Community Levels of Atmospheric Ammonia Near Industrial Hog Operations

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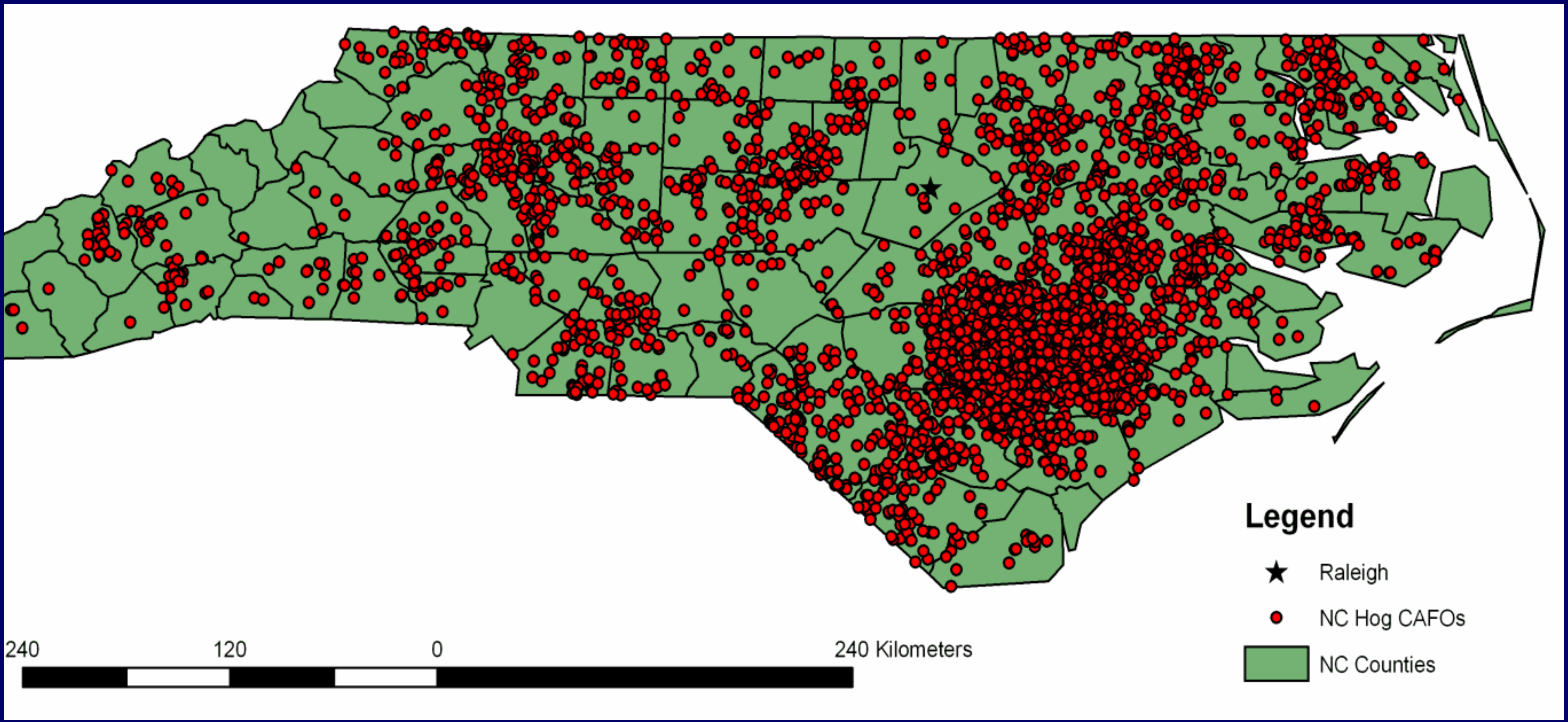
Outline

- Background on CAFOs
  - Problem
- Methods
  - NH_3 Monitoring
  - Spatiotemporal Mapping
- Results
- Conclusions

CAFOs

- Confined Animal Feeding Operations raise a large number of animals in a small confined space

