An Improved Processed Based Ammonia Emission Model for Agricultural Sources - Model Development

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Project Sponsor

- **Lake Michigan Air Directors Consortium (LADCo)**
  - Mark Janssen
  - Mike Koerber

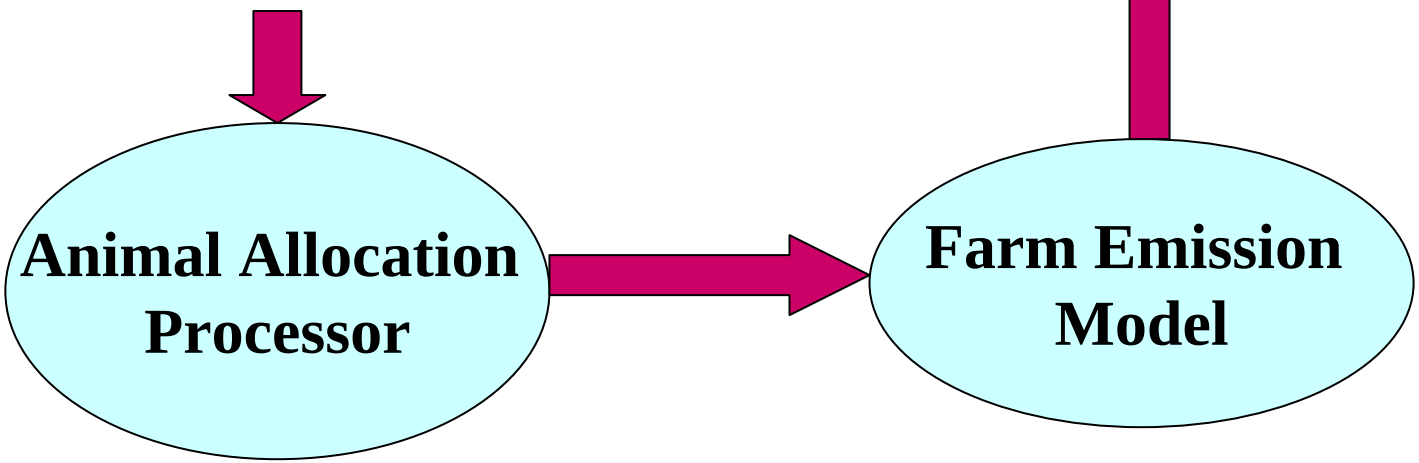
Research Objectives

- **Develop an improved processed-based, predictive model for estimating ammonia emission rates from agricultural sources, including animal feeding operations (AFOs) and fertilizer application.**

- **Estimate the ammonia emission rates from agricultural sources and compare them with the existing ammonia emission inventories.**

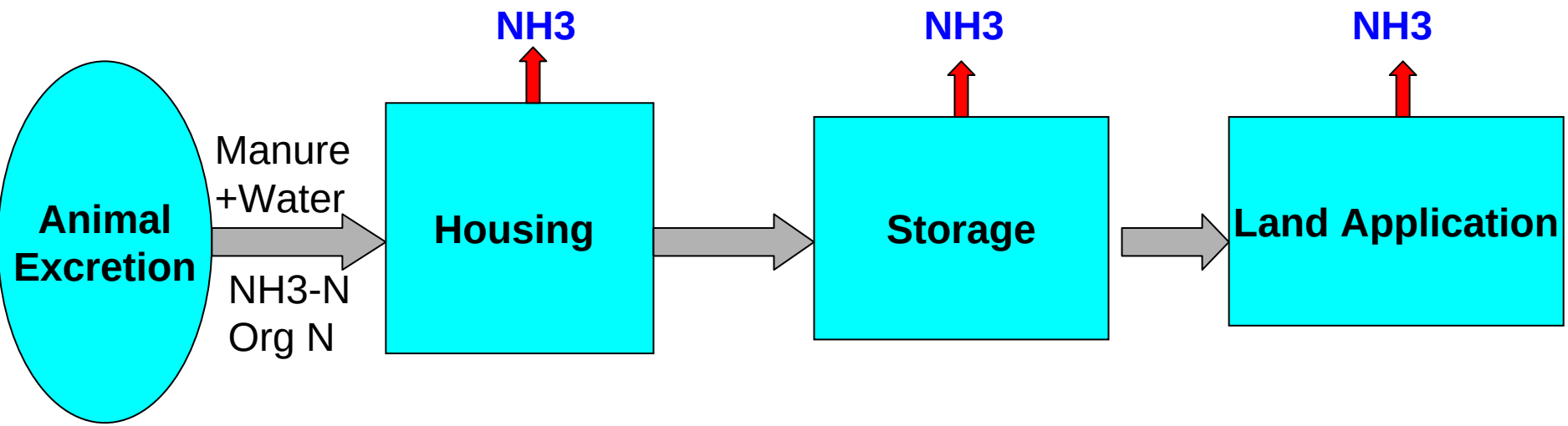
Ammonia Emission Model

Animal population
Animal feed composition
Manure management practices
Crop systems
Fertilizer application practices



Ammonia Emission Rate for different time resolution and geographical scales

Farm Emission Model for Animal Feeding Operations



Dairy
Beef cattle
Swine
Layers
Broilers
Turkeys

Confinement (Mechanically ventilated or Naturally ventilated)
Open Feedlot

Under-floor pit
Outside storage (liquid, solid)

Surface Application

Process-based Modeling Approach

- Considered and analyzed all physical, chemical and biochemical processes and reactions that take place and influence ammonia emission rate,
- Employed processed based mechanistic and empirical models (new and existing),
- Kept mass balances for the flow of manure, water and nitrogen through each component of an animal waste management system.

