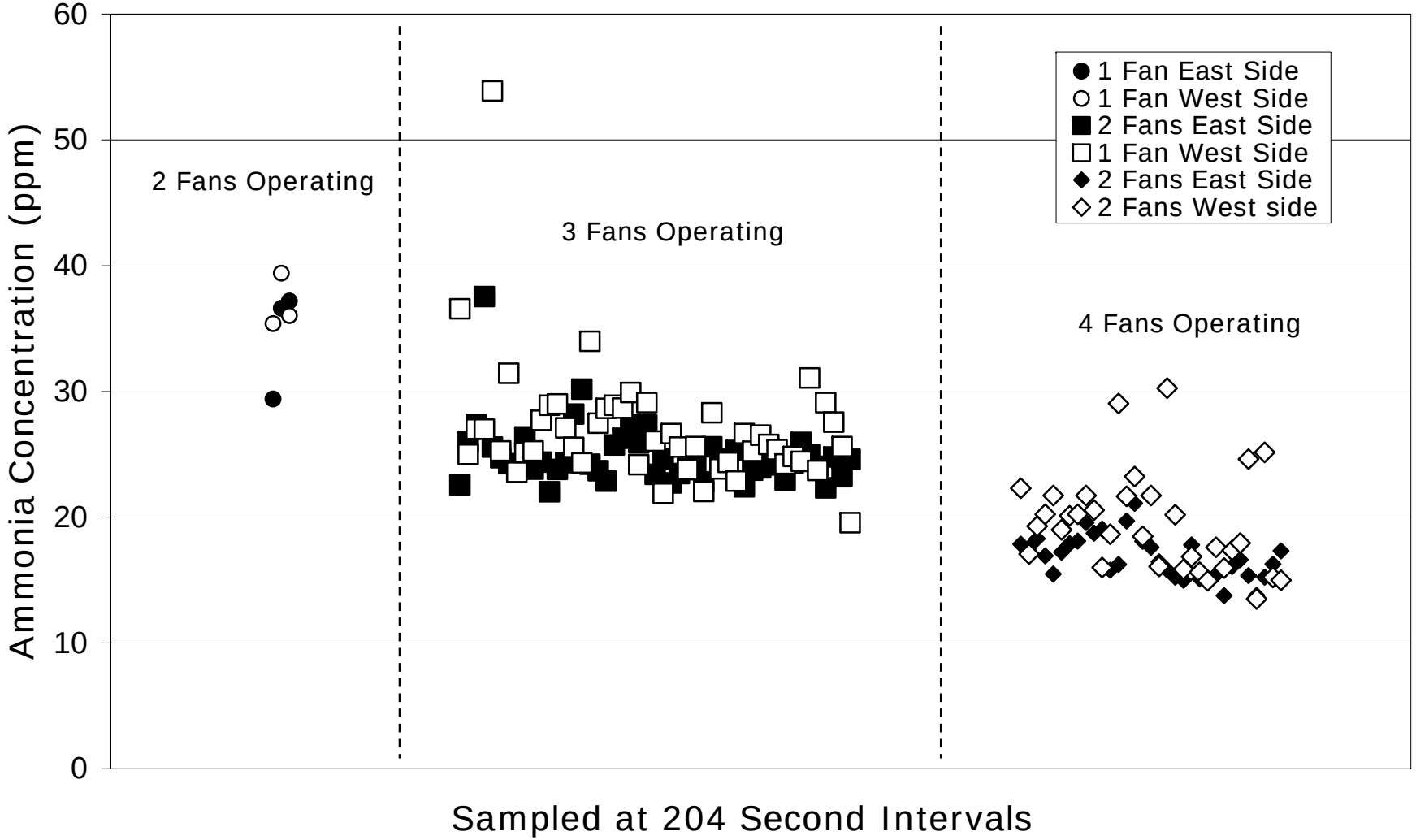
OP-TDLAS Ammonia Measurement of Poultry House