Location of Hog CAFOs in NC



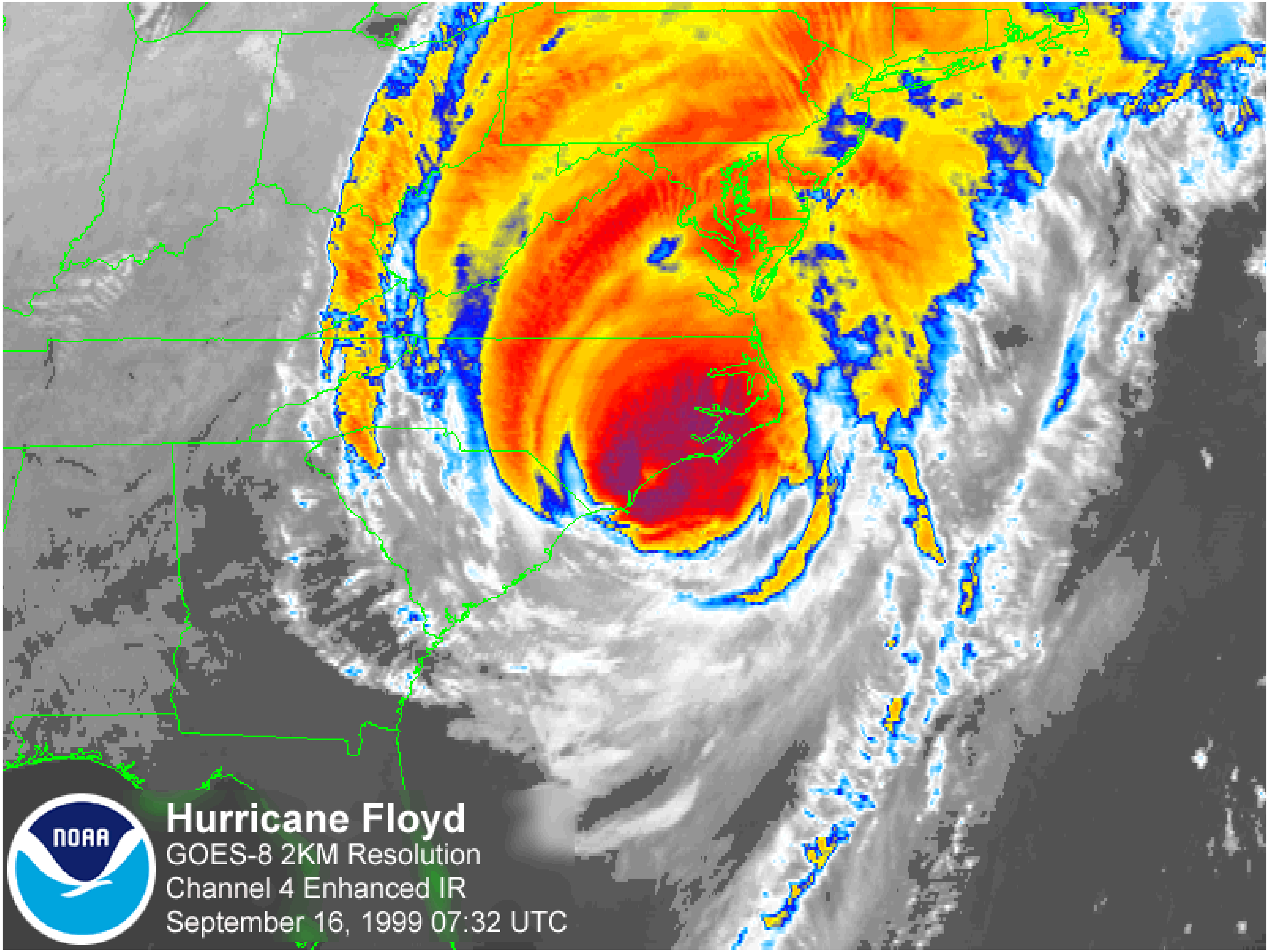
- Over 2500 hog CAFOs in North Carolina
- Over 10 million hogs raised primarily in Eastern NC

Why are hog CAFOs an issue?

- Confinement building, lagoon and sprayfields
- Over 10 million hogs raised in NC Coastal Plain
- Release H_2S, NH_3, NOx, SOx, PM, and VOCs
- Creates respiratory problems, mood disorders and QOL impacts
- Disproportionate burden of hog CAFOs on poor and communities of color

View inside of a confinement house showing hogs divided into different pens

Hog CAFO including several confinement houses where the pigs are raised (background) and pipes leading from the buildings to the lagoon where the waste is collected (foreground)


NOAA
Hurricane Floyd
GOES-8 2KM Resolution
Channel 4 Enhanced IR
September 16, 1999 07:32 UTC

Hurricane Floyd (1999)

- •100,000 dead hogs
- •500,000 dead turkey
- •2.4 million dead chickens

Environmental Monitoring

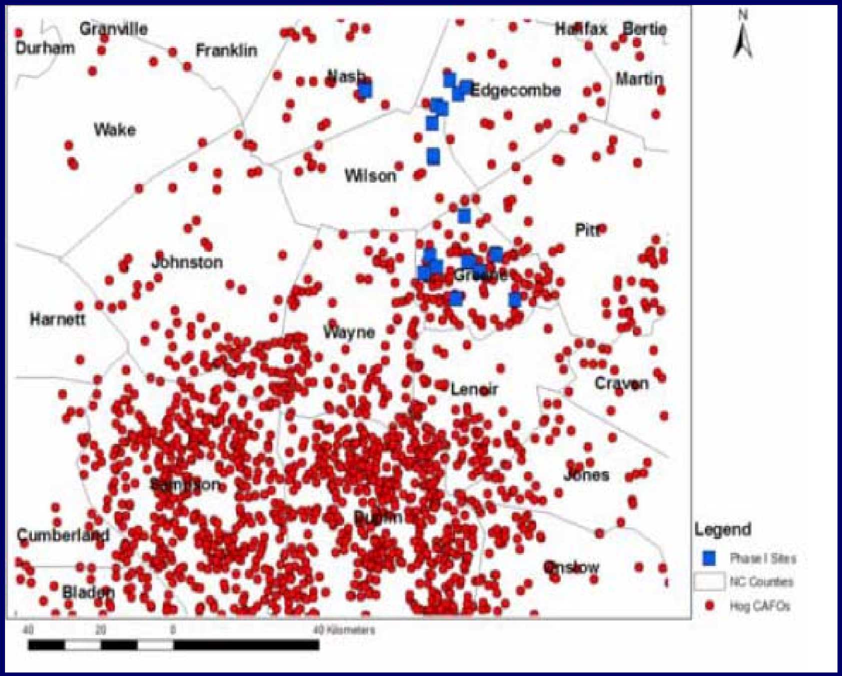
- Passive samplers were used because they are cheap, small, easy to secure, so they can be deployed inconspicuously near CAFOs in exposed communities
- Gradko passive tubes were exposed for one week or more at a time
- Ion Chromatography was used to calculate the total mass of NH3 in tubes, which was then converted to weekly averages of atmospheric concentrations (ppb)