Farm Emission Model (FEM)

- Animal Excretion Sub-model
- Animal Housing Sub-model
- Manure Storage Sub-Model
- Manure Land Application Sub-Model

Animal Excretion Sub-model

- **Calculates manure, urine, and nitrogen excretion from animals as function of**
  - Animal species
  - Growth stage
  - Feed rations
    - Feed intake
    - Dry matter content
    - Crude protein content
    - Digestibility

Input Variables for Animal Excretion Sub-model (example – finished pigs)

- **Animals**
  - Initial body weight
  - final body weight
  - Days on feed to finish pig
  - Fat free lean gain at final weight
  - Average daily feed intake over finishing period
- **Feed Ration**
  - Feed intake per finished pig
  - Concentration of crude protein in total wet ration
  - dry matter concentration
  - dry matter digestibility of total ration

Animal Housing Emission Sub-model

- **Calculates ammonia emission rate from housing as a function of**
  - ventilation rate
  - ammonia generation rate due to urea hydrolysis
  - Ammonia transfer rate from the manure into the air

Input Variables for Animal Housing Sub-model

- **Animals**
  - Number and body weight
- **Building structures**
  - Dimensions
  - Air inlet and outlet designs
  - Building material properties (heat transfer coefficient)
- **Indoor air temperature control requirement**
- **Outdoor environmental conditions**
  - Wind speed, Temperature, Relative humidity
  - Solar incidence

Outside Storage Sub-model

- **Calculates ammonia emission rate as a function of**
  - Organic nitrogen mineralization rate
  - Ammonia transfer rate from manure into the air
- **Considers the rain fall and evaporation**

Input Parameters for Outside Storage Sub-model

- **Manure properties**
  - pH, ammonia concentration, mineralization rate (first order reaction)
- **Storage structures**
  - Configurations and dimensions
  - Treatment lagoon vs. storage pond
  - Storage period
- **Environmental Conditions**
  - Ambient temperature
  - Air velocity
  - Precipitation and evaporation

Land Application Sub-model

- **Calculates ammonia emission rate as a function of**
  - Organic nitrogen mineralization rate
  - Ammonia transfer rate from manure into the air
- **Considers the soil infiltration rate, rain fall, and evaporation**

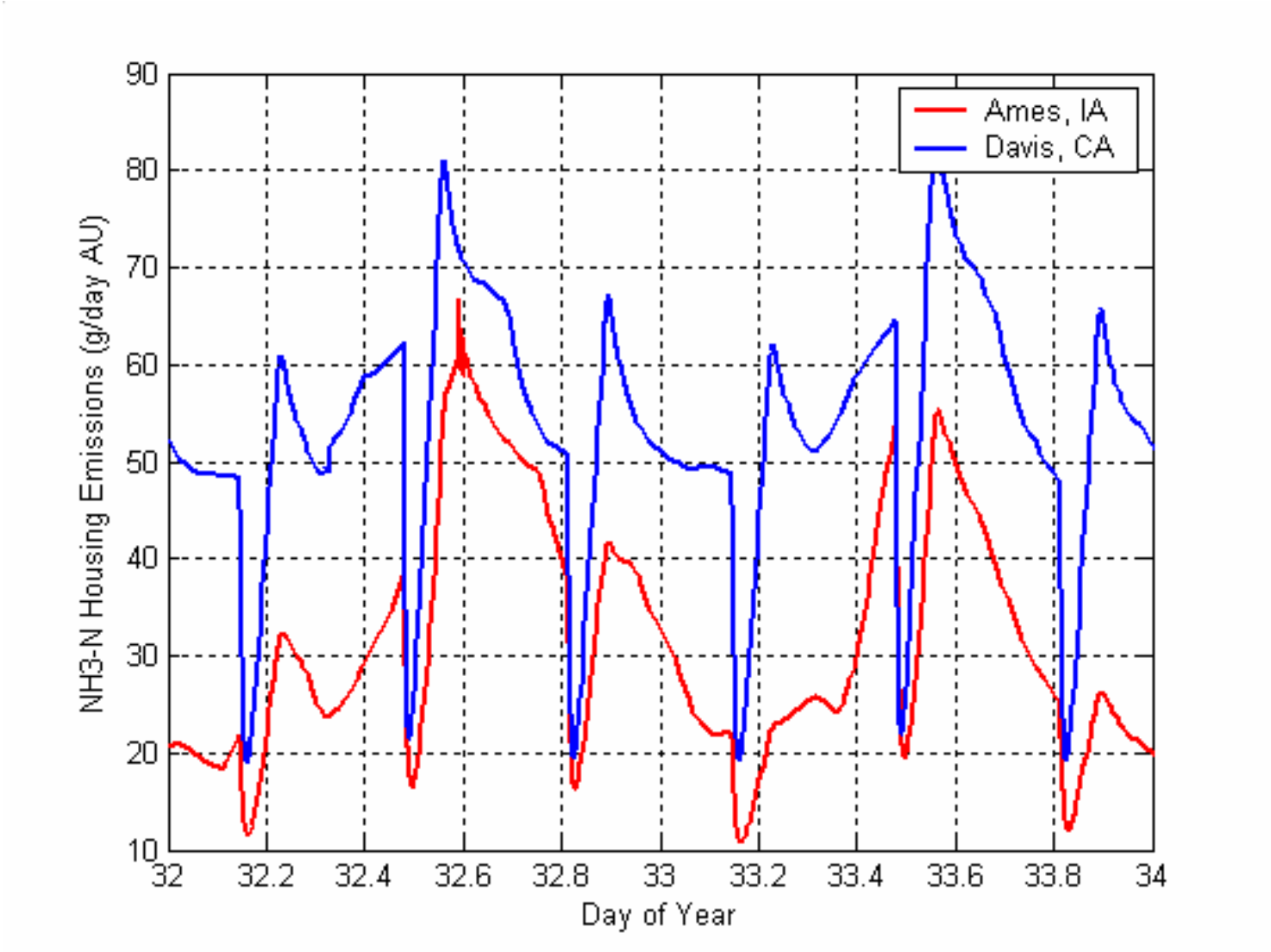
Input Variables for Land Application Sub-model

- **Manure properties**
  - pH, ammonia concentration, mineralization rate (first order reaction)
- **Land and crop specifications**
  - Crop type and N uptake rate
  - Dimensions
  - Manure application rate and time
  - Soil type and infiltration rate
- **Environmental Conditions**
  - Soil temperature
  - Ambient temperature
  - Air velocity
  - Precipitation and evaporation

