Inferential Modeling of Ammonia Dry Deposition in the Vicinity of a Swine Production Facility

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Research Needs

- Estimates of NH_3 dry deposition in the vicinity of animal production facilities are limited for U.S. sites

- This information is required to:
  - quantify atmospheric deposition of nitrogen to neighboring ecosystems
  - quantify the fraction of emitted NH_3 that is transported away from the animal production facility
  - evaluate subgrid-scale processes in regional air quality models

Project Objectives

- Measure horizontal gradients of NH_3 concentration around a commercial swine production facility from the barn/lagoon complex out to a distance of 500 m
- Estimate total NH_3 dry deposition over the same area using a combination of measurements and modeling
- Determine the fraction of emitted NH_3 that deposits within 500 m

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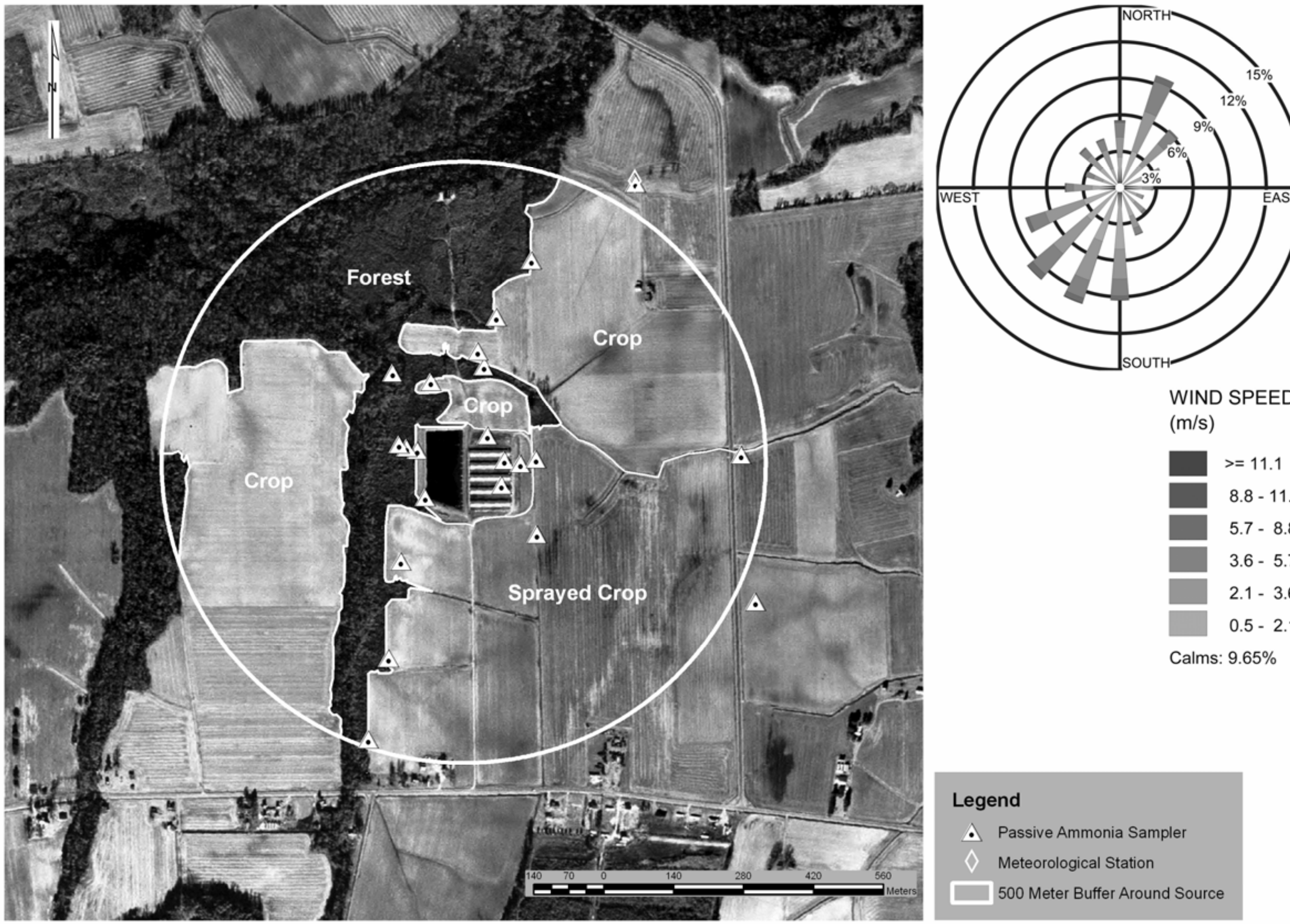
Lizzie Site