Picture of NH_3 diffusion tubes in collection jars

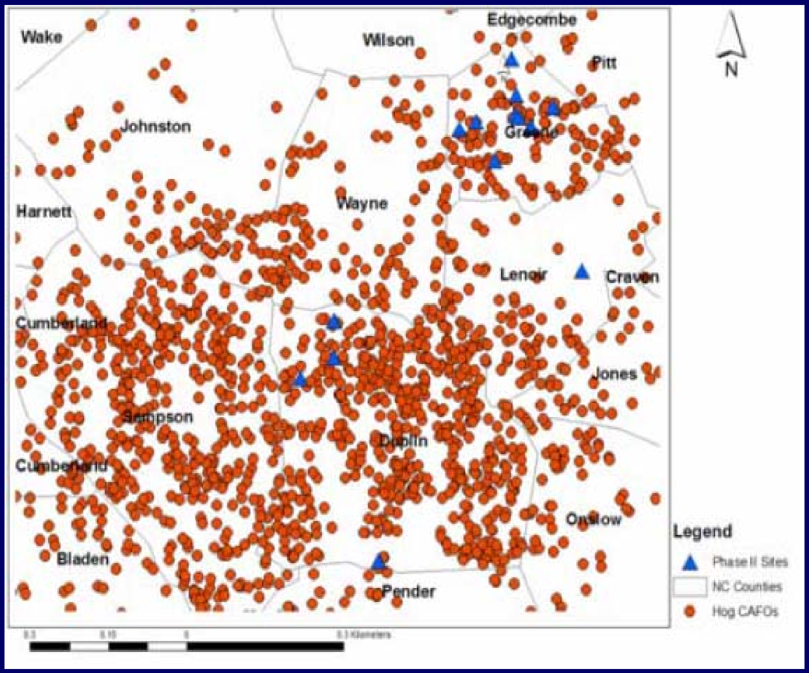
Picture of NH_3 tube shelter at monitoring site 4

Sampling phases

- Phase I sampling occurred from October 2003 to May 2004 and consisted of 28 weekly sampling events at 20 sites
- Phase II sampling occurred from July 2004 to October 2004 and consisted of 9 weekly sampling events at 23 sites
- Triplicate tubes were exposed at each sampling site and sampling event
- The sampling events usually lasted one week



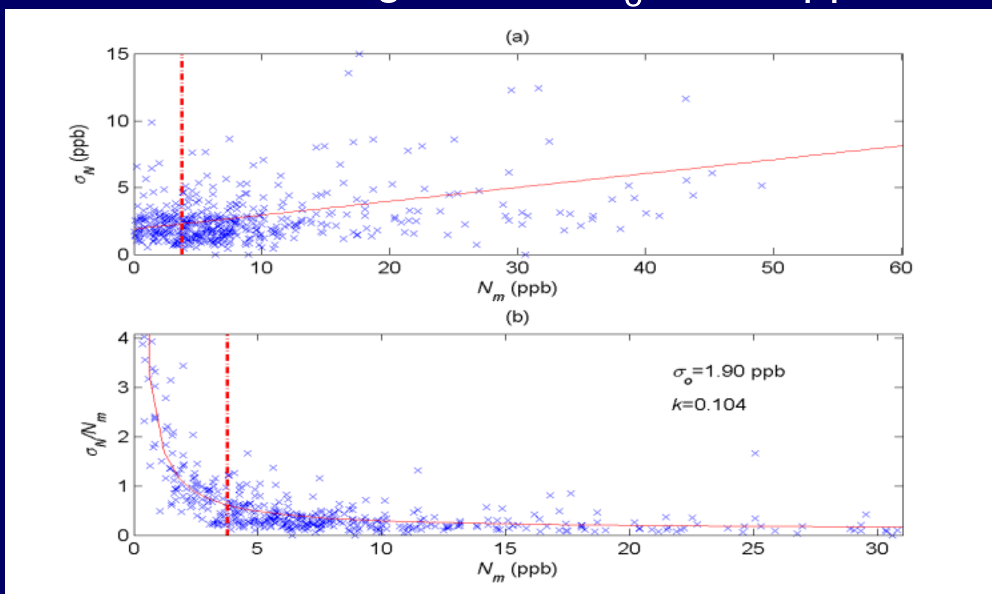
Sampling sites during phase I



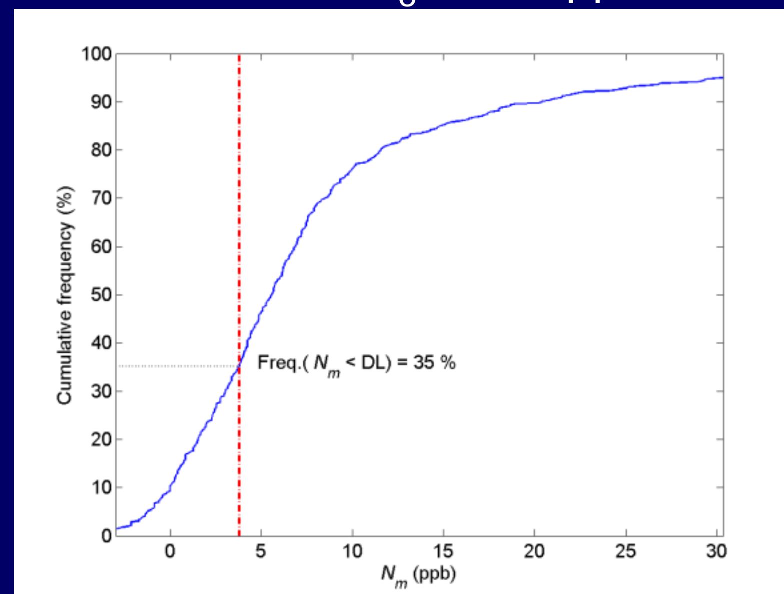
Sampling sites during phase II

Measurement Error Model

- From each triplicate measurements obtain its mean N_m and variance σ_N
- The measurement error model is $\sigma_N = \sigma_o + k\, N_m$
- From linear regression: σ_o = 1.91 ppb, k = 0.104, and DL=2 σ_o= 3.82 ppb