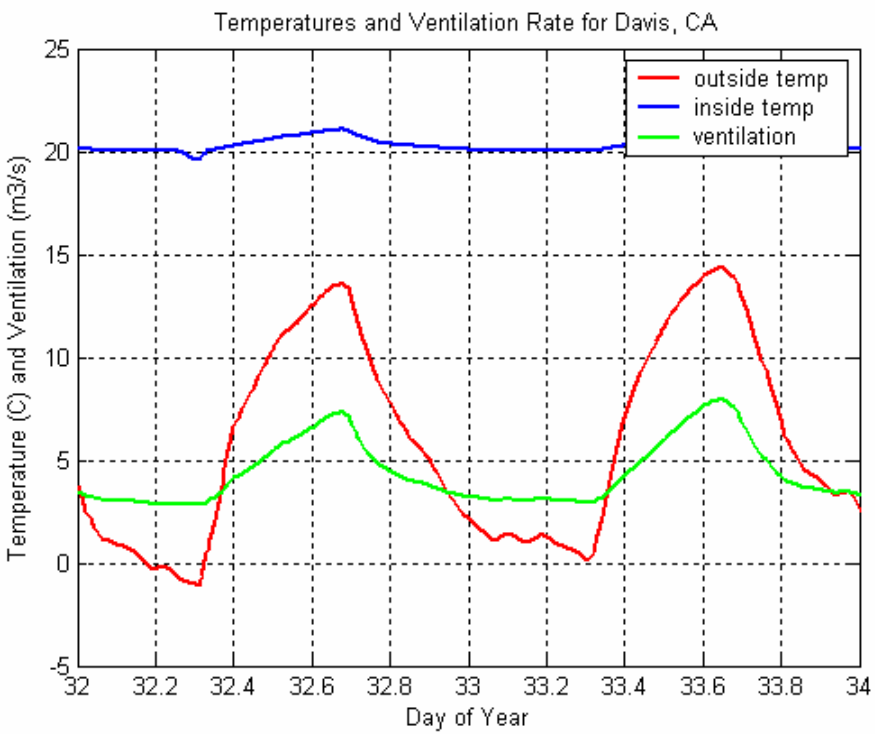
Swine Farm Emission Model - Example Simulation Results

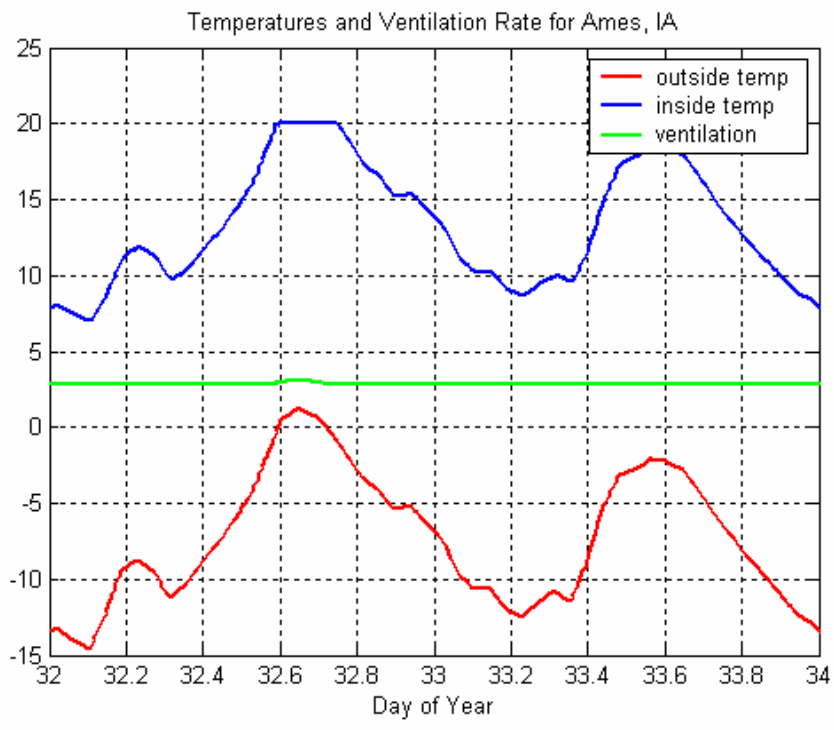
- **Swine finishing farm – 1000 head in two houses**
- **Mechanical ventilated housing**
- **Manure removal by flushing**
  - every 8 hours
- **Outside lagoon manure storage**
- **Twice a year manure removal from lagoon storage (180 day storage period)**
- **Locations**
  - Davis, California, Ames, Iowa

Ammonia Emission Rate from Swine Housing (two days in February)

