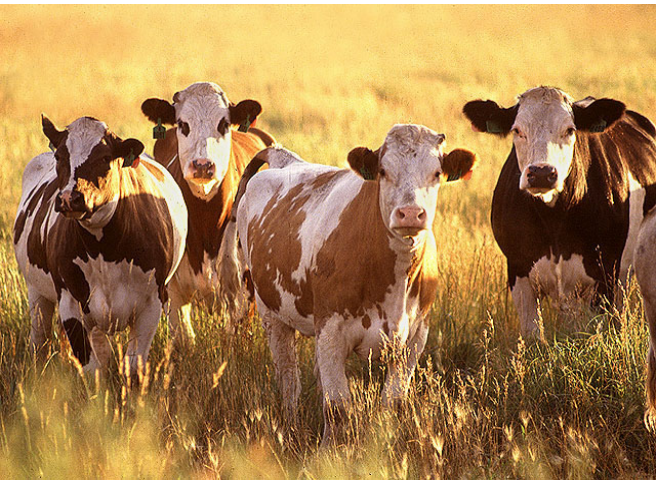

Modeling livestock ammonia emissions in the United States:

From farms to emissions to particulate matter

2015 Emissions Inventory Conference

April 15, 2015

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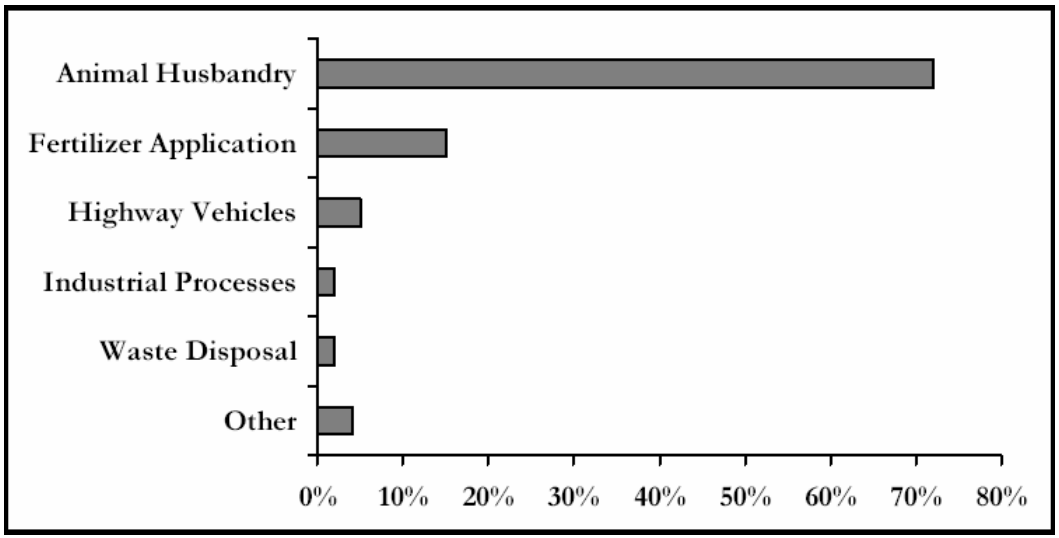
Civil and Environmental ENGINEERING

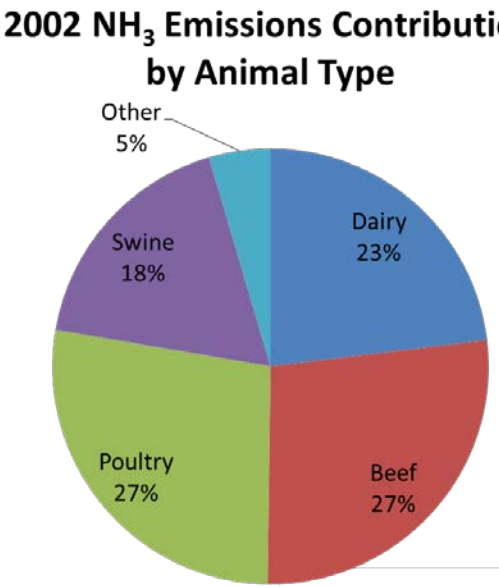
Presentation Outline

- Background and motivation
- Process-based farm emissions models (FEMs)
- Model performance evaluation:
  - Literature evaluation
  - Using the National Air Emissions Monitoring Study (NAEMS) to quantify model ability to capture seasonal and daily variability
- Next steps: Understanding regional differences and building an inventory

Sources of Ammonia Emissions in the US

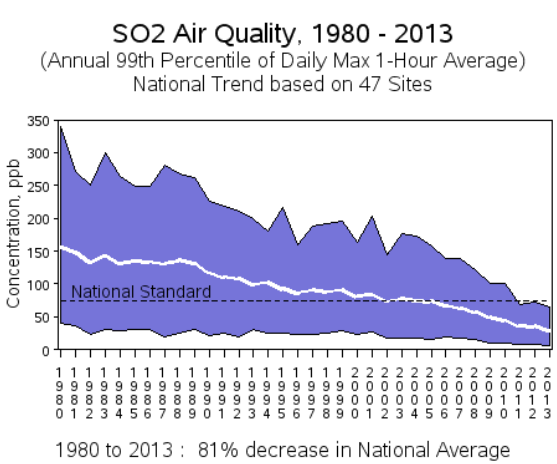


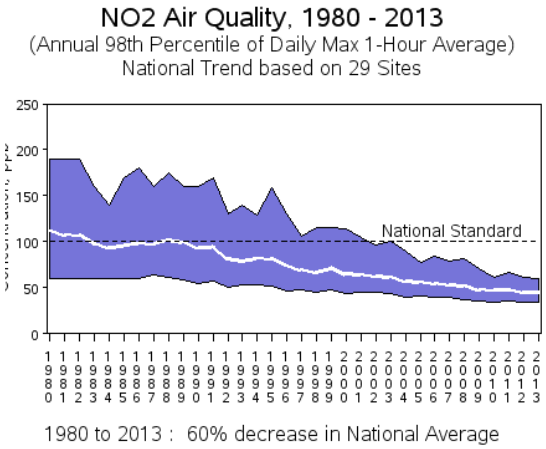
http://www.epa.gov/apti/course419b/studentmanual/sm_chapter_1.pdf