Study Area Image Source -- GlobeXplorer

Methods *NH_3 Concentrations*

Gradko Passive Sampler

Exposure time = 1 week

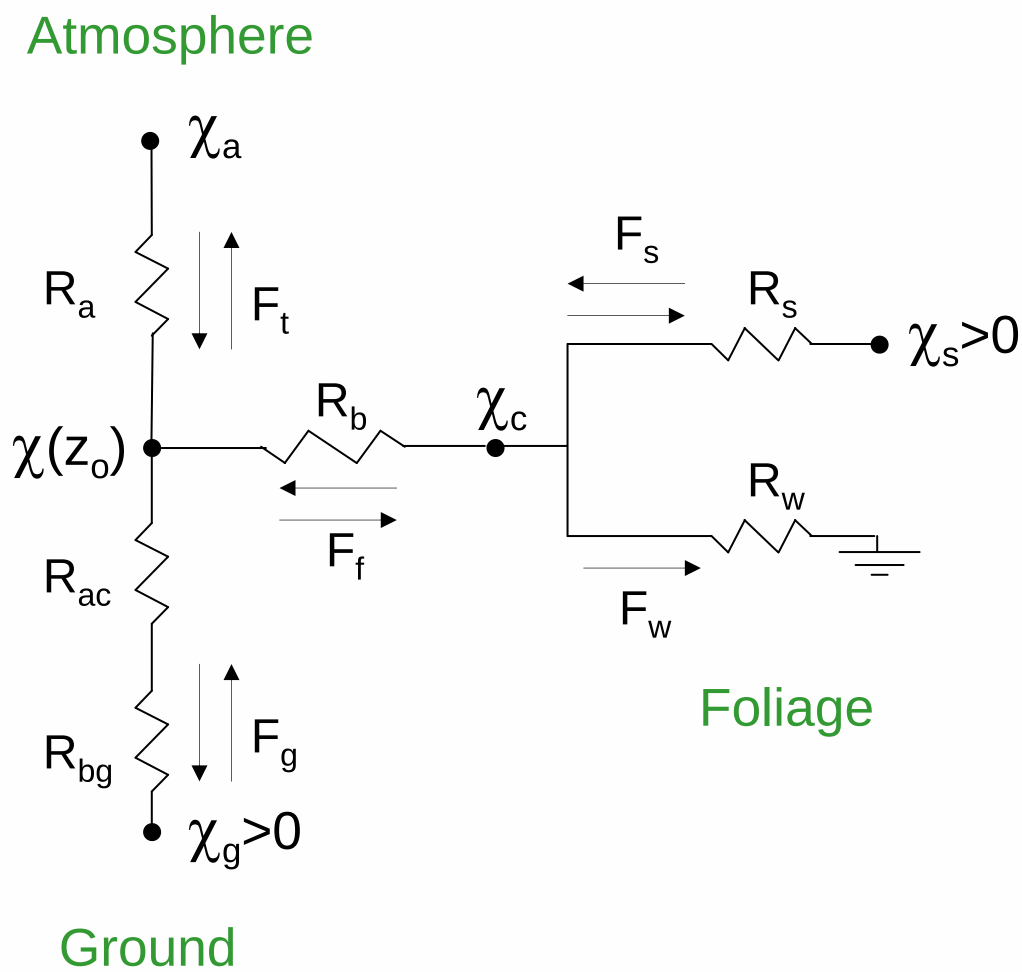
22 locations

3 samplers at each location

Sampling height = 1.5 m

Methods *NH_3 Air-Surface Exchange*

Two-layer canopy compensation point model
Nemitz et al., 2000



Methods *Model Parameterization*

- R_a, R_b, R_{ac}, R_{bg}, R_s calculated using standard approaches (Hicks et al., 1987; Wesely, 1989; Nemitz et al., 2000, Zhang et al., 2003)

- $R_w = f(NH_3, LAI)$ *based on Leith et al., 2004*

- $\chi_g = f(\Gamma_g, T_s)$ where $\Gamma_g = NH_4^+/H^+$ in soil solution

  Γ_g is measured (Nemitz et al., 2000, 2001)

- $\chi_s = f(\Gamma_s, T_A)$ where $\Gamma_s = NH_4^+/H^+$ in leaf apoplast

  $\Gamma_s = \Gamma_g$

- R_{ac}, R_{bg}, R_w, χ_g, χ_s are field specific

  crops sprayed with swine waste, other fertilized crops, forest

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Methods *Model Implementation*

• Based on weekly concentration measurements, a nonlinear regression model is used to predict NH_3 concentration vs. distance from the barn/lagoon complex.

• This produces a circular concentration surface with radius = 500 m extending outward from the barn/lagoon complex.

• For each weekly period, the average diurnal profile of meteorology is applied to the predicted concentration field to calculate an “average” diurnal flux profile at each grid point (5m).

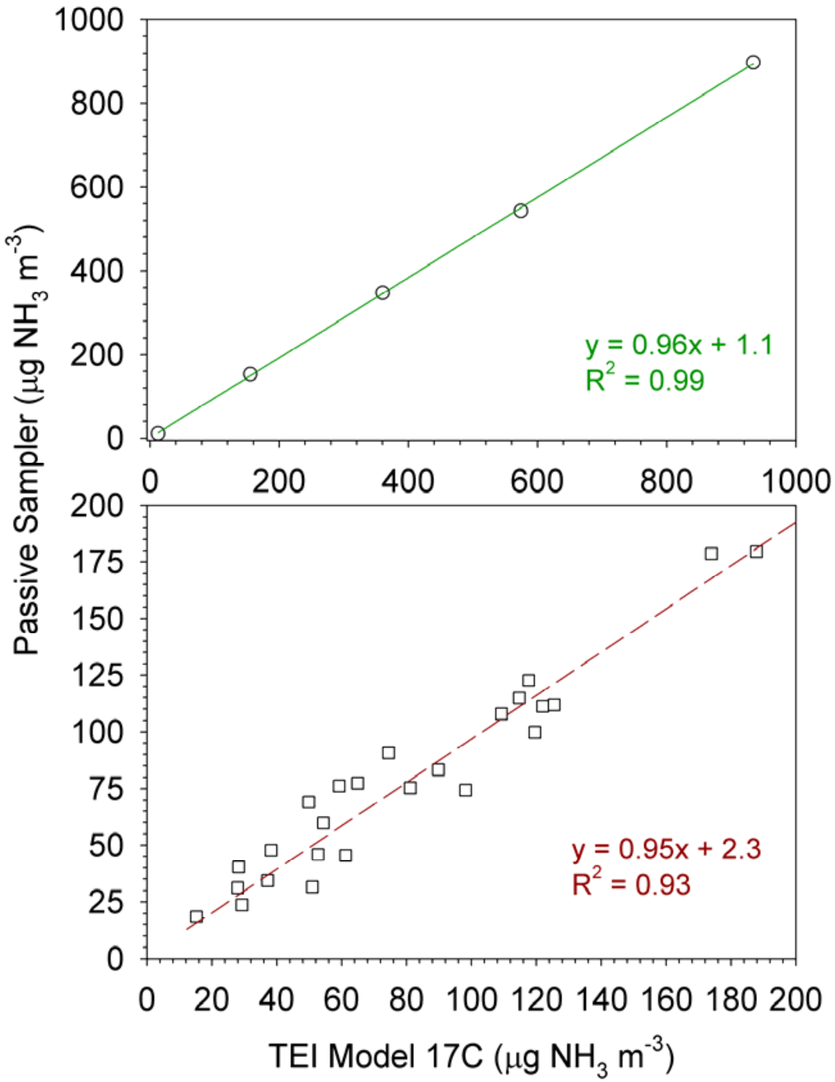
• The model domain is divided into quadrants centered on 45, 135, 225, and 315°. Within each quadrant, an area-weighted total flux is calculated from individual flux estimates for each surface type.