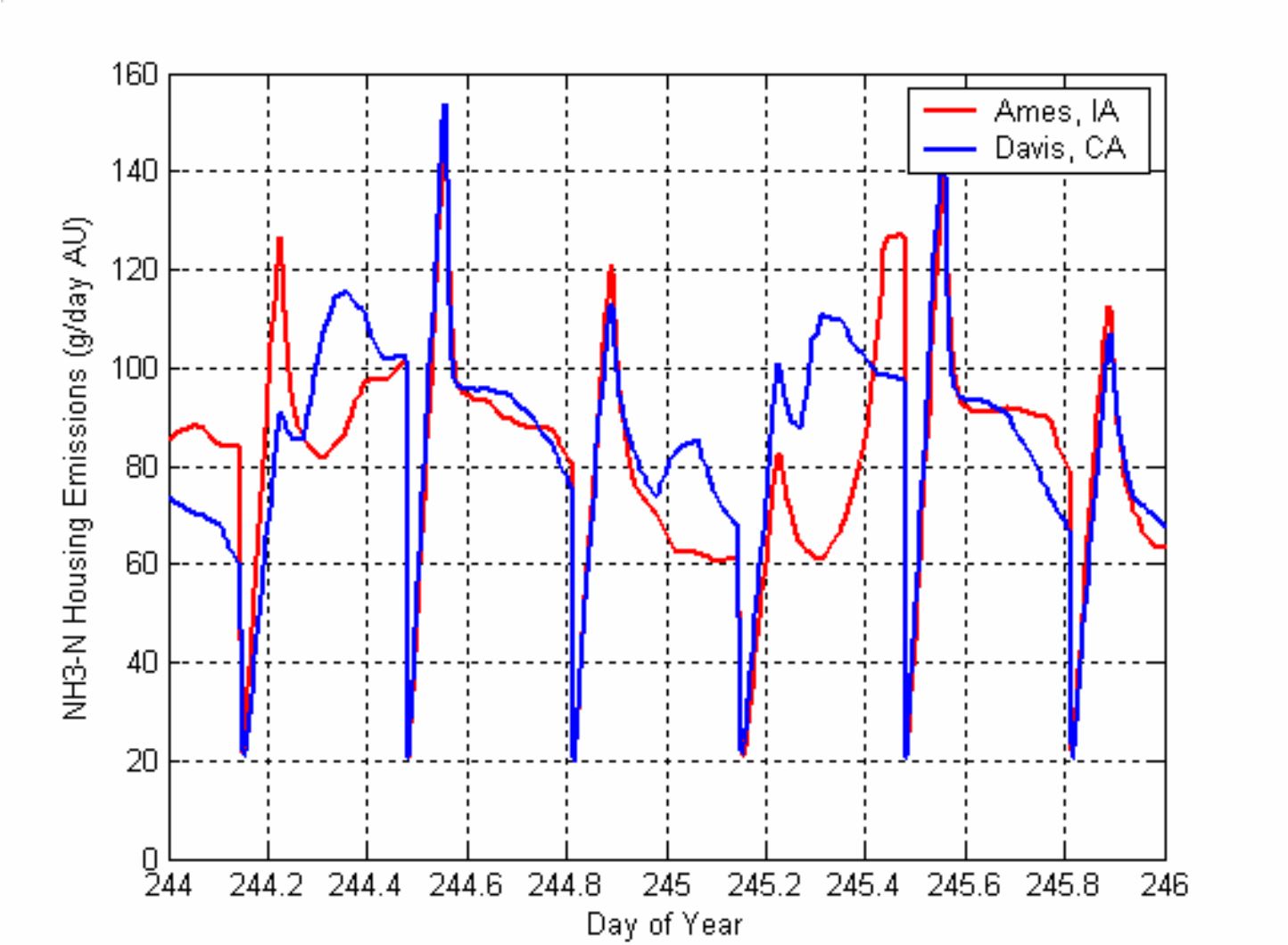


Temperature and Ventilation Rate in Swine Housing (two days in February)

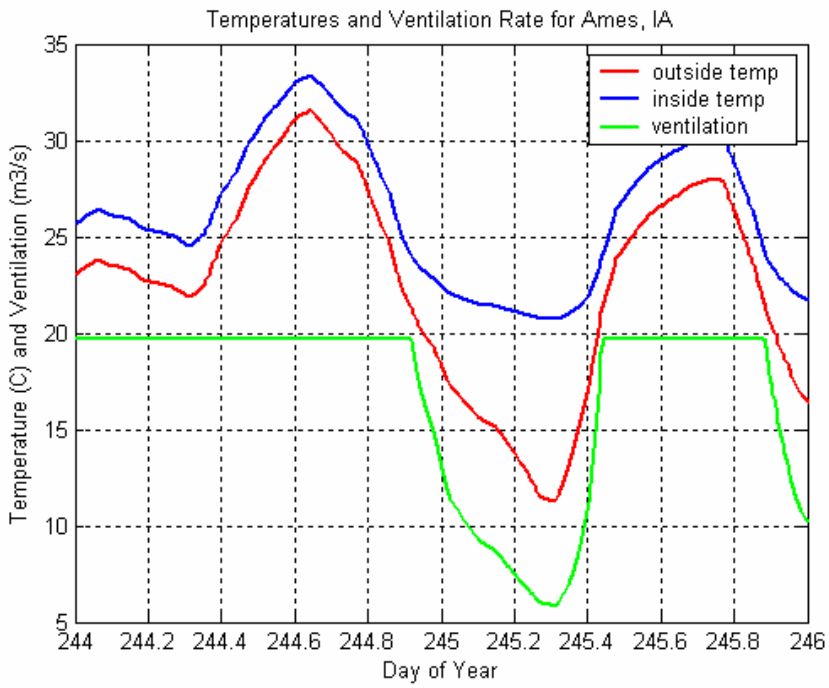


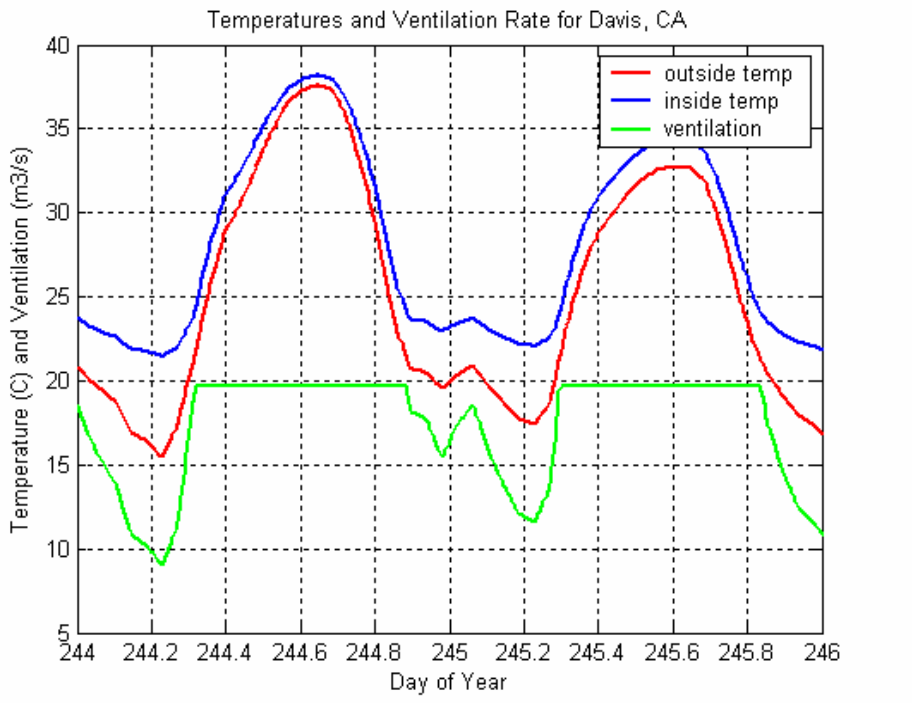


Ammonia Emission Rate from Swine Housing (two days in August)