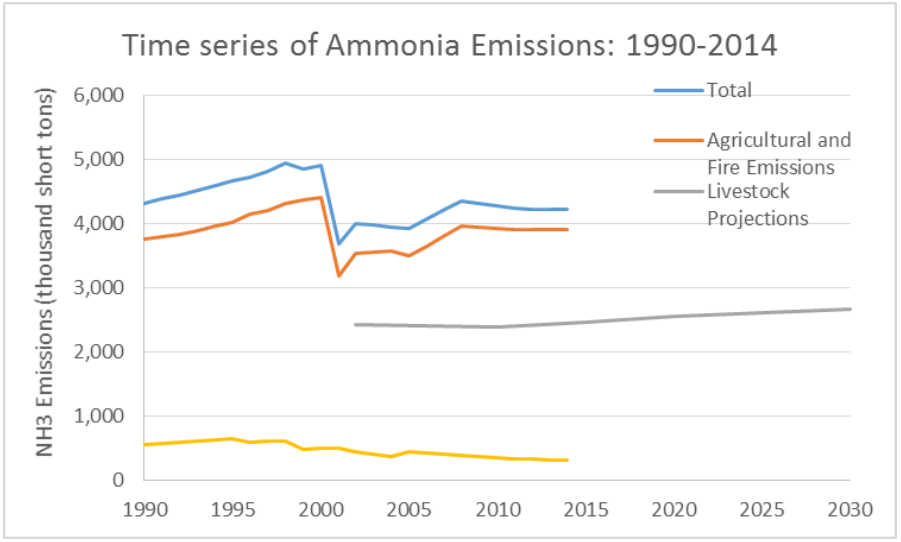


- Ammonia emissions in the US are primarily from animal agriculture
- Dairy and beef cattle, swine, and poultry make up 95% of livestock emissions
- Previous work (Pinder et al.) focused on dairy cow emissions; this work expands our approach to beef, swine, and poultry

Ammonia and Particulate Matter Formation



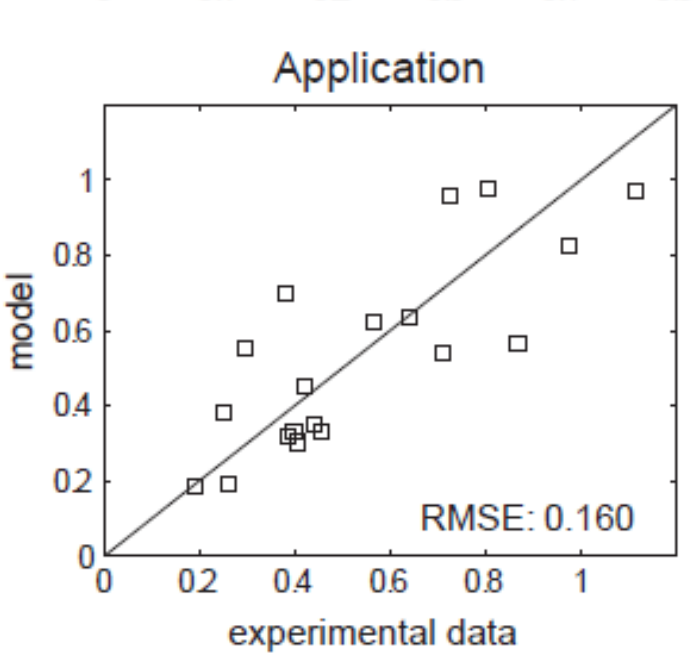




- Reductions in SO_2 and NO_x have led to reductions in PM levels
- These reductions have drawn attention to the role of ammonia in PM formation
- $(NH_4)_2SO_4$ is formed first, then ammonia goes to forming NH_4NO_3
- NO_x and SO_2 both must be controlled to reduce PM levels

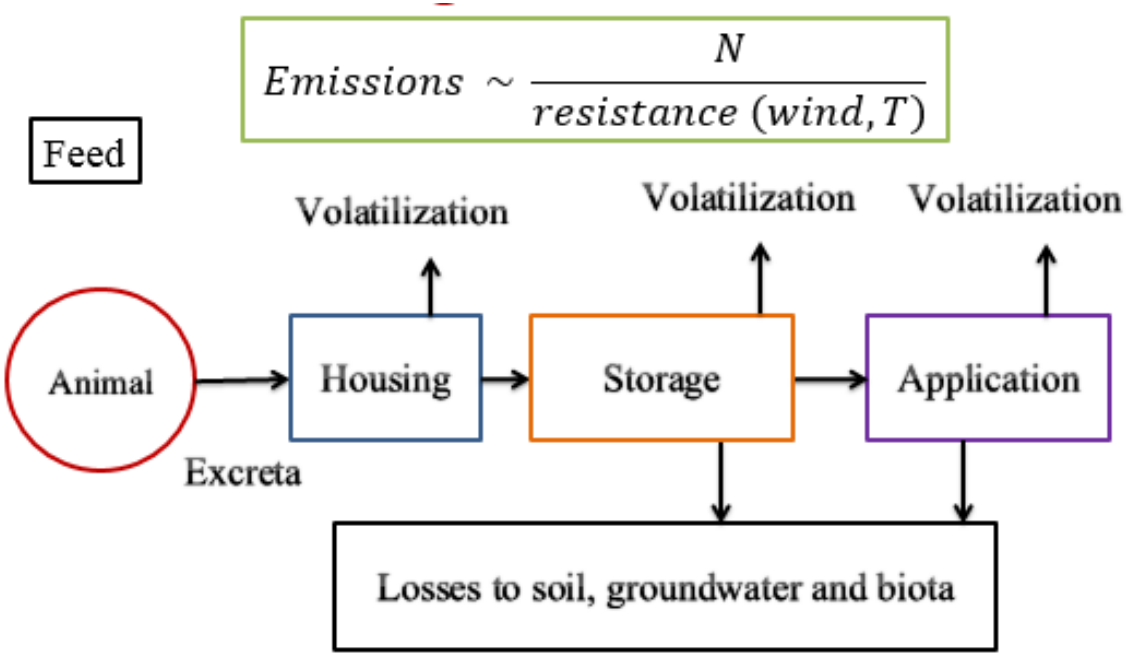
Variability in NH_3 emissions: Why models and measurements are important

- Emissions depend on a variety of factors including:
  - Meteorology
  - management practices
  - manure characteristics
- There are wide ranges of emission factors reported in the literature for swine, beef, and poultry ammonia emissions