100,000 Layer Hen High Rise - 34 Fans Operating - Manure Only and With Birds



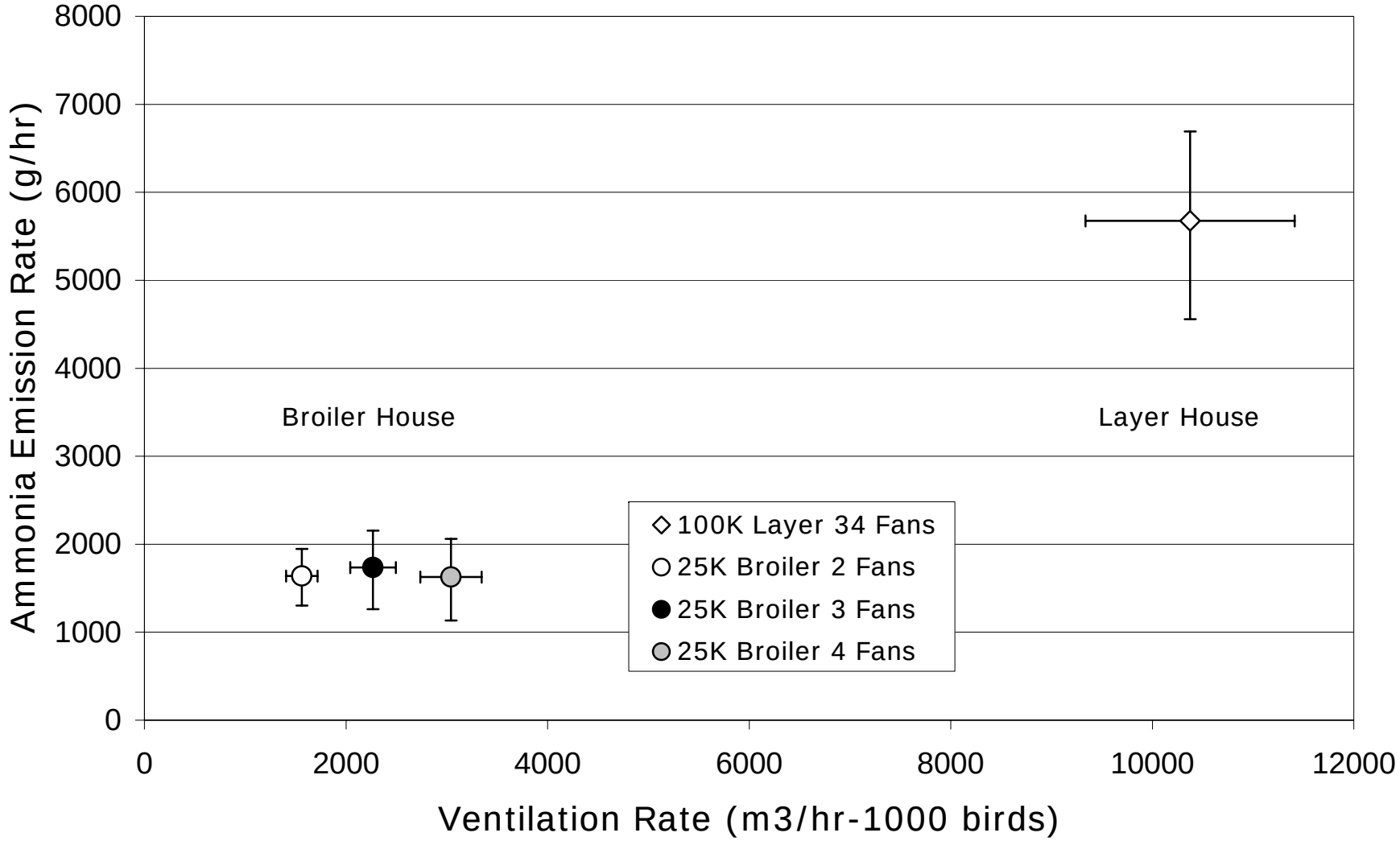
OP-TDLAS Ammonia Measurement of Poultry House