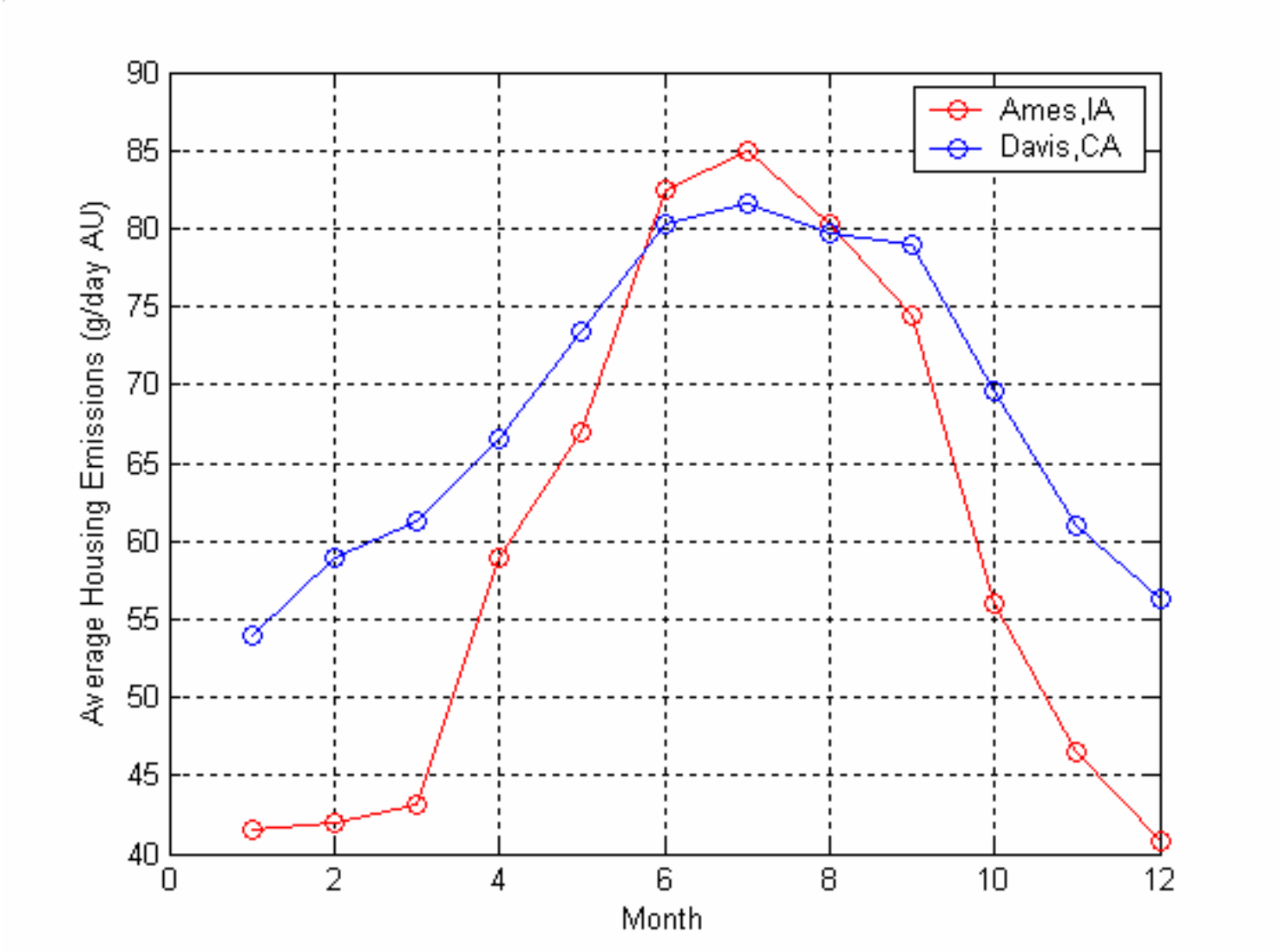


Temperature and Ventilation Rate in Swine Housing (two days in August)