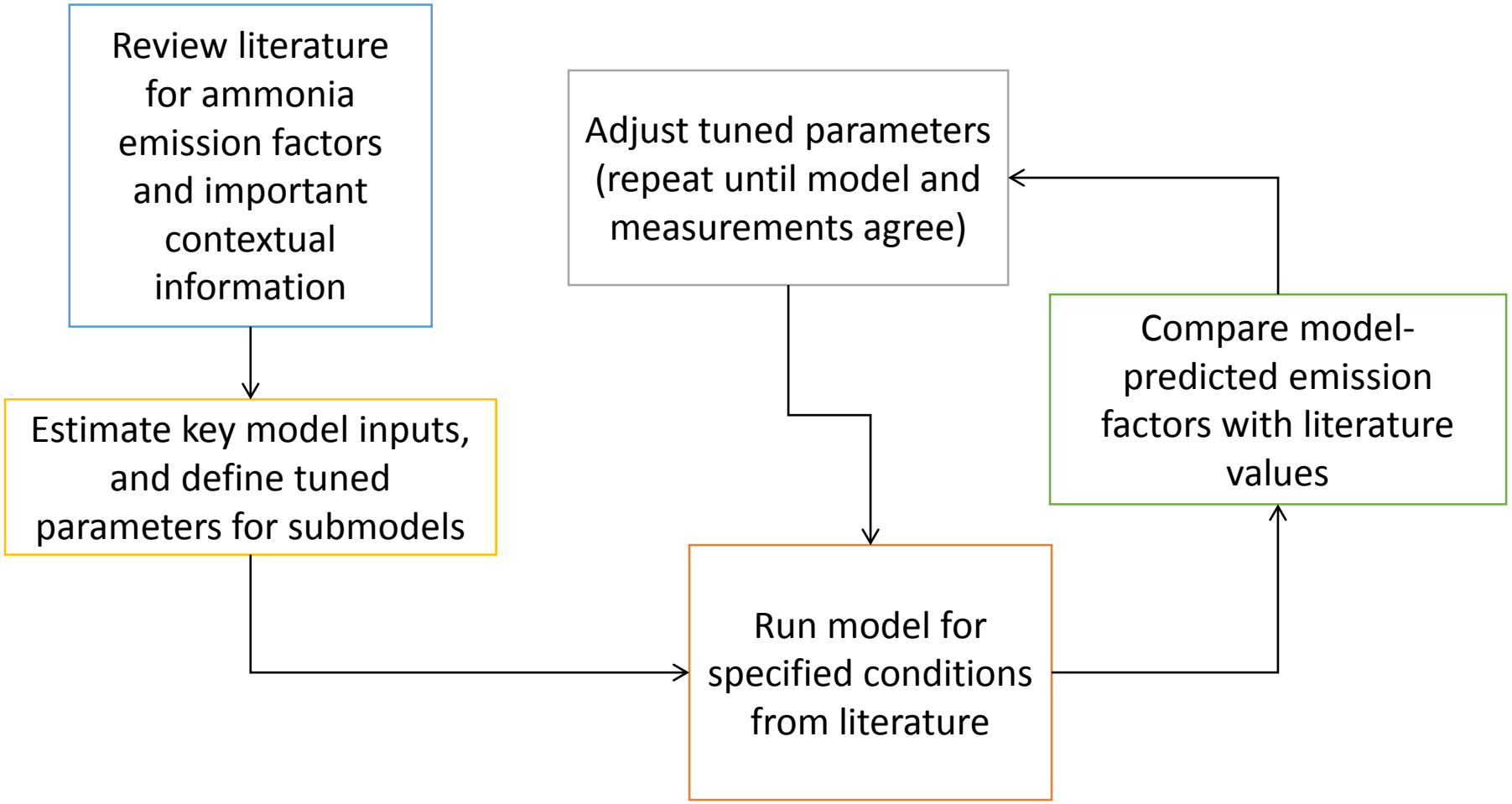
Scatter-plot of fraction of input nitrogen volatilized as ammonia, comparing application sub-model predictions and experimental data showing range of measured data (Pinder, et al., 2004)

The Farm Emission Model (FEM): A nitrogen mass balance



- Sub-models describe a part of the production system and are based on the mass balance of nitrogen
- Mass transfer resistance, r, depends on wind speed, temperature and infiltration rate
- r is tuned to match emissions measurements

Methods: Developing the FEMs



Constraining the Model: Literature Observations versus the National Air Emissions Monitoring Study (NAEMS)

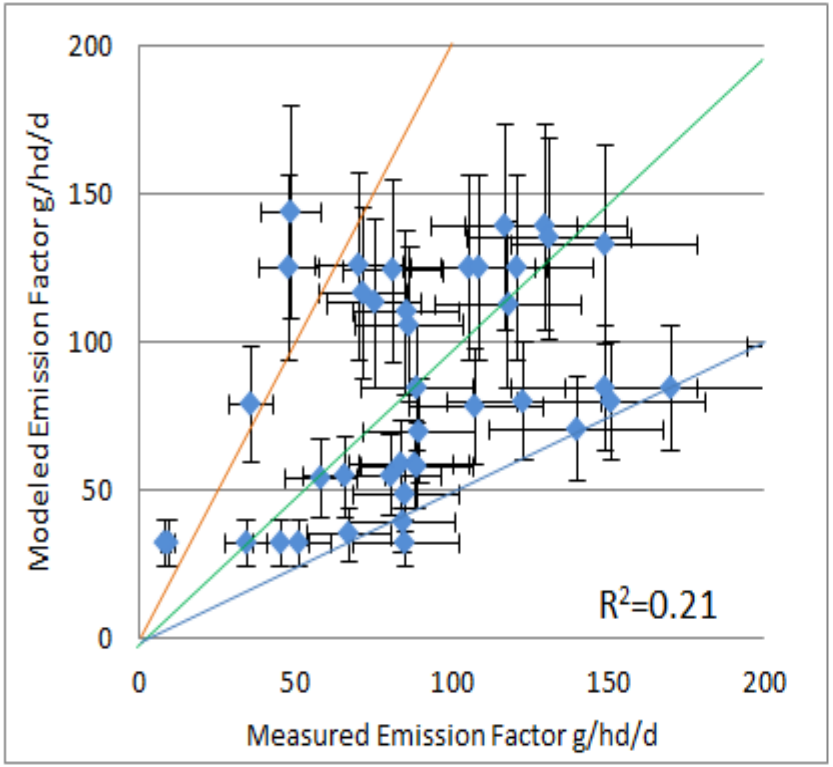
Historical Measurement Campaigns

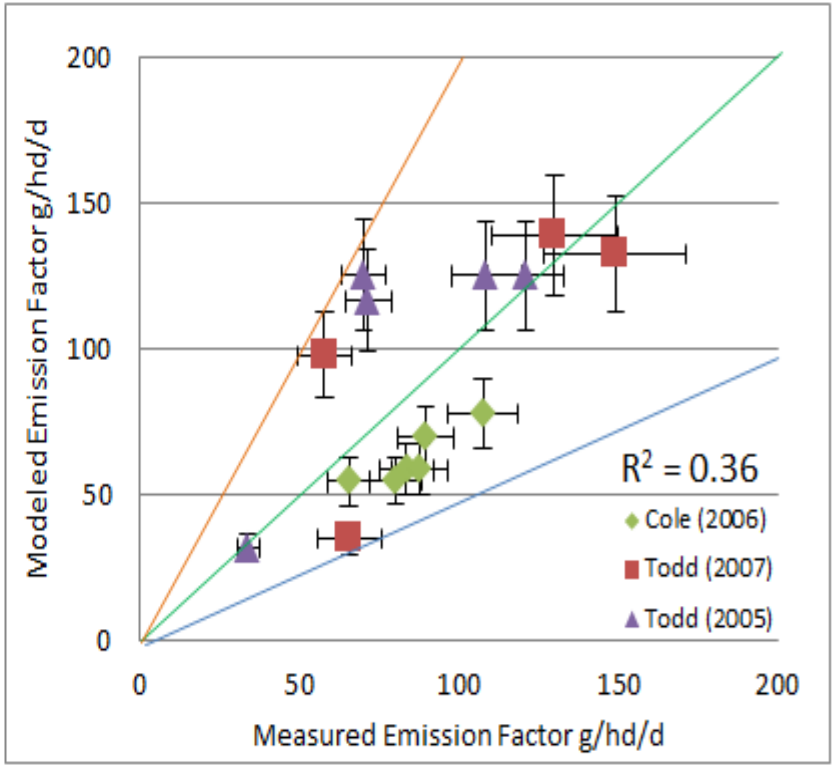
- Short-term monitoring deployments
- Many researchers, many farms
- Limited monitoring reporting of farm and measurement conditions

