# Research on Emissions from Cattle Operations and BMPs

## Ongoing Research in the Texas A&M System

AgriLIFE RESEARCH
Texas A&M System

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# Today's Objectives

- Summarize ongoing research in a federally funded consortium project
- Outline rationale for individual projects
- Provide contact information for key components of the project team

Assisted Search

# http://cris.csrees.usda.gov/

Investigator: Sweeten

Grant Year: 2006

# Air Quality: Odor, Dust, and Gaseous Emissions from Open-Lot Livestock Production in the Southern Great Plains

Dr. John Sweeten, Principal Investigator

# Project Partners

- Texas AgriLife Research (Amarillo and College Station)
- Texas AgriLife Extension Service (Amarillo and College Station)
- Kansas State University (Manhattan)
- USDA Agricultural Research Service (Bushland)
- West Texas A&M University (Canyon)
- Dr. Ray Knighton, CSREES Project Sponsor

# Five Objectives, Years 1-5

- Emissions Processes and Measurement Techniques
- Abatement Measures
- Emission Factors, Dispersion Modeling, and Regulations
- Animal Health
- Technology Transfer

# Primary Pollutants of Interest

- Particulate Matter: TSP, $PM_{10}$, $PM_{2.5}$, $PM_{10-2.5}$
- Major Gases: $NH_3$, $H_2S$
- Odor (as such)
- Volatile Organic Compounds (VOCs)
  - Reactive and highly reactive (RVOC, HRVOC)
  - Odorants (OVOC)

# Objective 1: Emissions Processes and Measurement Techniques

Objective Coordinator: Dr. David Parker, WTAMU

# Feedyard C

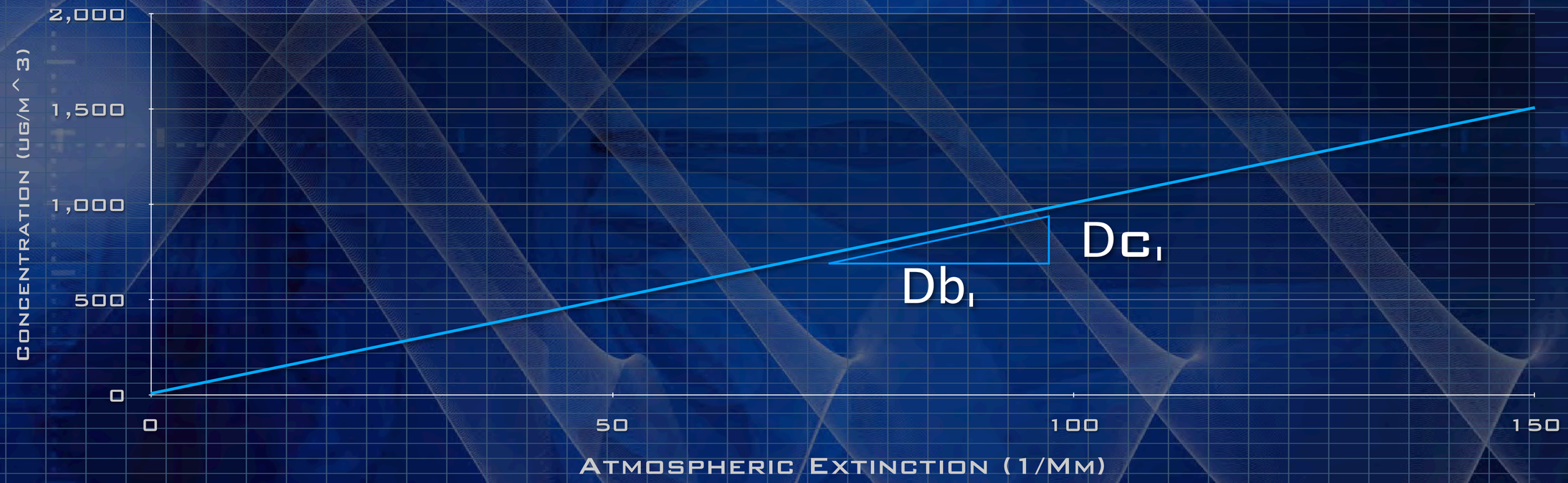
- Commercial feedyard, Texas Panhandle
- Capacity >40,000
- Also using other commercial yards in TX and KS