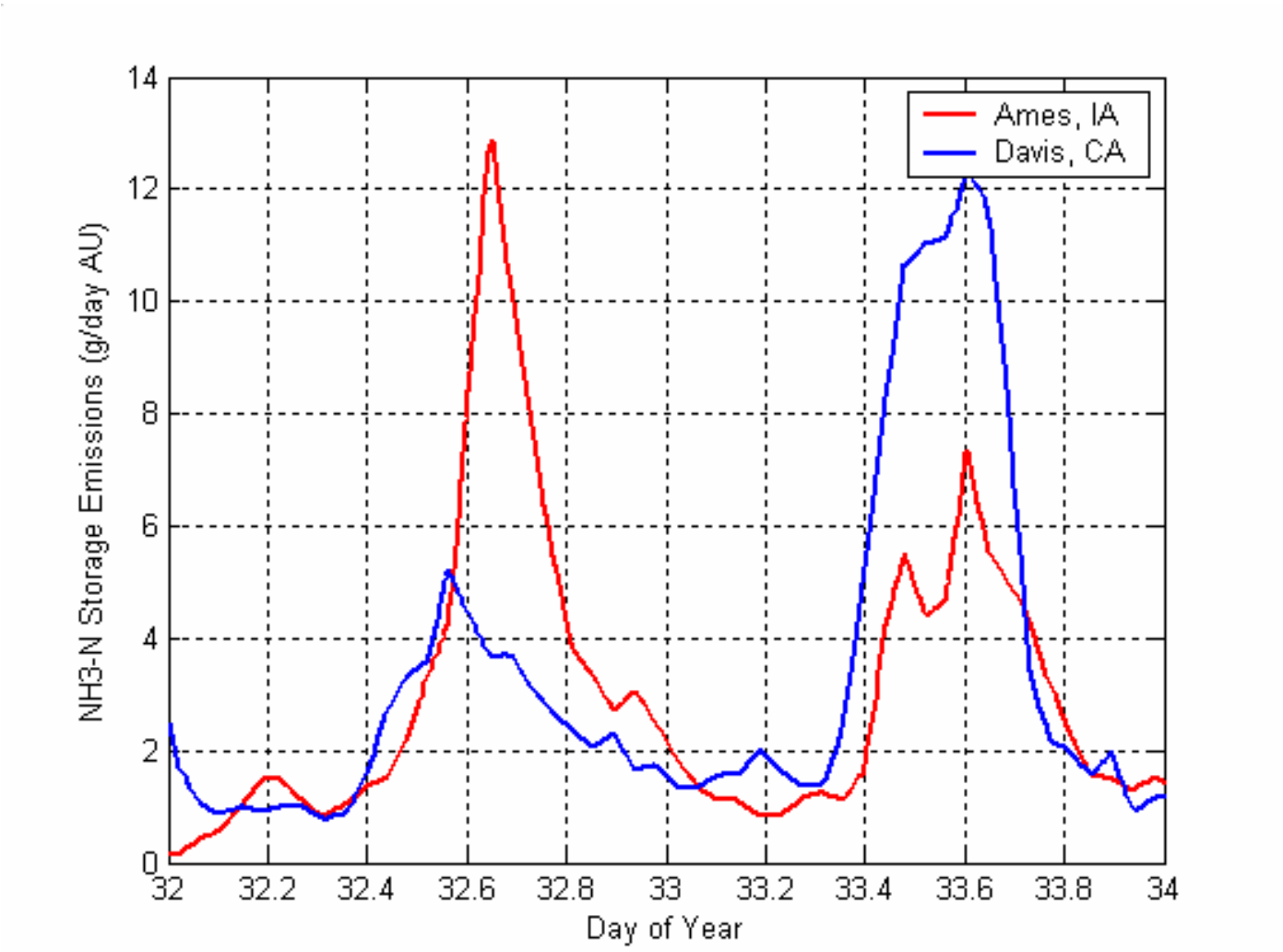




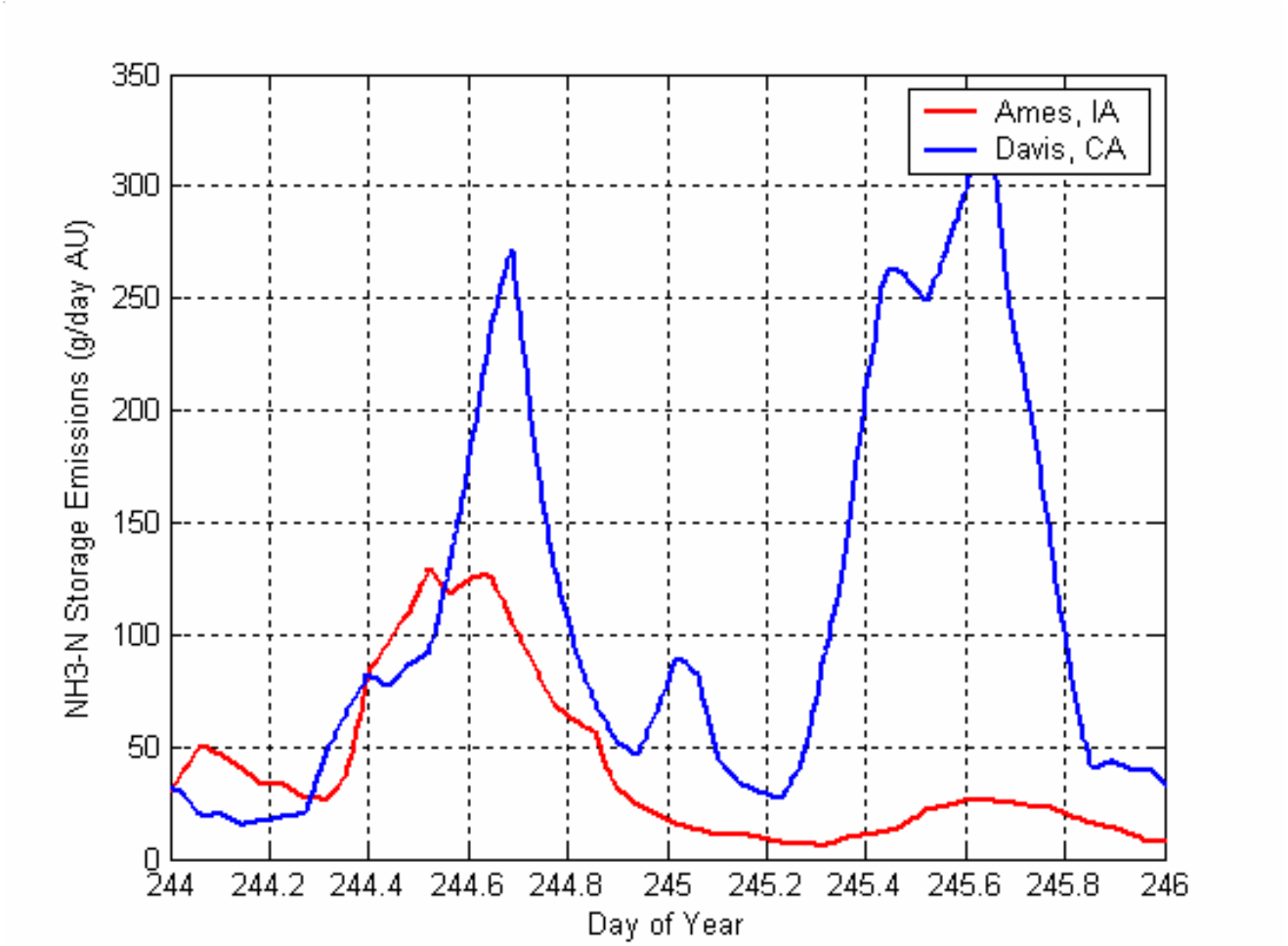
Ammonia Emission Rate from Swine Housing (monthly average)