National Air Emissions Monitoring Study

- 1-3 years of data collection (long-term measurements of seasonal cycles)
- Consistent measurement techniques
- Extensive monitoring of meteorological and farm management conditions

Literature Model Evaluation: Role of Contextual Information

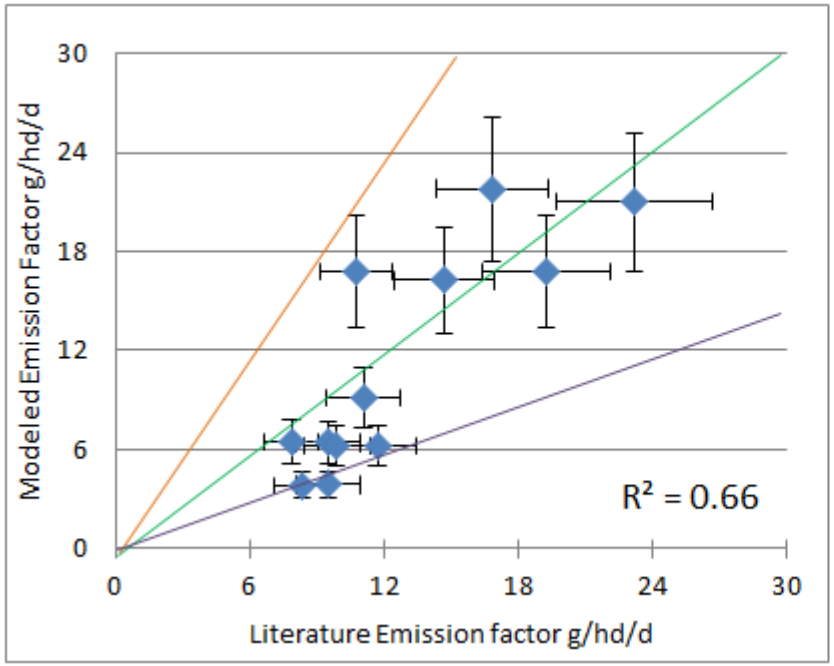




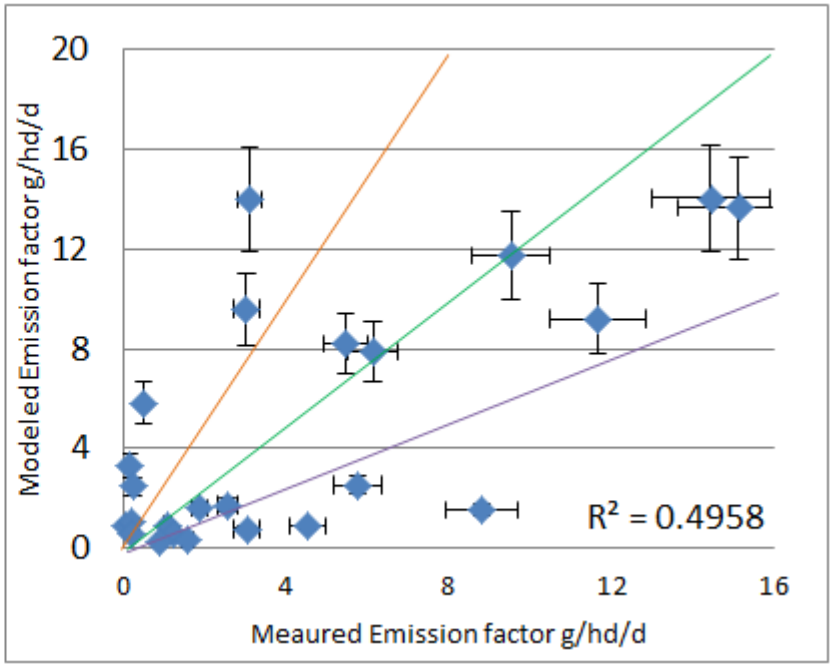
- Feed nitrogen content is a key model input parameter
- Measurements need to report feed N, other practices, and meteorological conditions to put results in context and be useful to process-based models and inventories