• Total (weighted) flux for the entire model domain is then calculated based on frequency of wind direction within each quadrant.

• Data covers the period June, 2003 – July, 2005
97 weekly periods are included in the deposition analysis.

Results *Passive Samplers*

Calibration



Laboratory

Exposure Chamber

Field

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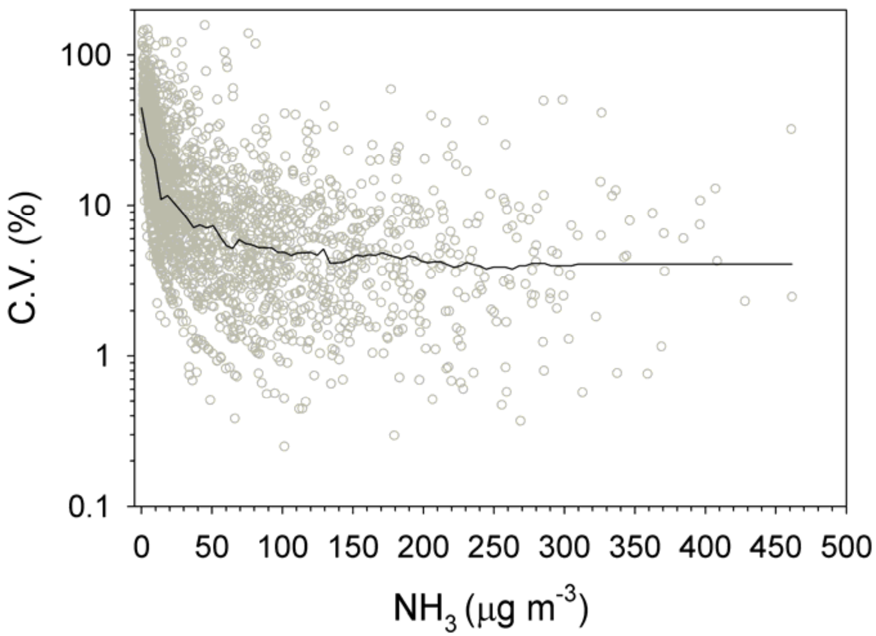
Results *Passive Samplers*

Blanks

Equivalent concentration of NH_3 in air (μg m^{-3})