25,000 Bird Broiler House with Reused Litter - 10:33 am to 4:05 pm-11/11/03

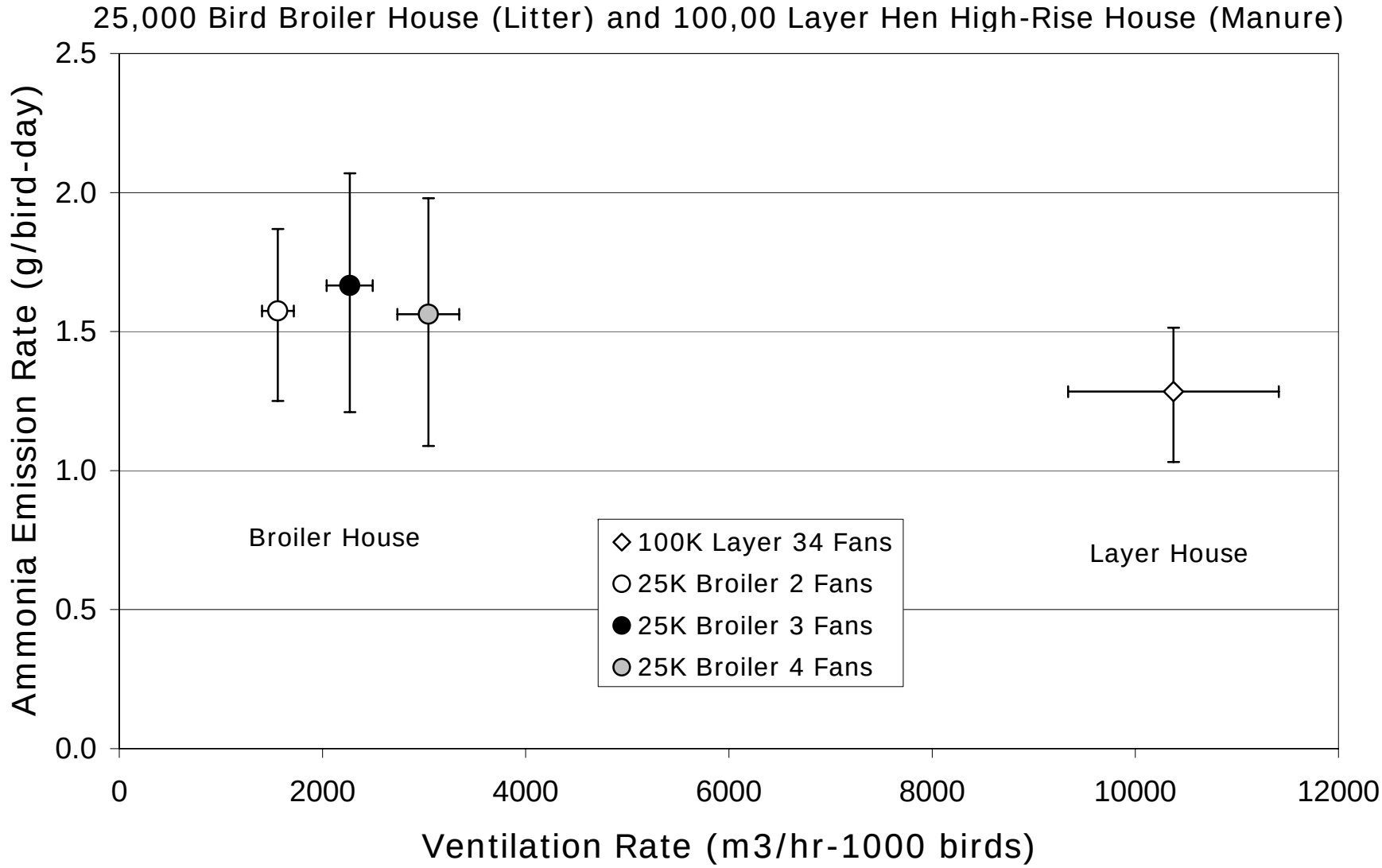


Ammonia Emission Assessments From Poultry Houses

25,000 Bird Broiler House (Litter) *and* 100,00 Layer Hen High-Rise House (Manure)