Model Evaluation: Open vs. Enclosed Sources

Swine Housing Evaluation

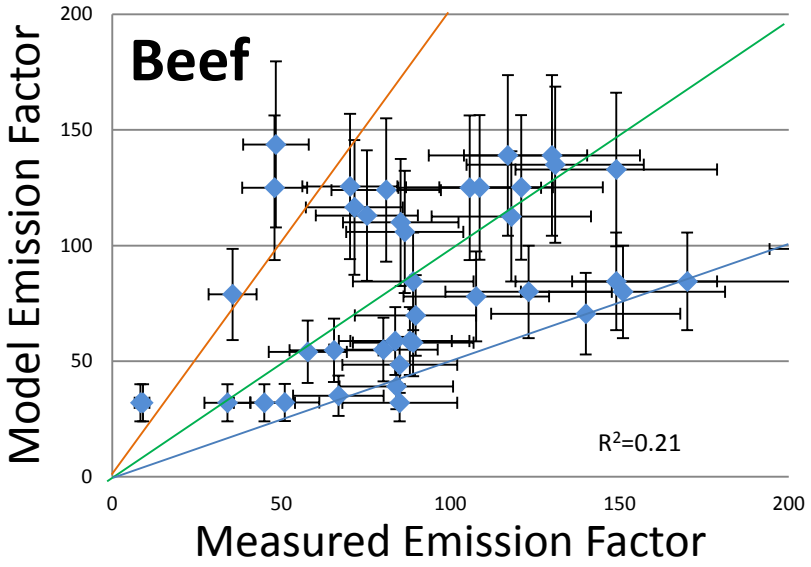


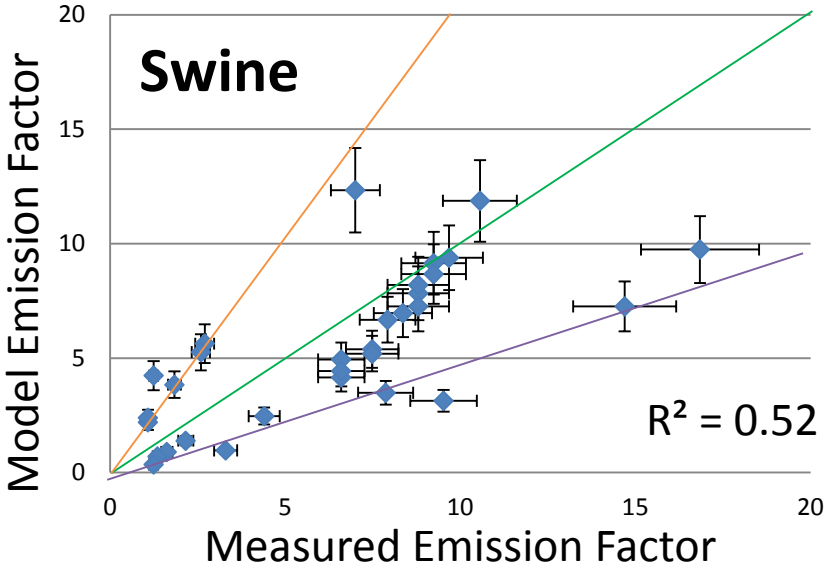
Swine Lagoon Evaluation

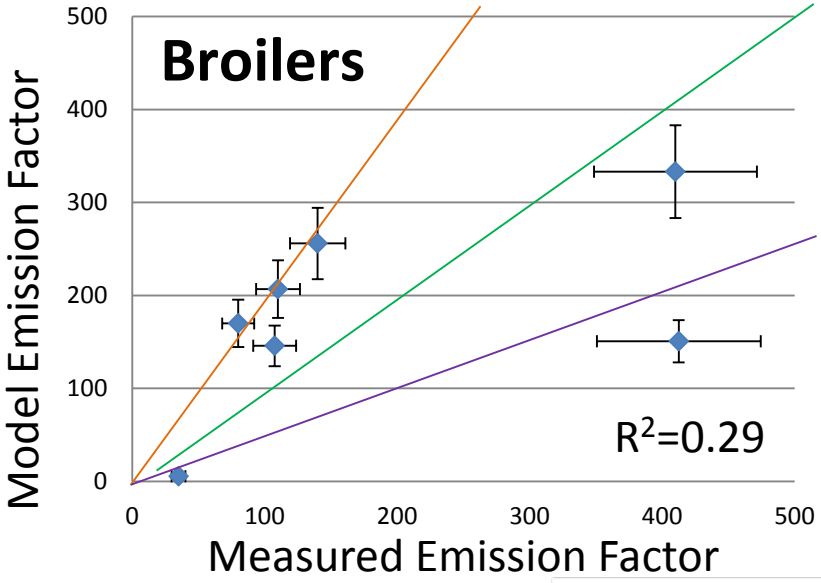


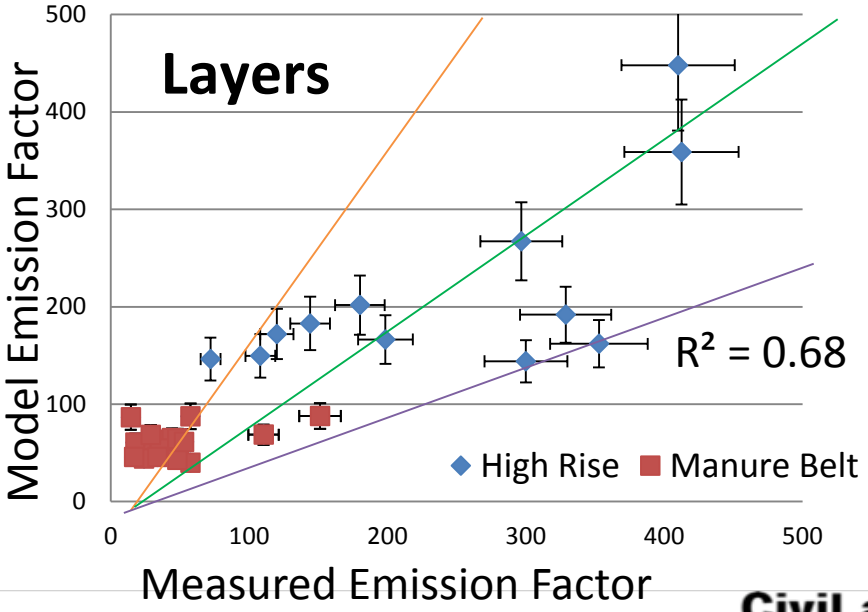
- Based on literature evaluation, model performance is better for enclosed sources
- Presumably, this because accounting for dispersion downwind of open sources is challenging