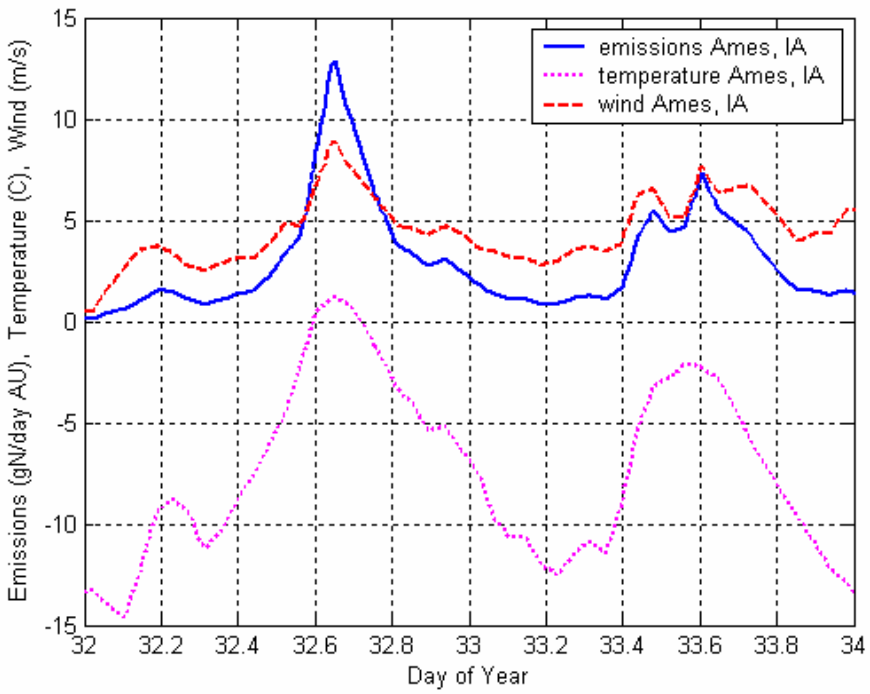
Ammonia Emission Rate from Manure Storage (for two days in February)

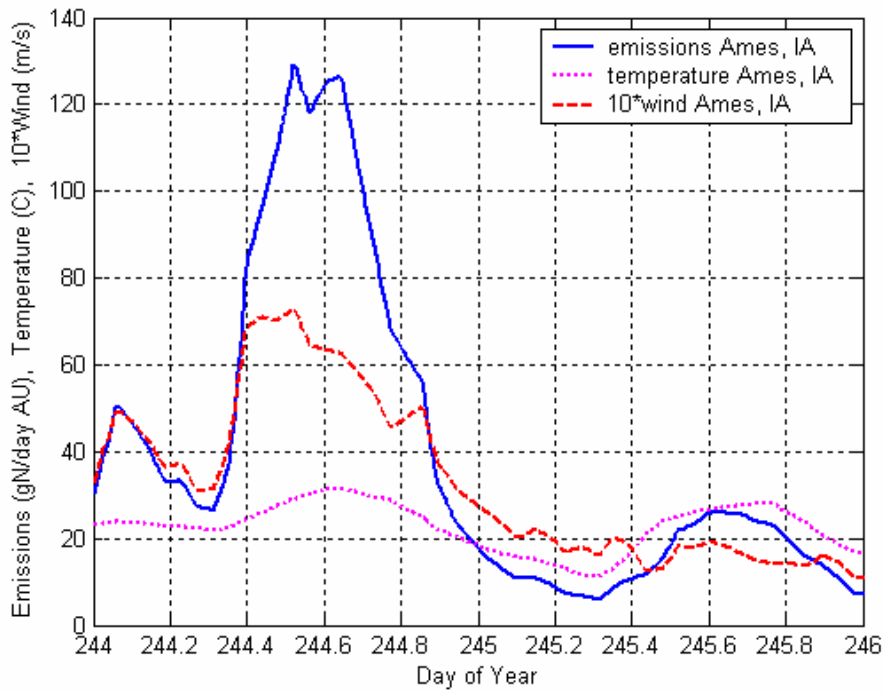


Ammonia Emission Rate from Manure Storage (two days in August)