	N	Mean	S.D.	Max.	Min.
Laboratory	97	1.8	1.8	16.3	0.8
Field	97	3.6	2.6	16.6	0.8

Precision



Median C.V. = 9.1%

C.V. = 25% @ 5.0 μg m^{-3}

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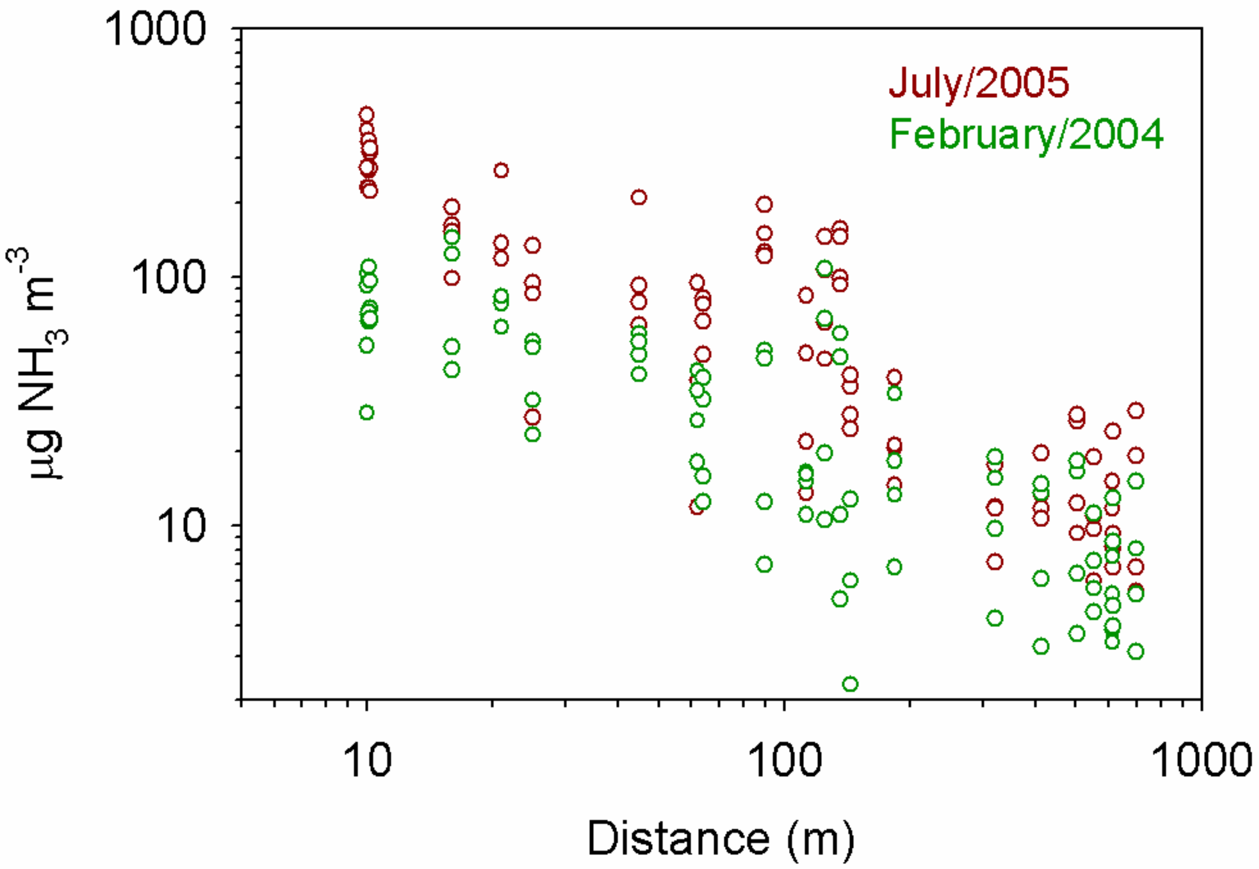
Results *Concentrations*

Gradients



- *Concentrations are lower during winter, though horizontal gradients show similar pattern*

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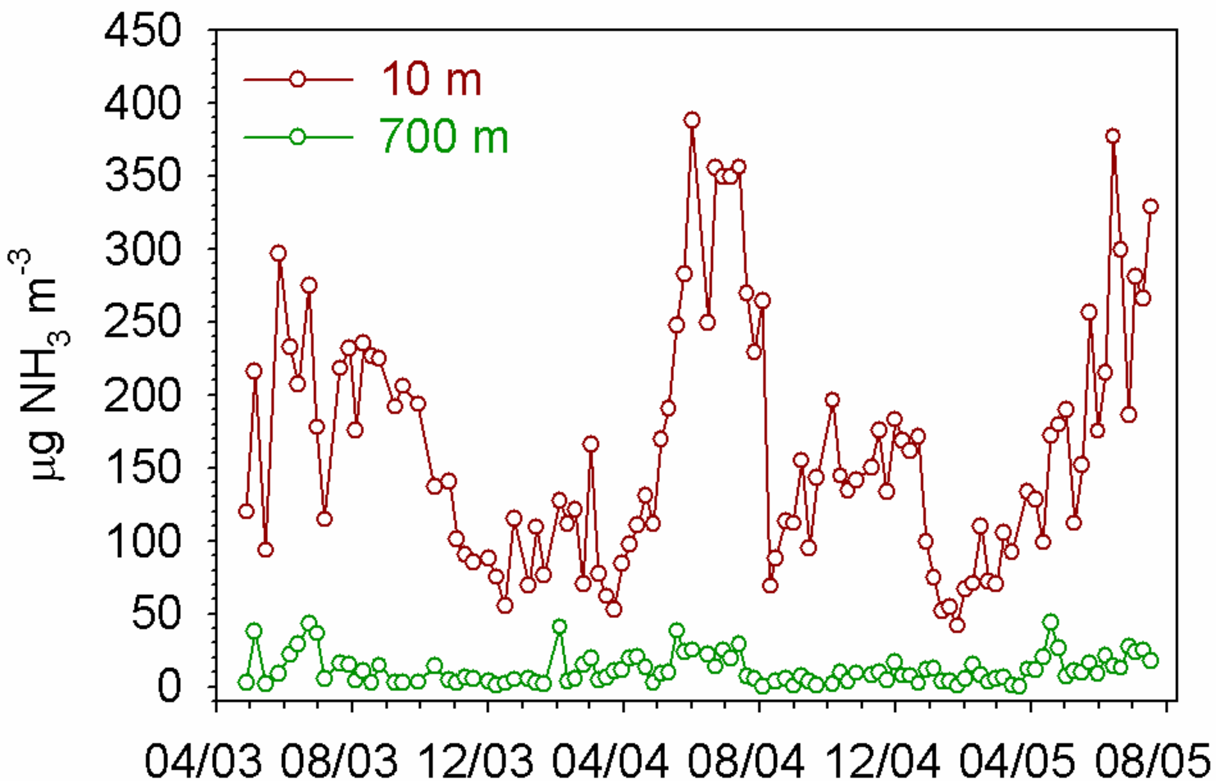
Results *Concentrations*

Seasonality



- *Concentrations show typical seasonality driven by the temperature dependence of emissions*