# Atmospheric Extinction

Rayleigh (10 $Mm^{-1}$)

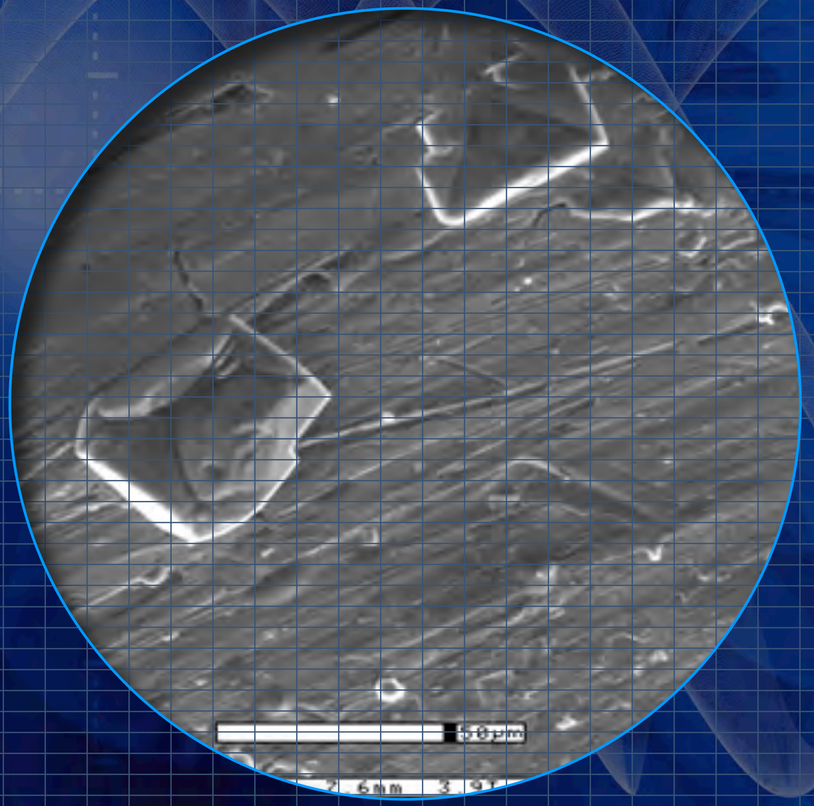
200 $Mm^{-1}$

# Extinction Efficiency