Plot of (a) σ_N versus N_m and (b) σ_N /N_m versus N_m



Cumulative frequency of N_m and fraction below detect

- Only 35% of measurements are below the DL, hence passive samplers are able to detect weekly NH_3 at the community level (Wilson and Serre, 2007a)

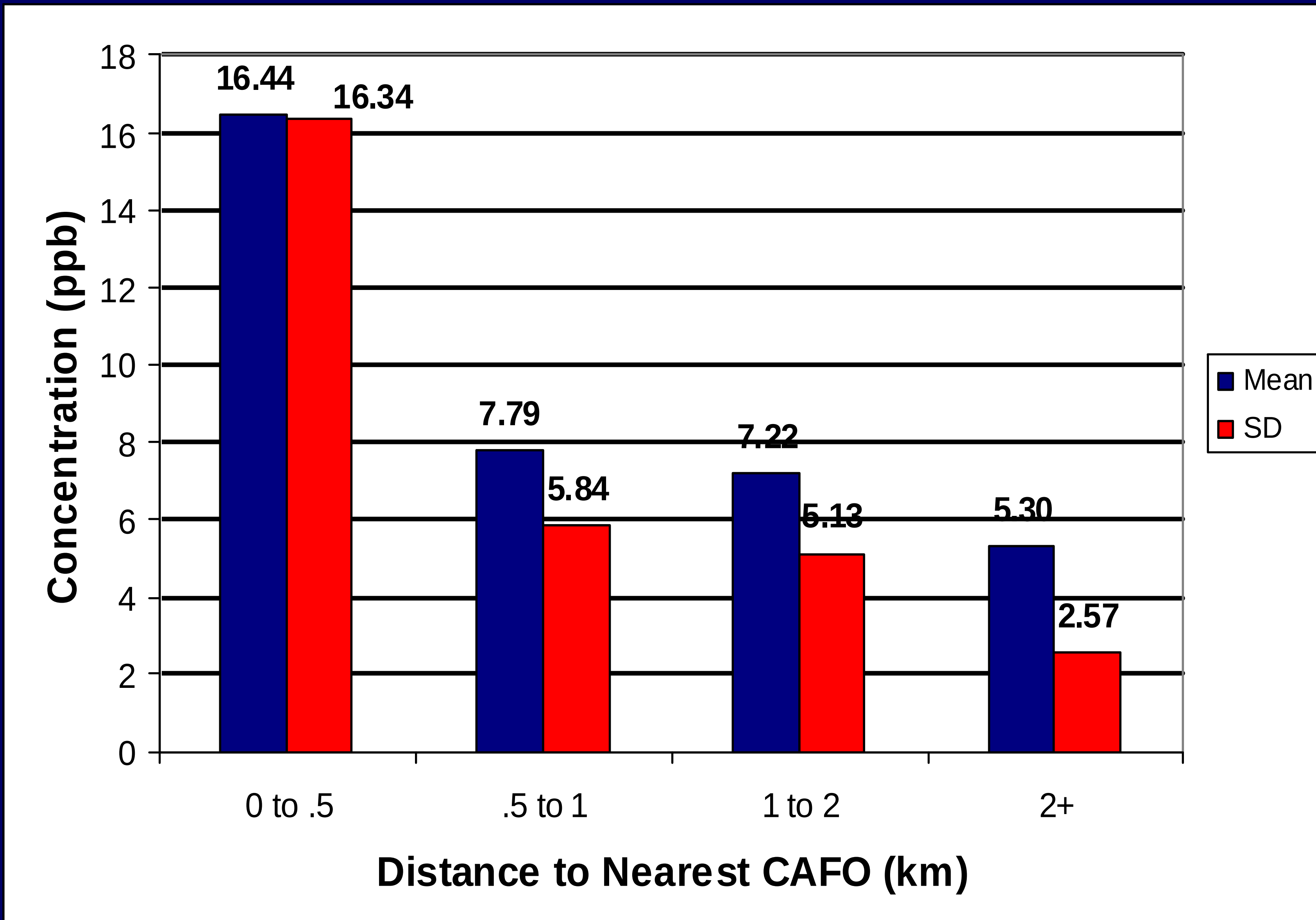
ID	Distance (km)	Mean
1	0.71	7.38
2	1.12	6.28
3	0.56	10.36
4	1.93	5.51
5	0.25	21.09
6	2.10	5.00
7	1.18	4.91
8	4.77	5.20
9	0.96	9.57
10	4.92	6.77
11	1.01	7.92
12	0.90	6.65
13	3.63	4.23
14	0.20	19.59
15	0.46	8.64
16	0.69	4.80
17	1.91	11.25
18	0.64	8.42
19	0.53	7.34
20	1.29	7.45

Descriptive Statistics for each Passive Sampling Station in Phase I (ppb)

- Sites 3, 5, 9, 14, and 17 had mean levels above 10 ppb

- Sites 6-8, 13, and 18 had mean levels < than 5 ppb

NH_3 Concentration vs Distance (Phase I)