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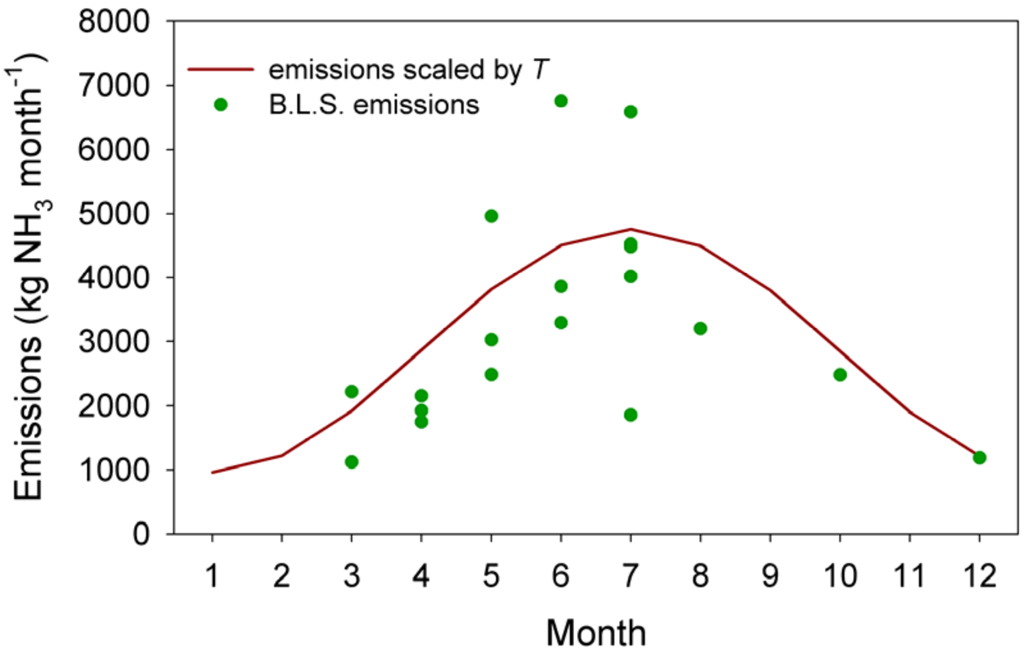
Results *Emissions*

Assuming a static emission factor of 7.0 kg NH_3 animal^{-1} yr^{-1}, annual emissions are approximately 34,300 kg NH_3

For comparison to weekly deposition estimates, emissions are temporally allocated based on temperature

Scaled emissions are compared to estimates derived from the *WindTrax* B.L.S. model



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Results *Gamma Values*

Soil Samples

	N	pH	NH_4^+ ($\mu g\ g^{-1}$)	M.W. ($g\ g^{-1}$)	Γ_g
Forest	34	4.98	0.74	0.20	20
Crop	40	5.72	9.04	0.18	1514
Spray Crop	32	6.05	26.15	0.18	8935

$$\chi_g = \frac{161500}{T_g} \exp\left(-\frac{10380}{T_g}\right) \Gamma_g$$

Nemitz et al., 2000

$$\Gamma_s = \Gamma_g$$

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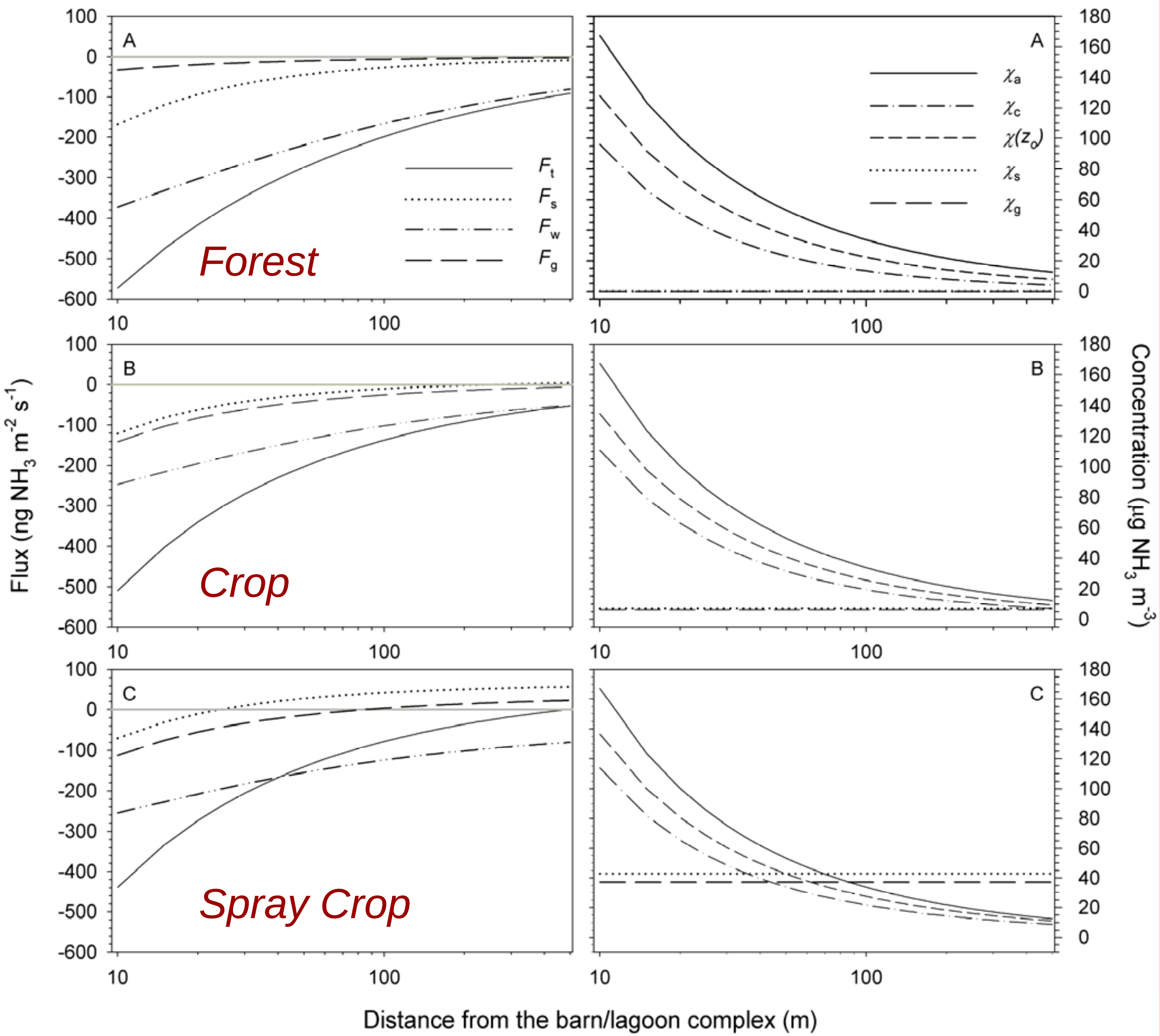
Results *Deposition*