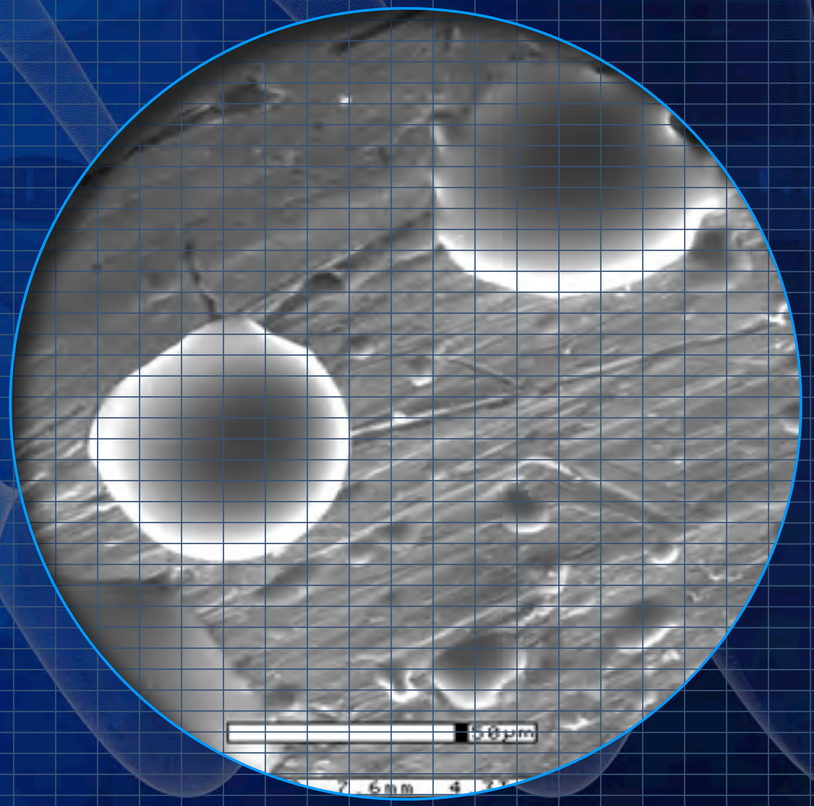


# Deliquescence

RH=67.5%

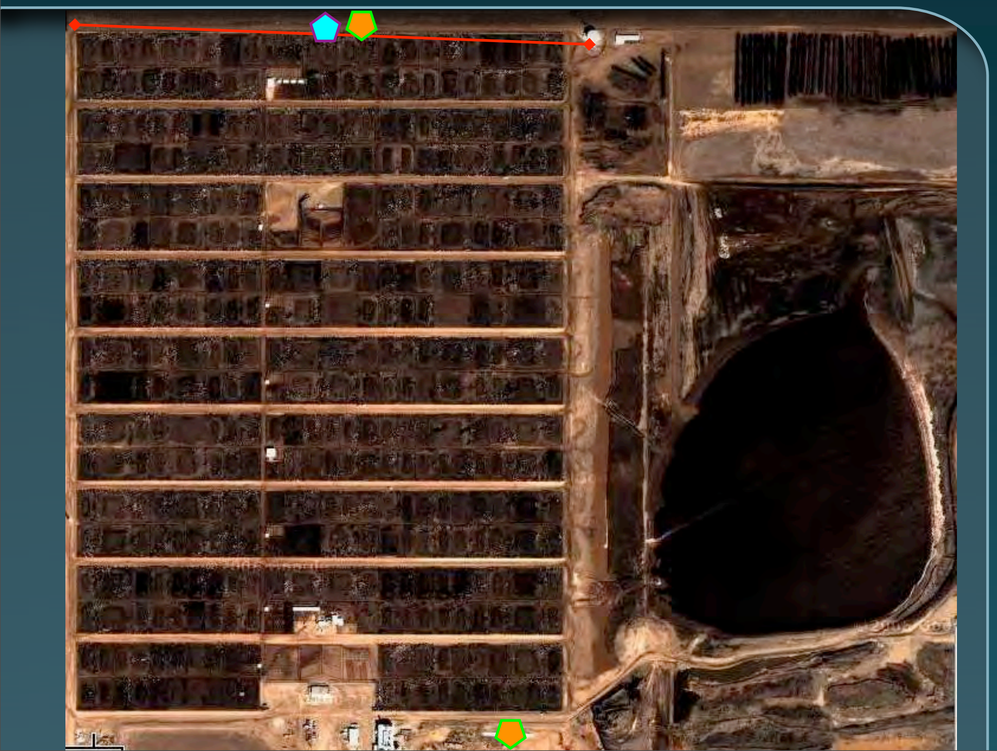



RH=75%