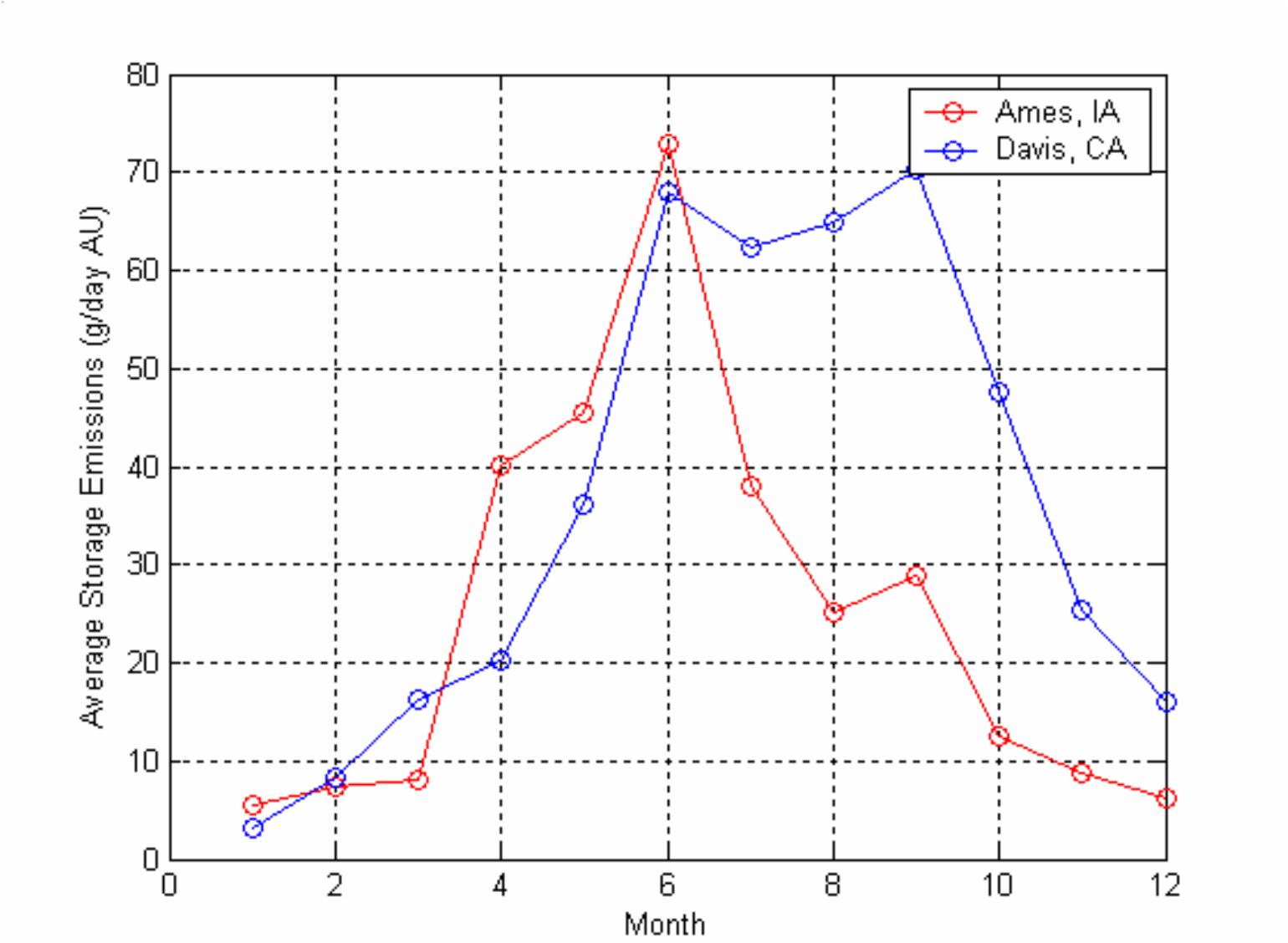


Ammonia Emission Rate vs. Temperature and Wind Speed for Manure Storage (Ames, IA)

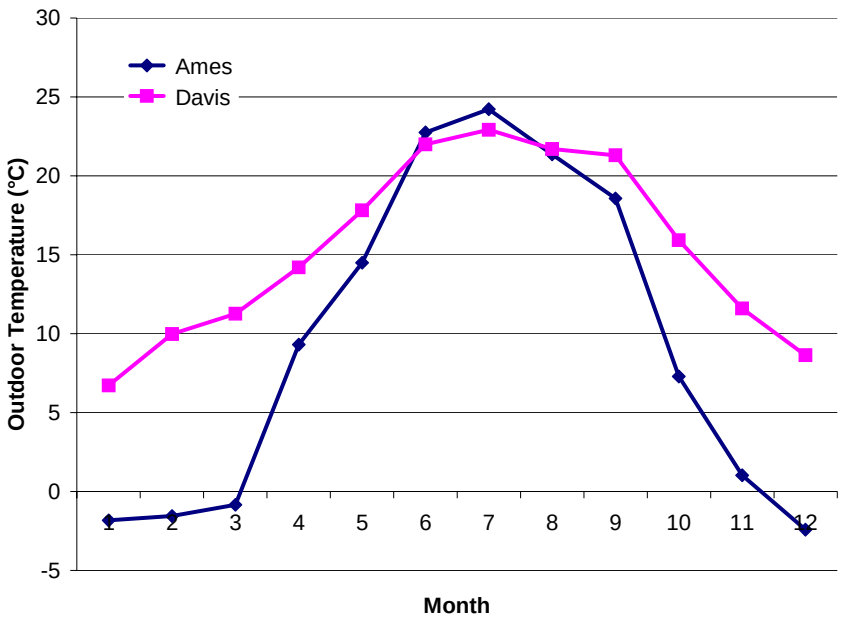




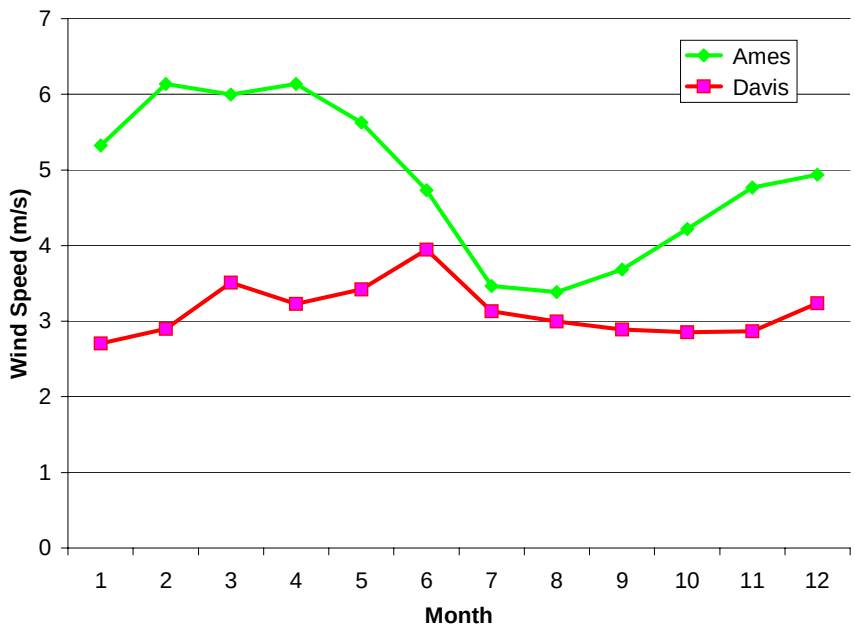
Ammonia Emission Rate from Manure Storage (monthly average)



Outdoor Temperature and Wind Speed (monthly average)



Temperature



Wind Speed

Conclusions

- A framework for a comprehensive, process-based ammonia emission model has been developed for four animal species (swine, dairy, beef cattle and poultry).
- The Farm Emission Model (FEM) is capable of calculating ammonia emission rate from a single farm with known animal diet composition, manure handling and storage and land application practices.

Conclusions

- Simulation results of FEM showed that ammonia emission rate from a given farm is highly variable during the day and different time of year due to changes in climatic conditions and will vary with changes in animal feeding and manure management practices on the farm.
- Only part of the FEM has been validated with the emission data available in the literature and more work needs to be done to calibrate and validate the FEM.

Conclusions

- **The FEM involves over 60 variables and the sensitivities of predicted ammonia emission rate in response to the changes of these variables still need to be determined.**