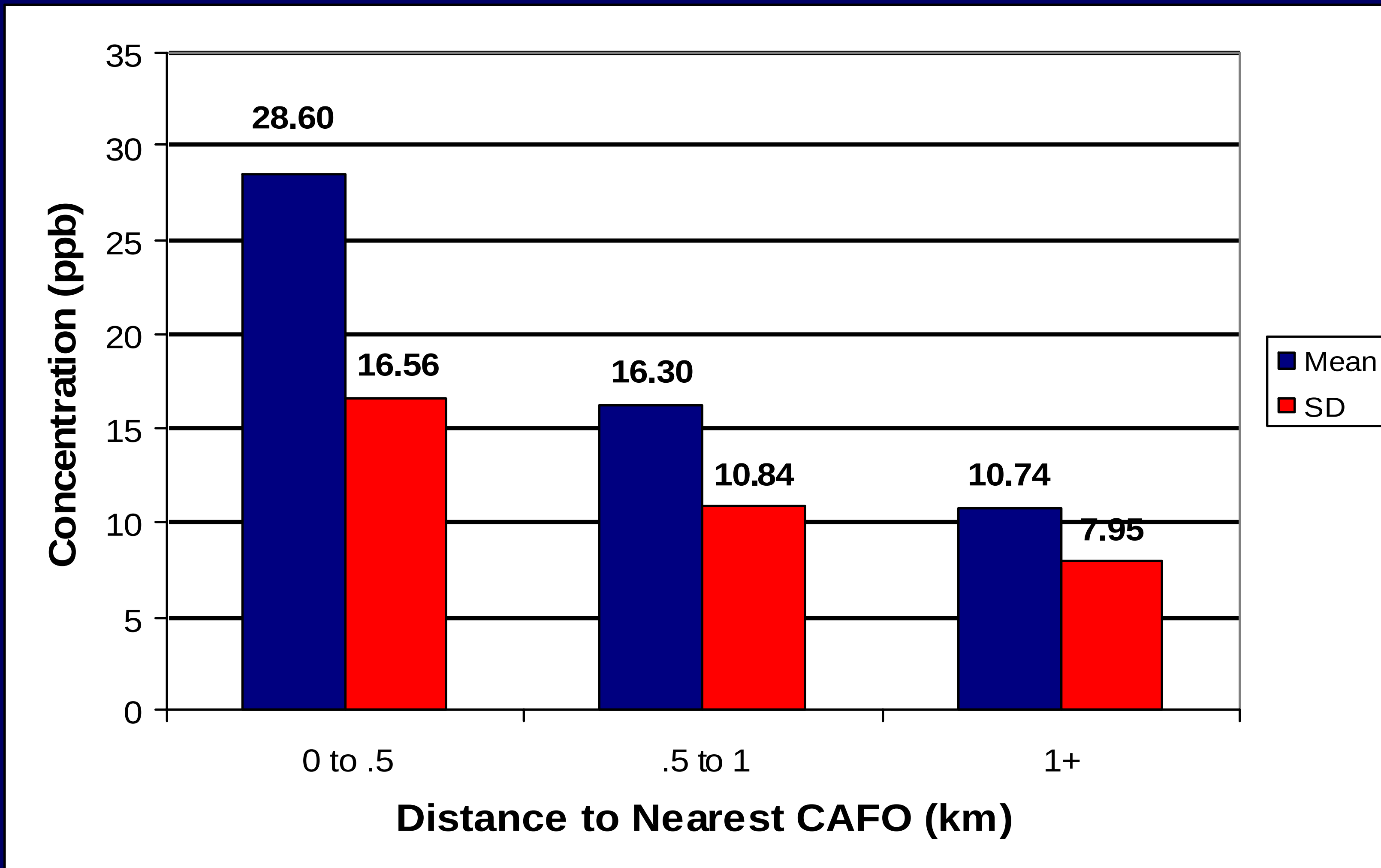
ID	Distance (km)	Mean
1	1.01	10.54
2	1.02	7.91
3	1.01	9.13
4	0.79	20.11
5	0.81	19.48
6	0.84	21.51
7	1.12	10.59
8	0.69	8.56
9	0.64	18.17
10	0.2	20.37
11	0.21	23.2
12	0.56	9.57
13	1.26	4.6
14	0.53	8.81
15	1.8	11.56
16	1.01	4.25
17	0.44	36.63
18	0.45	32.12
19	0.48	48.95
20	0.48	32.12
21	1.83	11.57
22	1.8	12.64
23	5.94	6.09

Descriptive Statistics for each Passive Sampling Station in Phase II (ppb)

- Sites 1, 3-7, 9-12, 15, 17-22 had mean levels > 10 ppb

- Sites 13 and 16 had mean levels less than 5 ppb

NH_3 Concentration vs Distance (Phase II)