SEM photos courtesy Dr. Sarah Brooks, TAMU Atmospheric Sciences

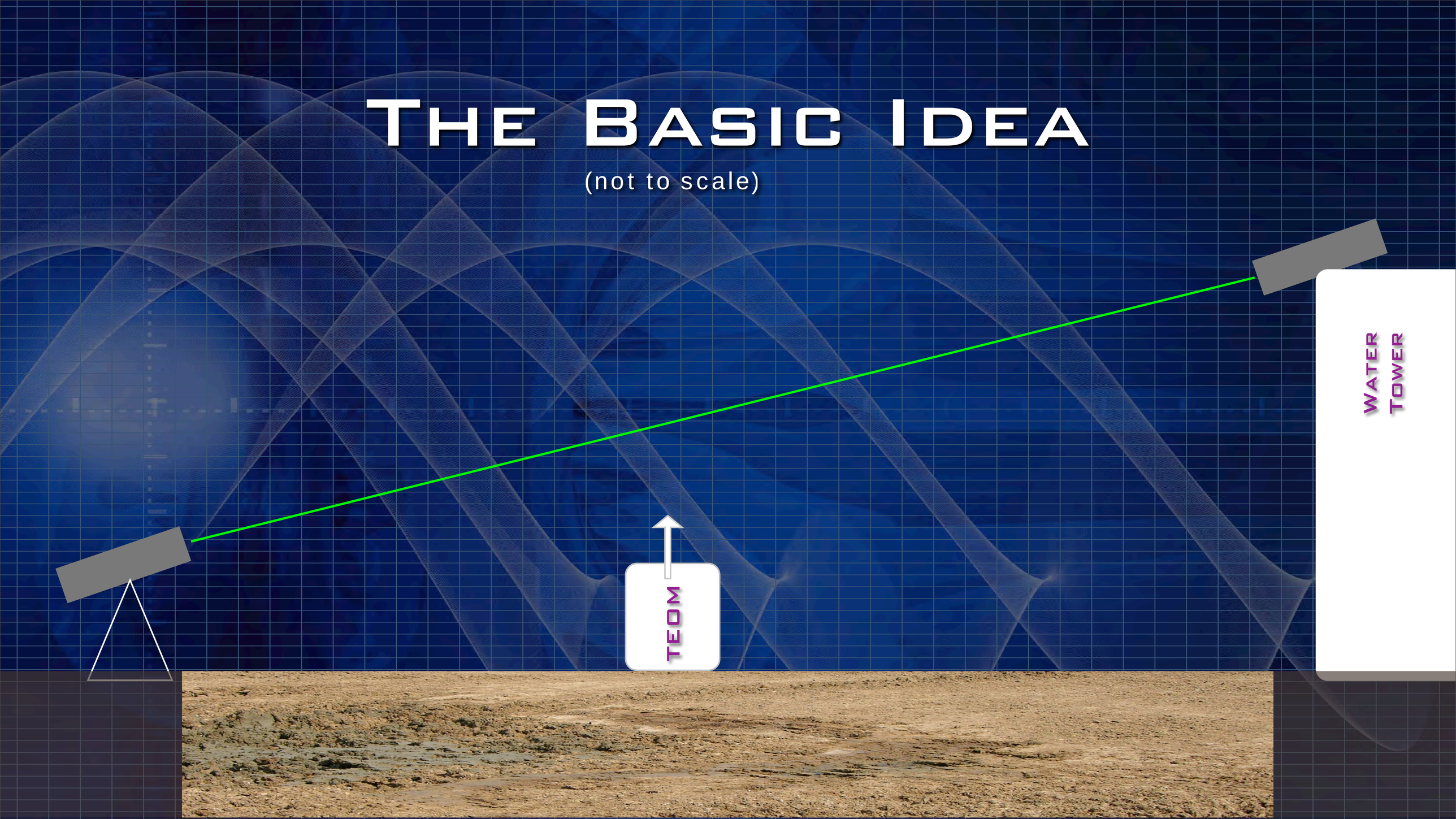
# Monitoring Devices and