FEM Evaluations for all new animal types

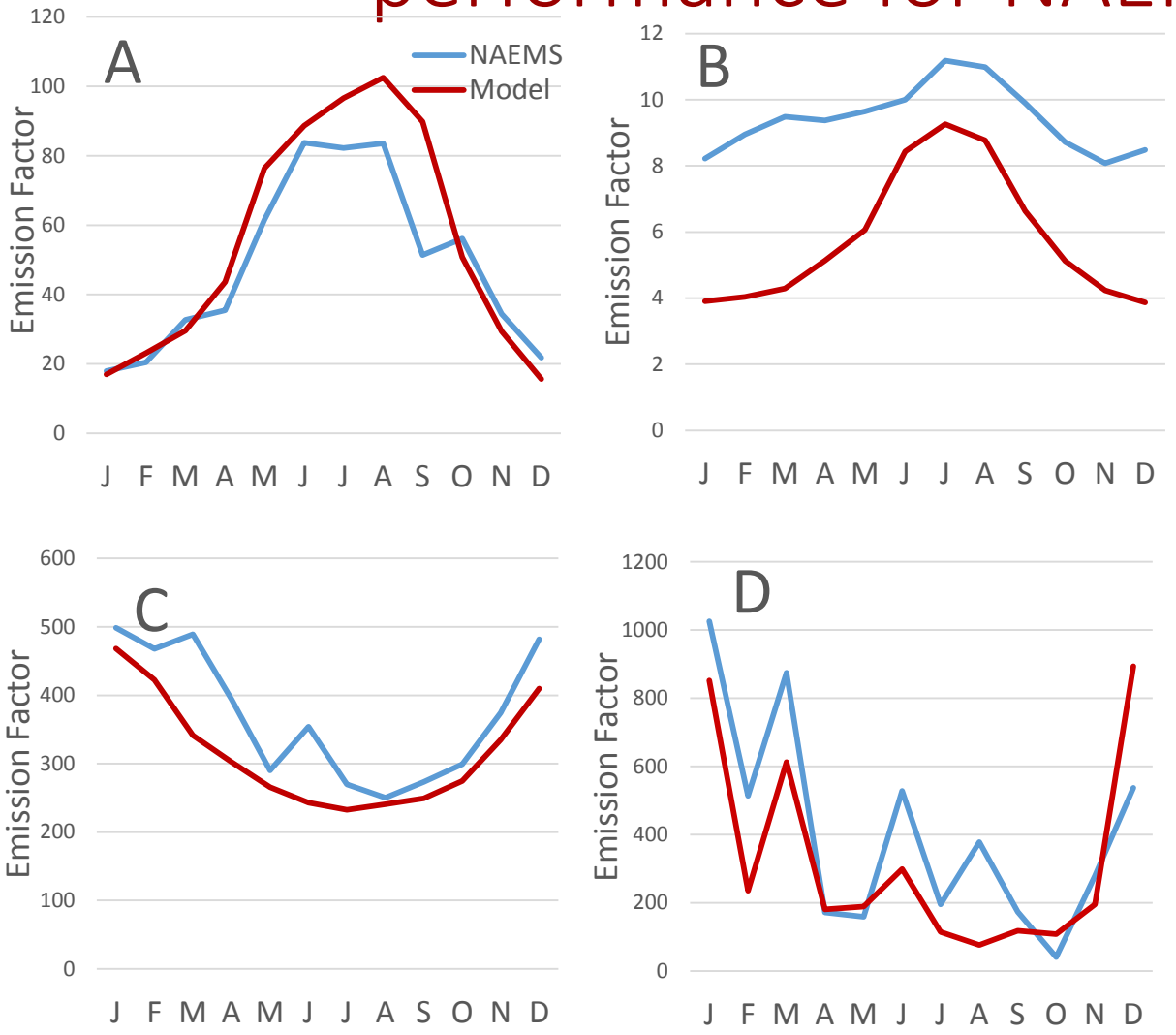








FEM Evaluation: Seasonal Model performance for NAEMS data

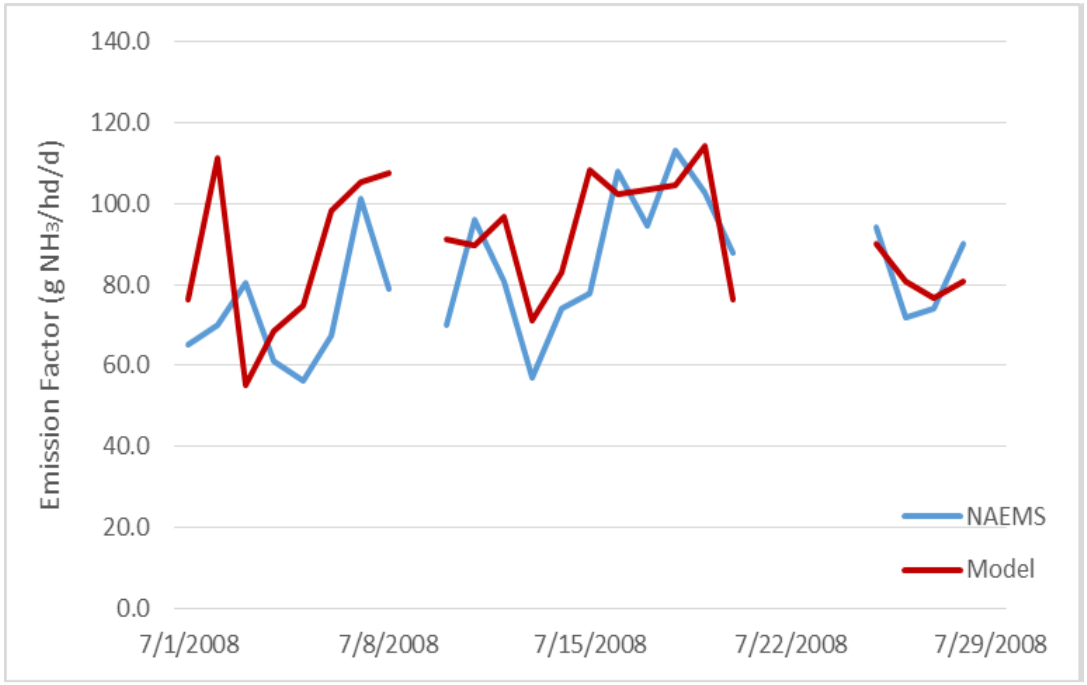


Typical seasonal model performance for each NAEMS animal type:

A. Dairy
B. Swine
C. Layers
D. Broilers

Note: Emission factors are reported in *g NH_3/animal/d* for swine and dairy and *g NH_3/animal unit/d* for poultry

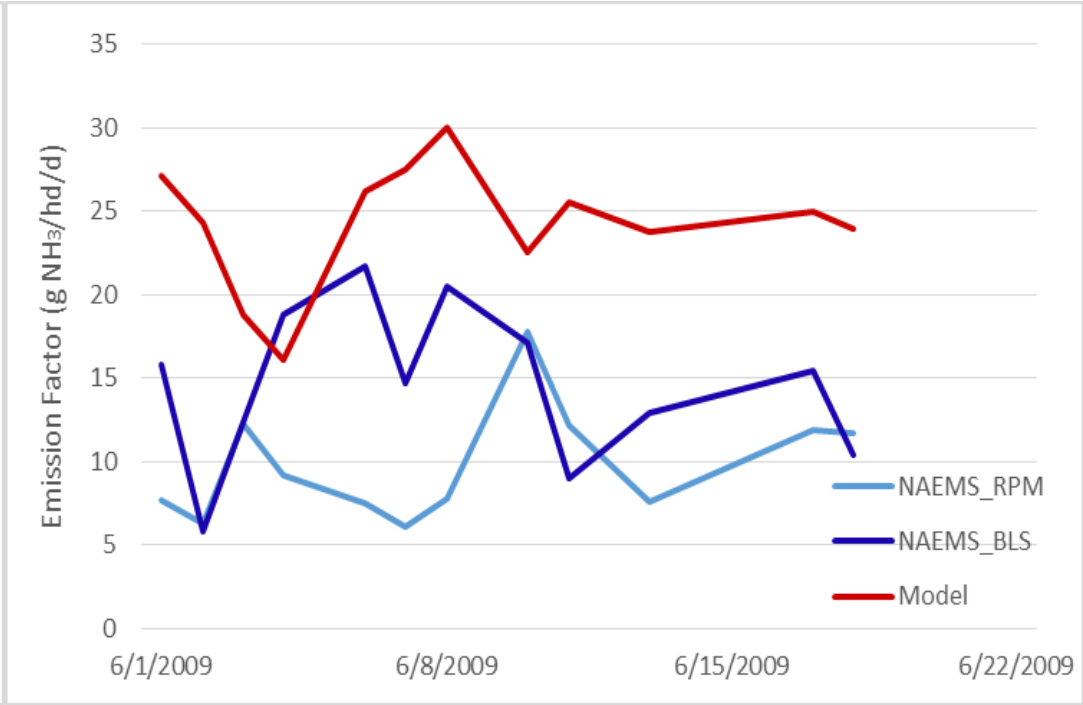
FEM Evaluation: Daily Model performance for NAEMS housing



R = 0.47 **MFE = 18%**

- Model results are less consistent in capturing day-to-day variability
- Housing results tended to show better agreement
- Sample result for a free-stall dairy house in Indiana during July 2008