Vegetation Type



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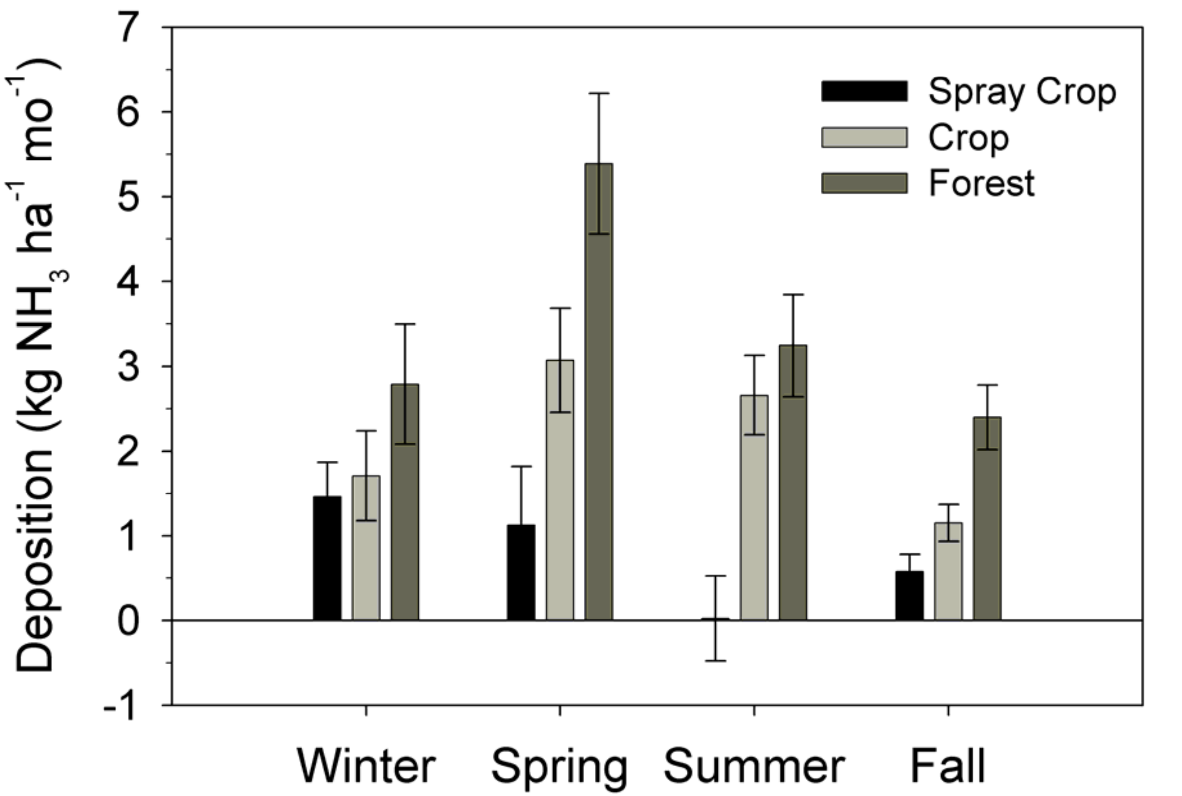
Results *Deposition*

Vegetation Type



- *Seasonality of fluxes over crops sprayed with swine waste reflects the temperature dependence of soil and stomatal compensation points.*
- *Seasonality of deposition rates for forest and non-spray crops reflects higher ambient concentrations during spring and summer.*