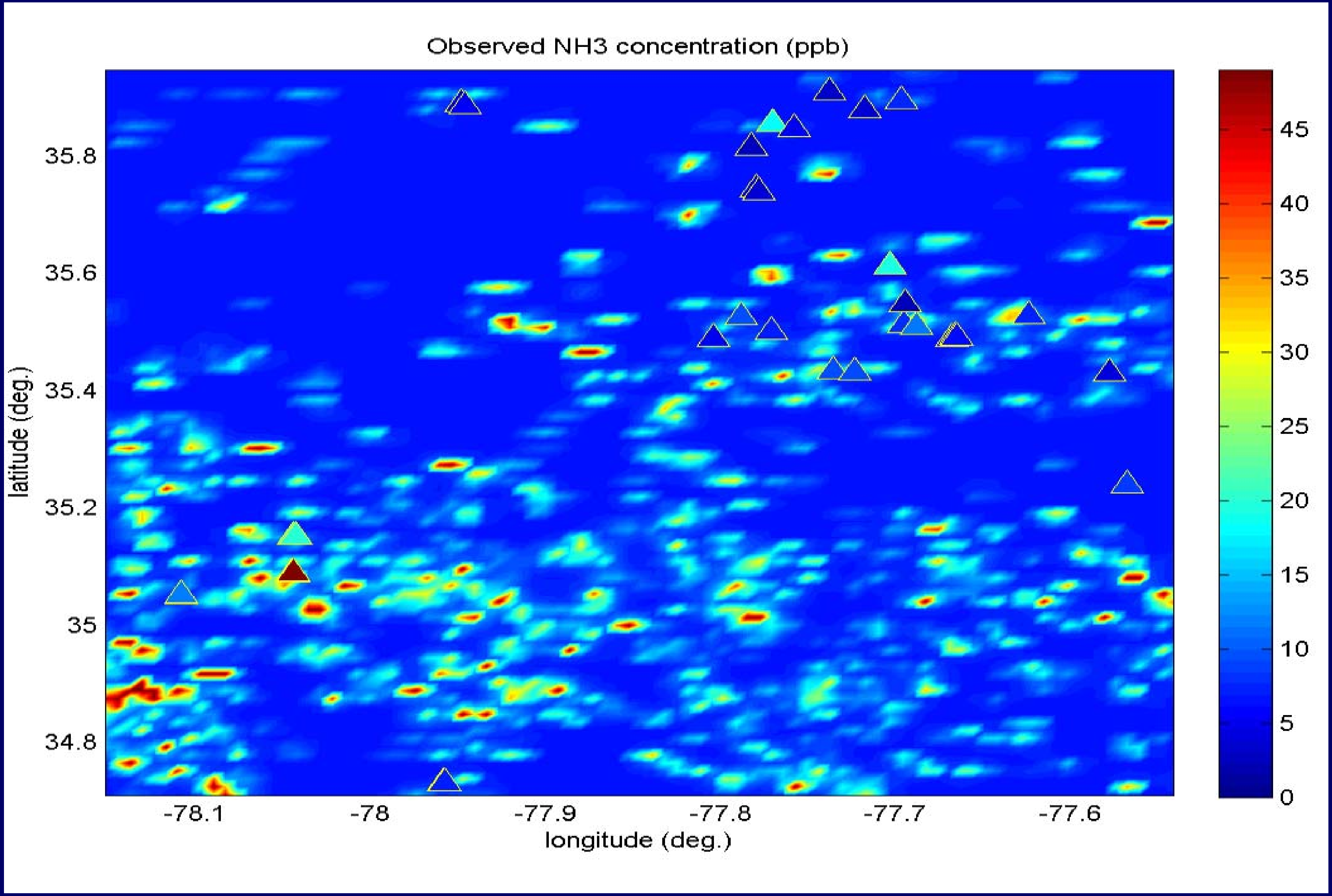
•Results supports the negative trend that exists between distance and source (Walker et al 2004, Fowler et al 1998; Rabaud et al 2001)

Additive Plume Model

The space/time mean trend of NH_3 can be expressed using the an additive exponential plume model that includes the following parameters:

- Regional background NH_3 concentration N_o = 6.58 (ppb)
- Average Hog NH_3 emission : β = 3.7e-5 (ppb NH_3 per *lb* Hog)
- Average effective radius of the exponential plume around each CAFO : a_p = 1.1 Km
- Relative amplitude in the seasonal change in NH_3 concentration: γ =0.35
- Time of the year when NH_3 reaches its seasonal peak : t_o = 200 days past Jan 0
- Maximum yearly NH_3 mean trend = 327.5 ppb
- Average of yearly NH_3 mean trend at CAFOs with 5000+/-1000 hogs is 92.1 ppb