FEM Evaluation: Daily Model performance for NAEMS storage



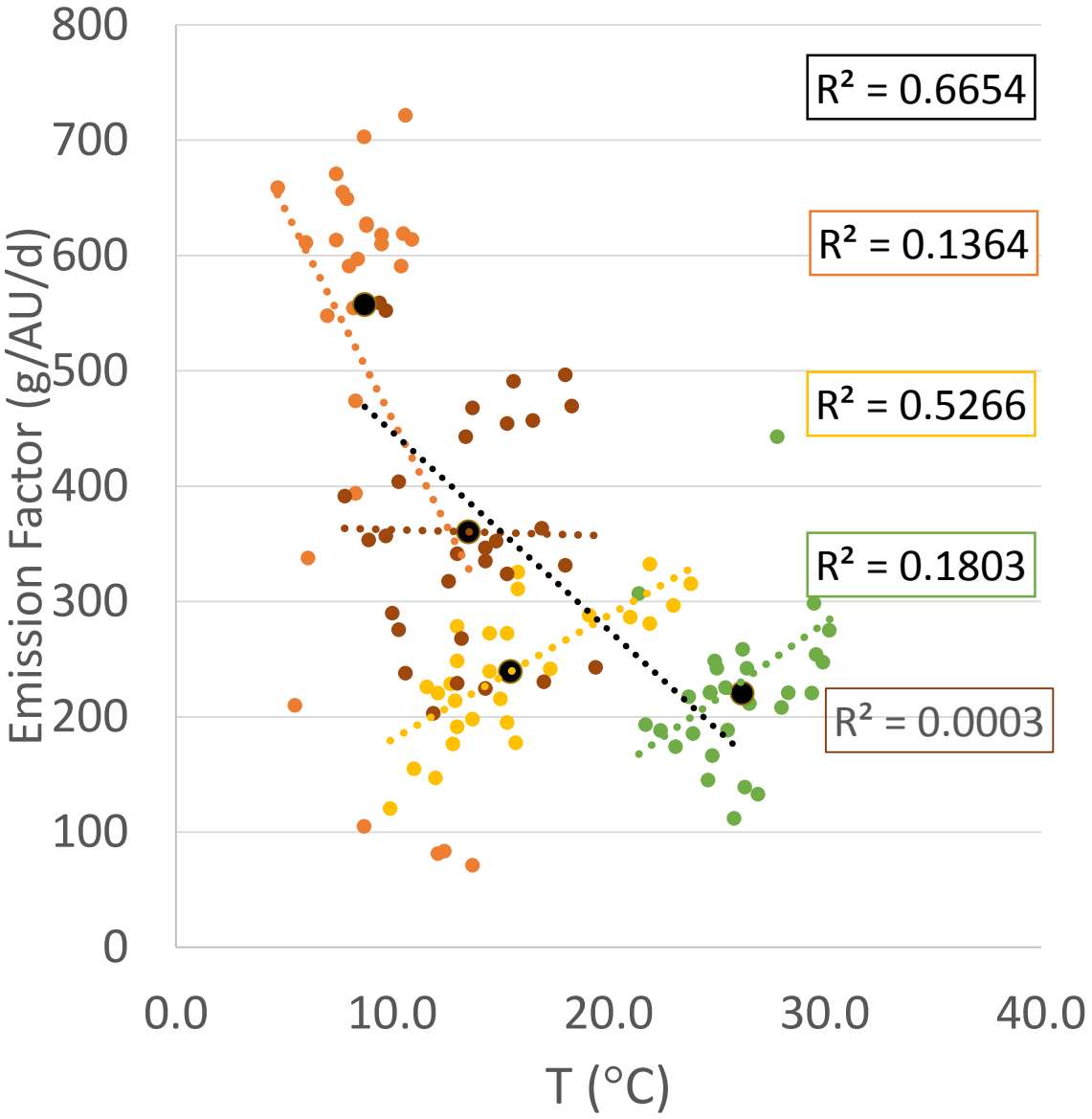
R (with RPM) = -0.36
R (with BLS) = 0.10

MFE (with RPM) = 85%
MFE (with BLS) = 55%

- Model results tended to vary more for storage day-to-day variability in emissions
- Sometimes multiple measurement techniques don't agree well
- Sample result for a dairy lagoon in Indiana during June 2009 (for both RPM and BLS methods)

Note: **RPM** refers to the emissions estimating technique called **R**atiometric **P**lume **M**apping while **BLS** refers to **B**ackwards **L**agrangian **S**tochastic modeling

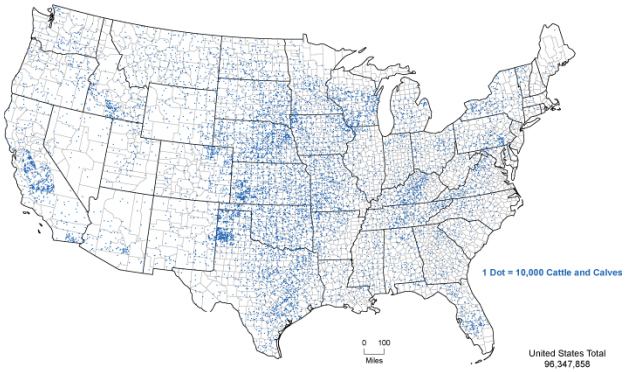
FEM Evaluation: Layer Housing Model results



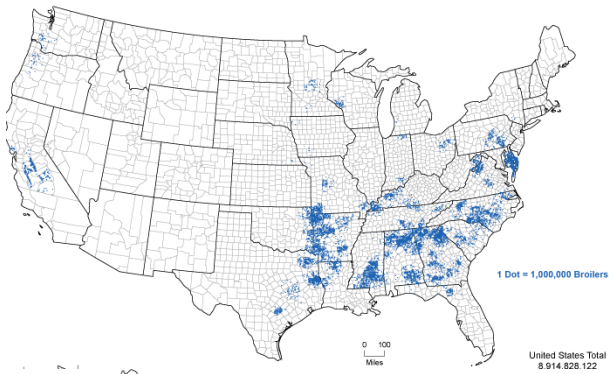
- Not all poultry behaves the same; we see farm to farm and animal type variability
- Day-to-day variability positively correlated with temperature
- Emissions are higher during winter at most farms