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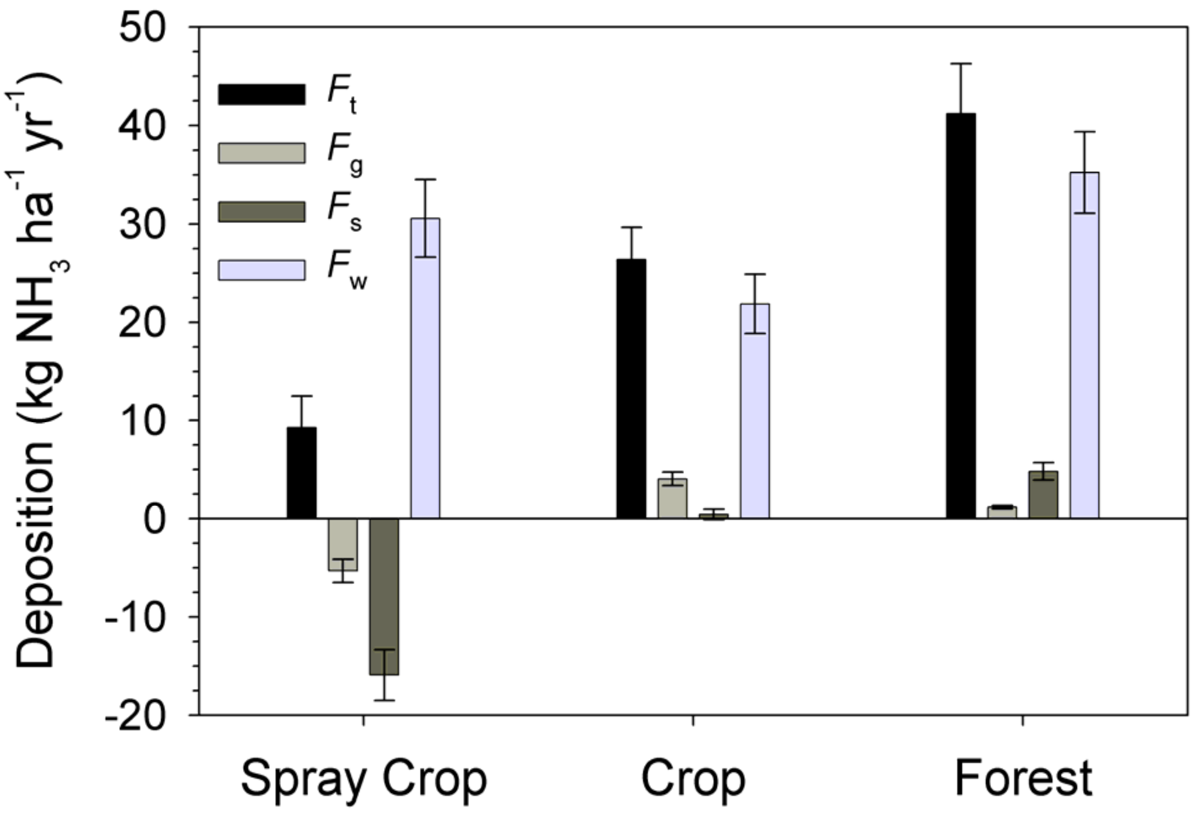
Results *Deposition*

Component Fluxes



- *For crops, deposition to the leaf cuticle is offset by stomatal and soil emissions*

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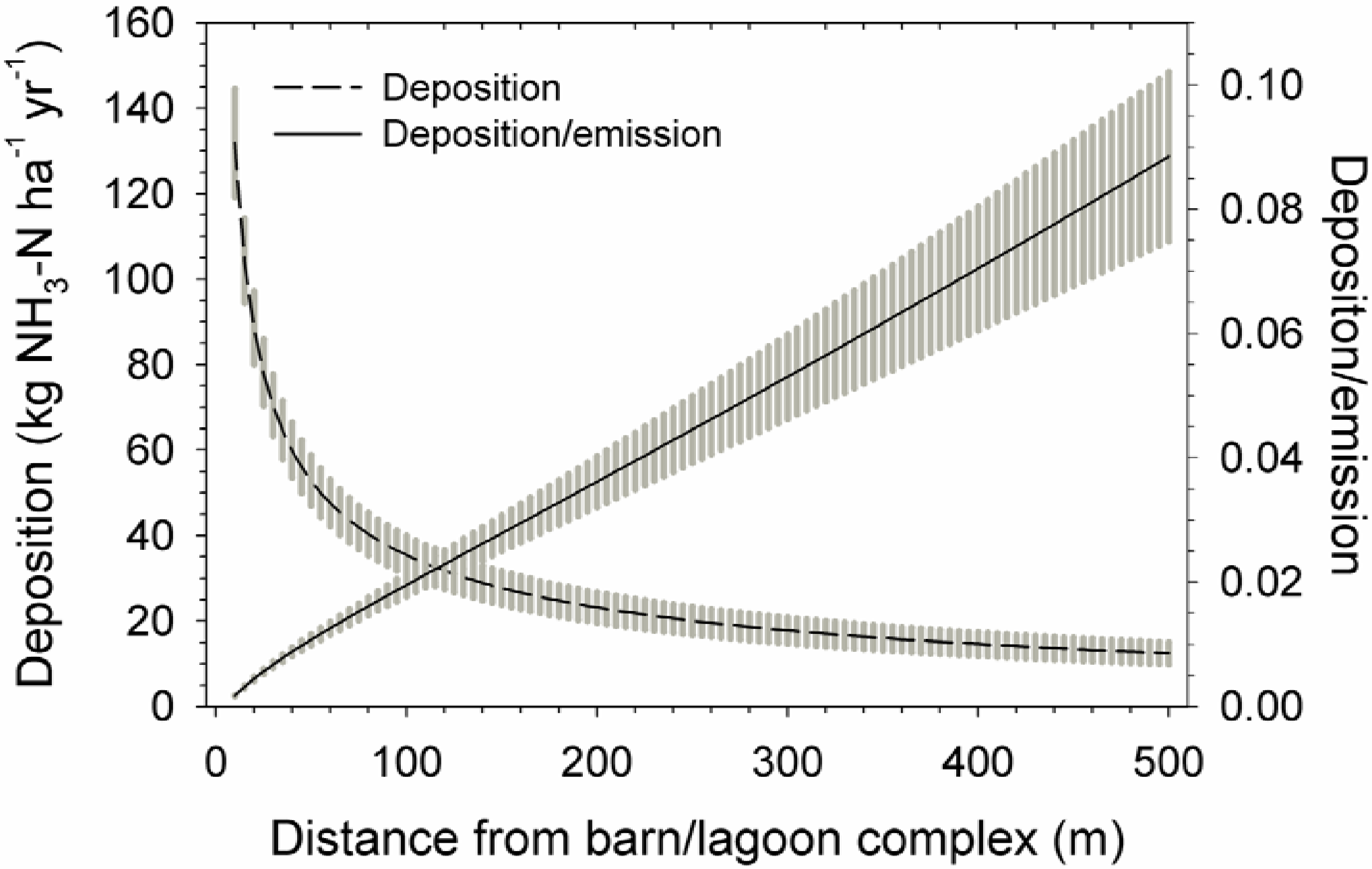
Results *Deposition*