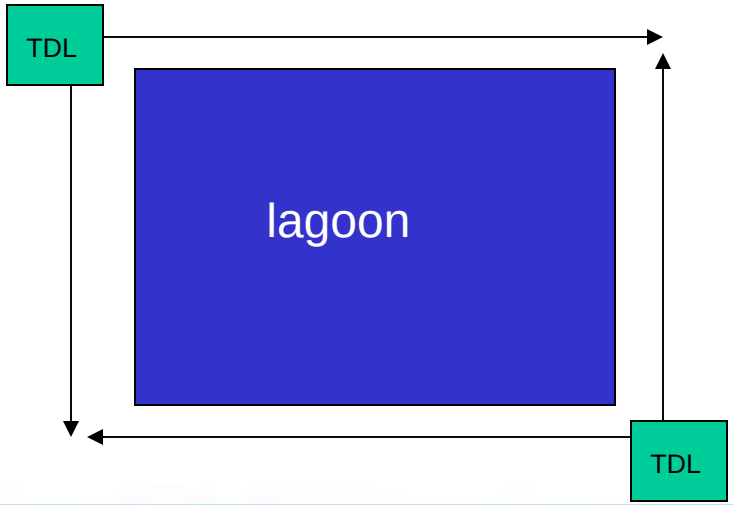


Ammonia Emission Assessments From Poultry Houses

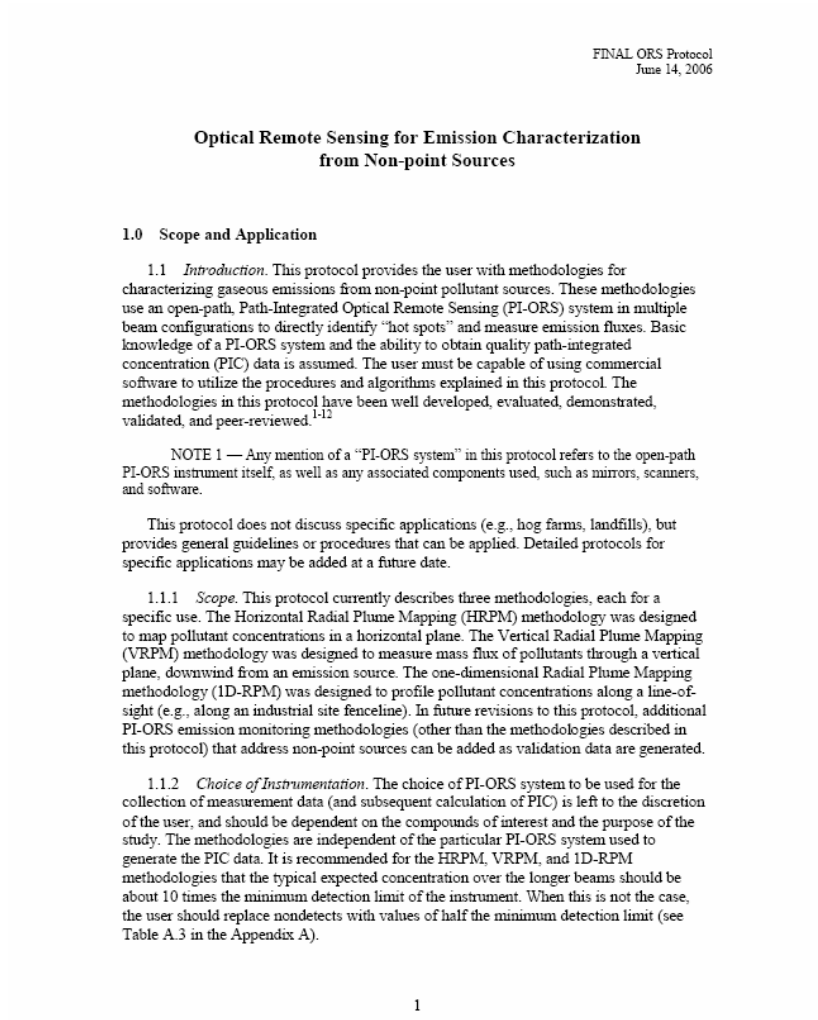


Animal Feeding Operations (AFO) Air Emissions Consent Agreement and Final Order

- **Funding provided by participating AFO**
- **Purpose: gather data for developing emission estimating methodologies**
- **OAQPS provide QA oversight**
- **APPCD provides support to OAQPS in development of sampling protocol**
  - **APPCD VRPM method adopted for measurement of ammonia emissions from waste lagoons--allows for plume measurement regardless of wind direction**



USEPA OTM-10



FINAL ORS Protocol
June 14, 2006

Optical Remote Sensing for Emission Characterization from Non-point Sources

1.0 Scope and Application

1.1 *Introduction*. This protocol provides the user with methodologies for characterizing gaseous emissions from non-point pollutant sources. These methodologies use an open-path, Path-Integrated Optical Remote Sensing (PI-ORS) system in multiple beam configurations to directly identify "hot spots" and measure emission fluxes. Basic knowledge of a PI-ORS system and the ability to obtain quality path-integrated concentration (PIC) data is assumed. The user must be capable of using commercial software to utilize the procedures and algorithms explained in this protocol. The methodologies in this protocol have been well developed, evaluated, demonstrated, validated, and peer-reviewed.[1-12]