Yearly NH_3 concentration

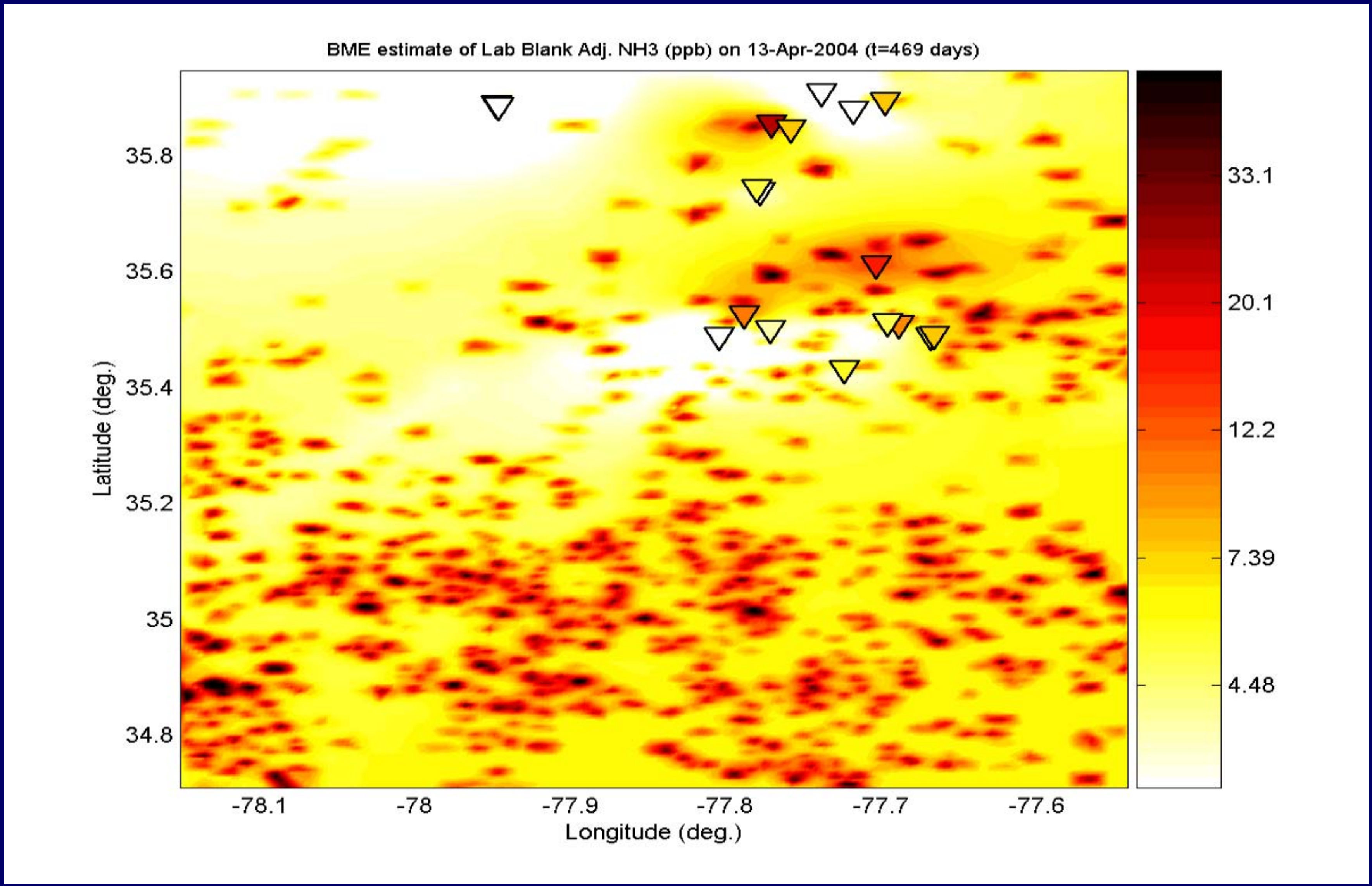


Map of observed and predicted yearly NH_3 concentration in Eastern NC

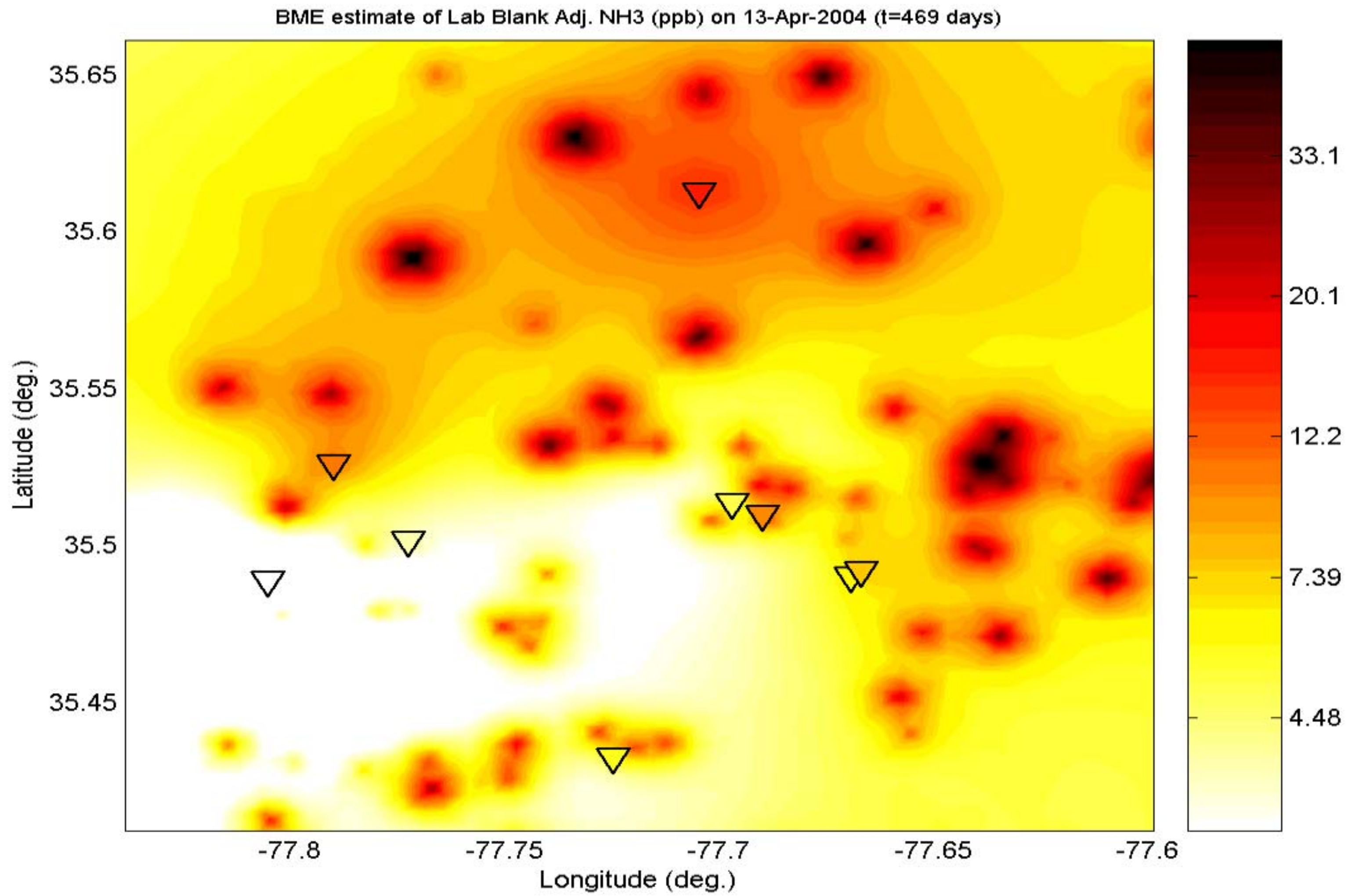
BME Space/Time (S/T) Modeling

- The Bayesian Maximum Entropy (BME) of modern spatiotemporal Geostatistics provide a framework for the space/time integration of data from multiple sources
- The output are maps showing the BME estimate of NH_3 across Eastern North Carolina for different times of interest

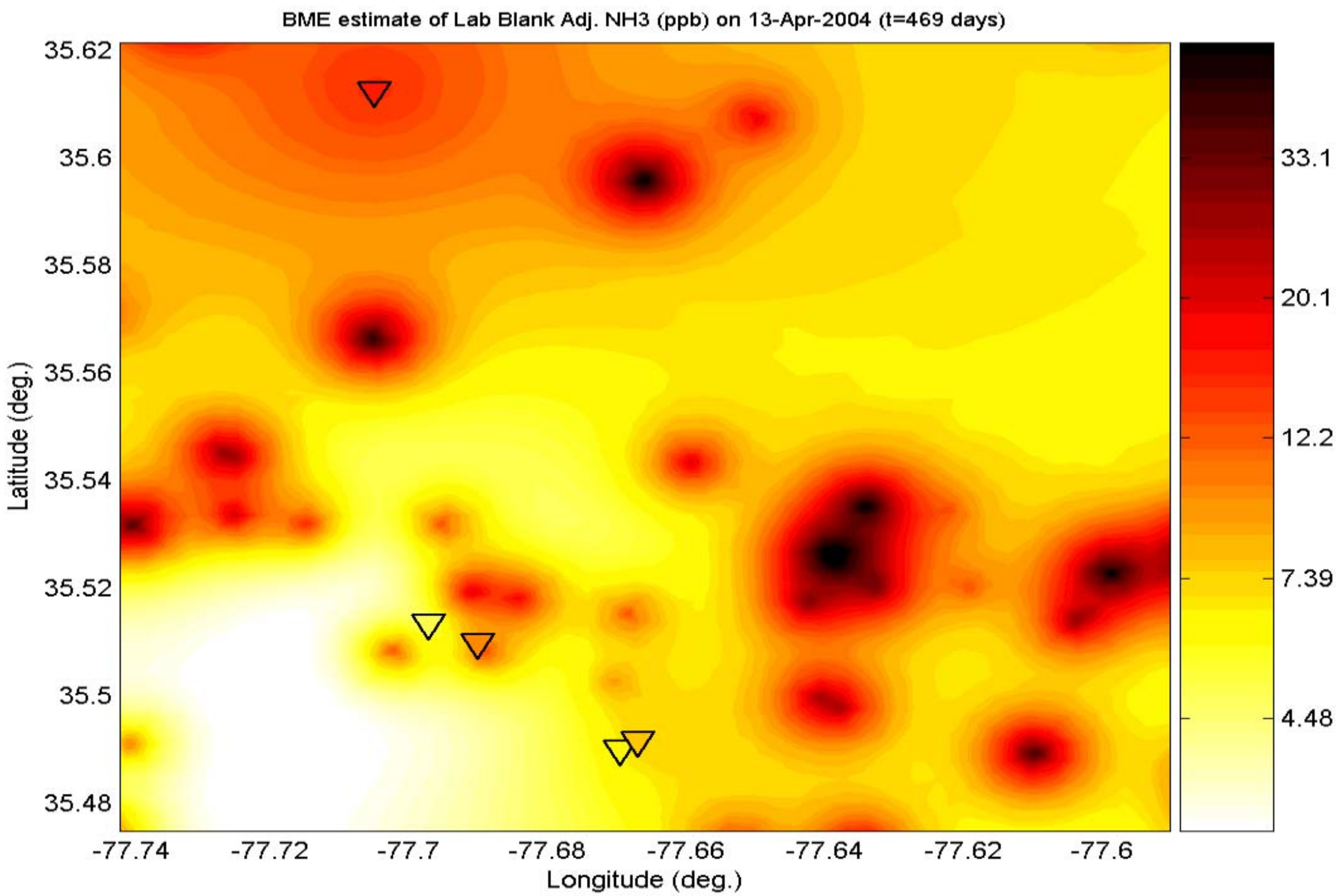
BME Maps of NH_3 in Eastern NC



BME Map of NH_3 (zoom 1)



BME Map of NH_3 (zoom 2)



Conclusion

- This work provides the maps of the mean trend in the spatial distribution of weekly ammonia concentrations in Eastern NC. These maps show that the plumes of 1.1 *Km* around each CAFO might lead to substantial community exposure, and indicate that the density of CAFOs lead to a regional increase in background air pollution from about 2-3 ppb to about 6-7 ppb.

- The regional increase in background NH_3 suggests that the current standard based solely on buffer distance may not be protective enough, and instead a concentration based standard should be considered

- Future work should combine the use of active and passive samplers to elucidate the relationship between weekly ammonia concentrations (chronic exposure), and 15-minutes concentrations (acute exposure)

- As a result, a community-based participatory approach needs to be used to develop a **sustained community driven environmental surveillance system to seek action and social change**

Thank You!!!