Summary



- *Dry deposition at 500m ≈ 2.5X wet deposition of NH_4^+-N*
- *7 – 10% of emissions deposited within 500m*

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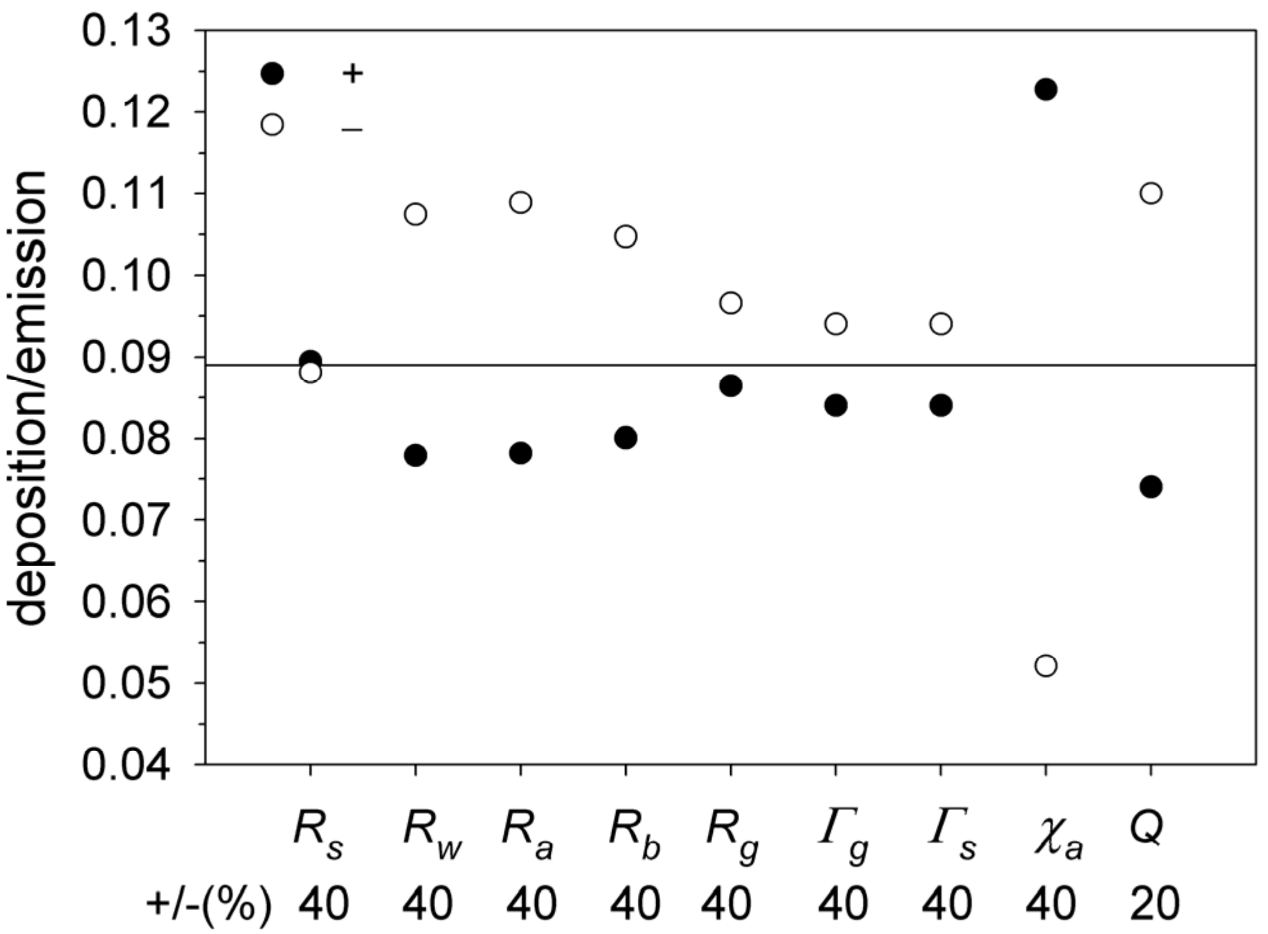
Results *Model Sensitivity Analysis*



Results

Previous Studies

Study	% deposited within 300m
Asman and van Jaarsveld, 1992	10.0
Asman, 1998	5.0 – 50.0
Fowler et al., 1998	3.0 – 10.0
Sutton et al., 1998	2.0 – 17.0
This study	4.5 – 6.0

• *Estimates derived from multiple approaches suggest that < 20% of emissions are deposited within 500m of the source.*

Results *Uncertainties*

- Spray residue not taken into account in R_w
- Near-source leaf surface chemistry important but not measured
- Role of leaf surface water not taken into account
- Estimates presented in this study may represent an upper limit?

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Conclusions

- The majority of NH_3 emitted from animal production facilities is available for $PM_{2.5}$ formation and deposition to downwind ecosystems
- Accurate modeling of near-source deposition requires characterization of leaf surface chemistry
- Representative R_w parameterizations are needed for U.S. modeling efforts

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