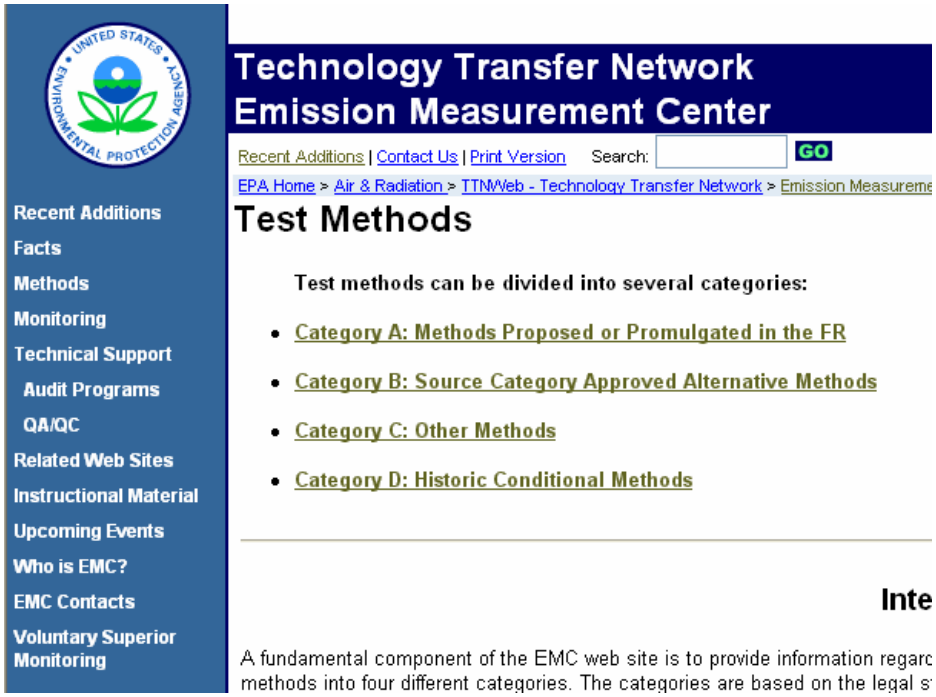
NOTE 1 — Any mention of a "PI-ORS system" in this protocol refers to the open-path PI-ORS instrument itself, as well as any associated components used, such as mirrors, scanners, and software.

This protocol does not discuss specific applications (e.g., hog farms, landfills), but provides general guidelines or procedures that can be applied. Detailed protocols for specific applications may be added at a future date.

1.1.1 *Scope*. This protocol currently describes three methodologies, each for a specific use. The Horizontal Radial Plume Mapping (HRPM) methodology was designed to map pollutant concentrations in a horizontal plane. The Vertical Radial Plume Mapping (VRPM) methodology was designed to measure mass flux of pollutants through a vertical plane, downwind from an emission source. The one-dimensional Radial Plume Mapping methodology (1D-RPM) was designed to profile pollutant concentrations along a line-of-sight (e.g., along an industrial site fenceline). In future revisions to this protocol, additional PI-ORS emission monitoring methodologies (other than the methodologies described in this protocol) that address non-point sources can be added as validation data are generated.

1.1.2 *Choice of Instrumentation*. The choice of PI-ORS system to be used for the collection of measurement data (and subsequent calculation of PIC) is left to the discretion of the user, and should be dependent on the compounds of interest and the purpose of the study. The methodologies are independent of the particular PI-ORS system used to generate the PIC data. It is recommended for the HRPM, VRPM, and 1D-RPM methodologies that the typical expected concentration over the longer beams should be about 10 times the minimum detection limit of the instrument. When this is not the case, the user should replace nondetects with values of half the minimum detection limit (see Table A.3 in the Appendix A).

1



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Test Methods

Test methods can be divided into several categories:

- Category A: Methods Proposed or Promulgated in the FR
- Category B: Source Category Approved Alternative Methods
- Category C: Other Methods
- Category D: Historic Conditional Methods

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A fundamental component of the EMC web site is to provide information regarc methods into four different categories. The categories are based on the legal s

http://www.epa.gov/ttn/emc/tmethods.html

Recent Publications

- Lagoon cover evaluation
  - *Plane-integrated Open-path Fourier Transform Infrared Spectrometry Methodology for Anaerobic Swine Lagoon Emission Measurements,* Shores, R. C. et al, Applied Engineering in Agriculture, **21**(3), 487-492.
- Building emissions
  - *Open Path Tunable Diode Laser Absorption Spectroscopy for Acquisition of Fugitive Emission Flux Data;* Thoma, E. D.; Shores, R. C.; Thonpson, E. L.; Harris, D. B.; Thorneloe, S. A.; Varma, R. M.; Hashmonay, R. A.; Modrak, M. T.; Natschke, D. F.; Gamble, H.A., Journal of the Air and Waste Management Association, **55**, 658-668 (2005).
  - *Measurement of Ammonia Emissions form Mechanically Ventilated Poultry Houses using Multi-path Tunable Diode Laser Spectroscopy;* Thoma, E. D.; Shores, R. C.; Harris, D. B.; Natschke, D. F.; Hashmonay, R. A.; Casey, K. D. and Gates, R. S.. In Proceedings of the 98th Annual Conference of the Air & Waste Management Association, MN June 21-24, 2005.