Ongoing Work and Next Steps

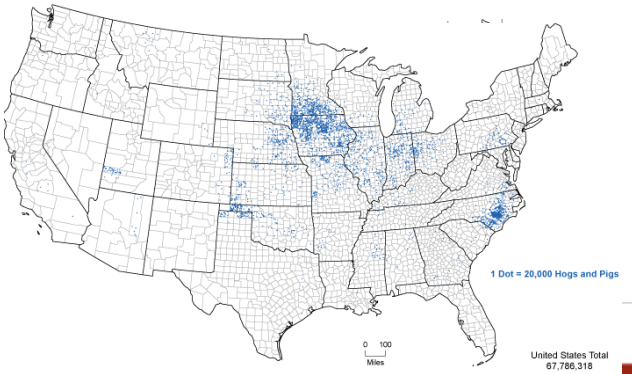
Beef



Broilers

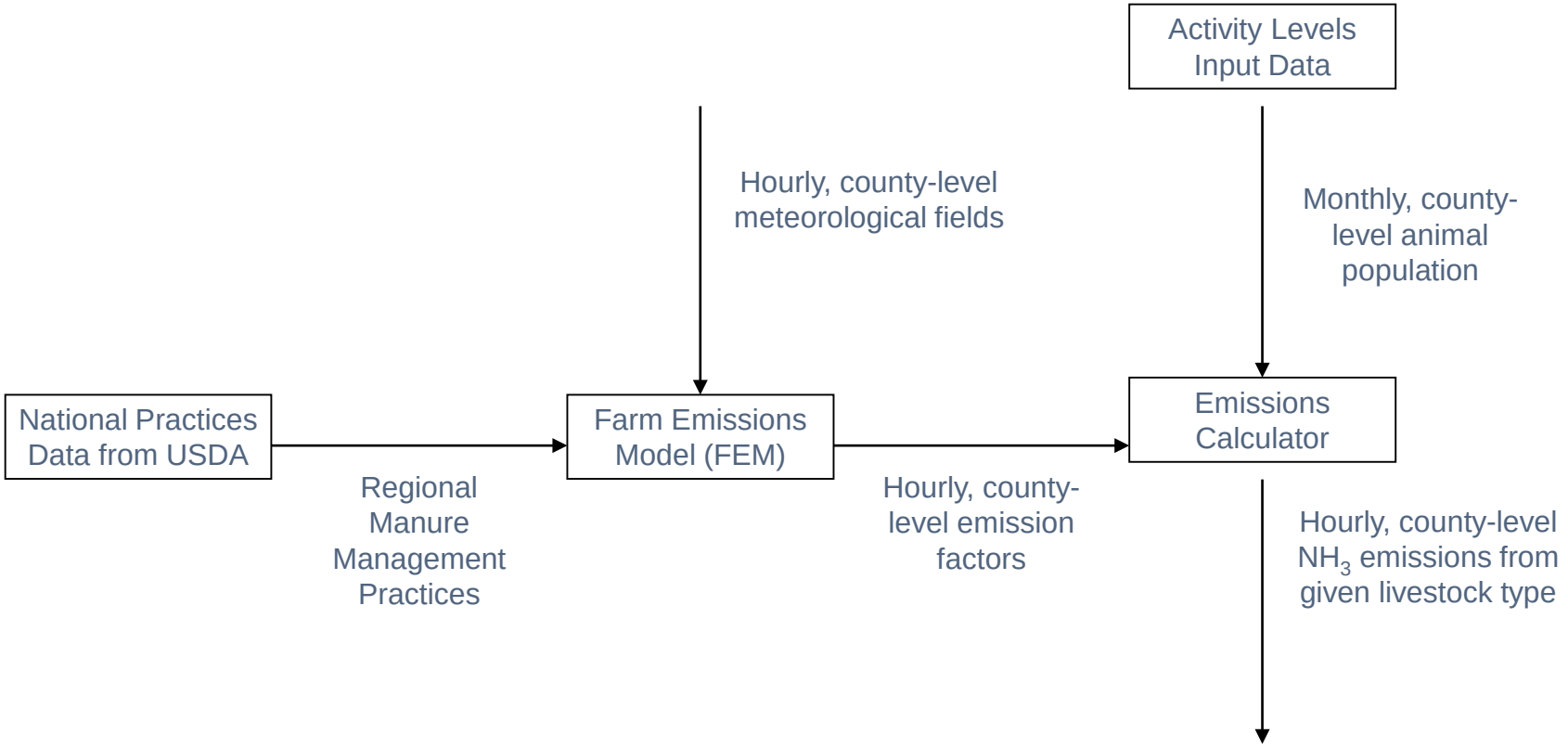


Swine



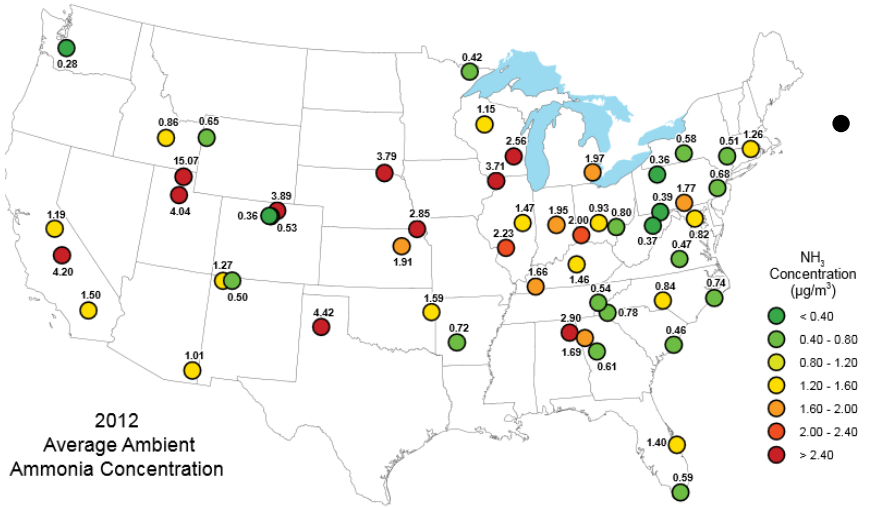
- Current work is ongoing to construct a national inventory for different animal types using the FEMs we have developed and evaluated
- Practices and animal populations vary greatly between locations
- Inventory will then be evaluated against currently existing model inventories

Building an Inventory: Model and Data sources



Evaluating the inventory: Using observations

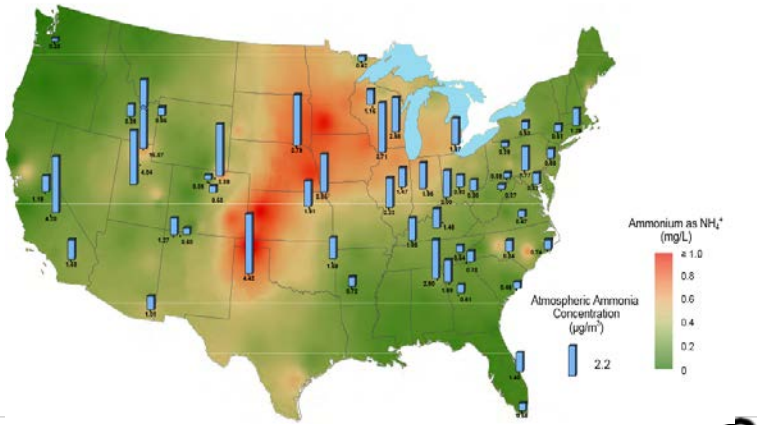
AMoN Locations



http://nadp.sws.uiuc.edu/amon/AMoNfactsheet.pdf

- To understand the impact of ammonia emissions, we need to know about [NH_3] and [NH_4^+]
- New additions to the national monitoring network, AMoN have added to the numbers of co-located NH_3 and NH_4^+ measurement locations

NADP Locations



Conclusions

- FEMs have been evaluated and improved using data from the literature and the NAEMS
- FEMs capture seasonal variability in emissions well; less skillful for daily variability
- Animal production location can determine manure management practices used
- Knowing numbers and types of farms around the country is important for inventory development
- Our inventory will be evaluated using data from the Ammonia Monitoring Network (AMoN) and a chemical transport model

Any Questions?

Acknowledgements:

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- EPA for funding:

  EPA Agreement Number:

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