Layout

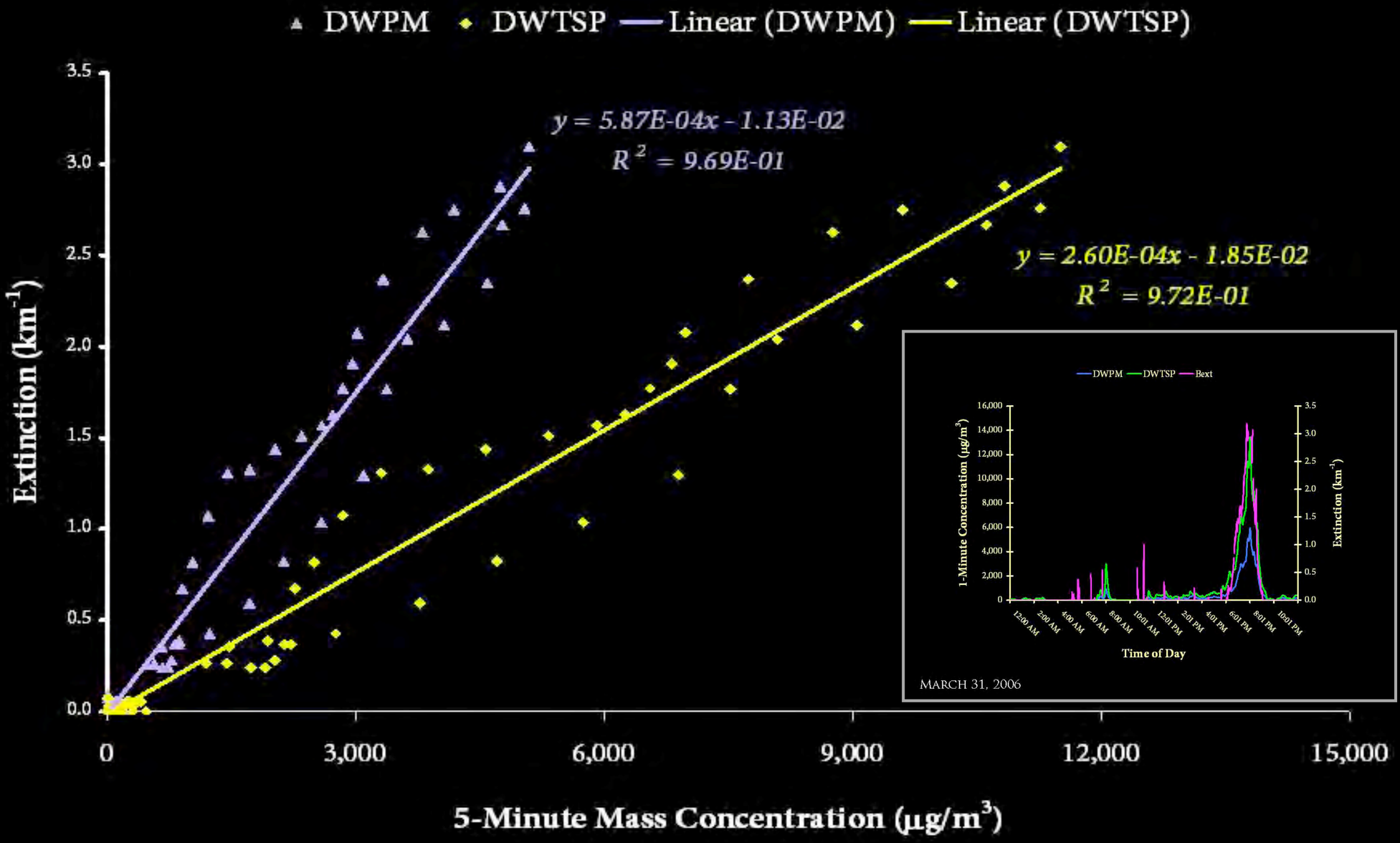


- Transmissometer
- TEOM-$PM_{10}$
- TEOM-TSP

# The Basic Idea

(not to scale)



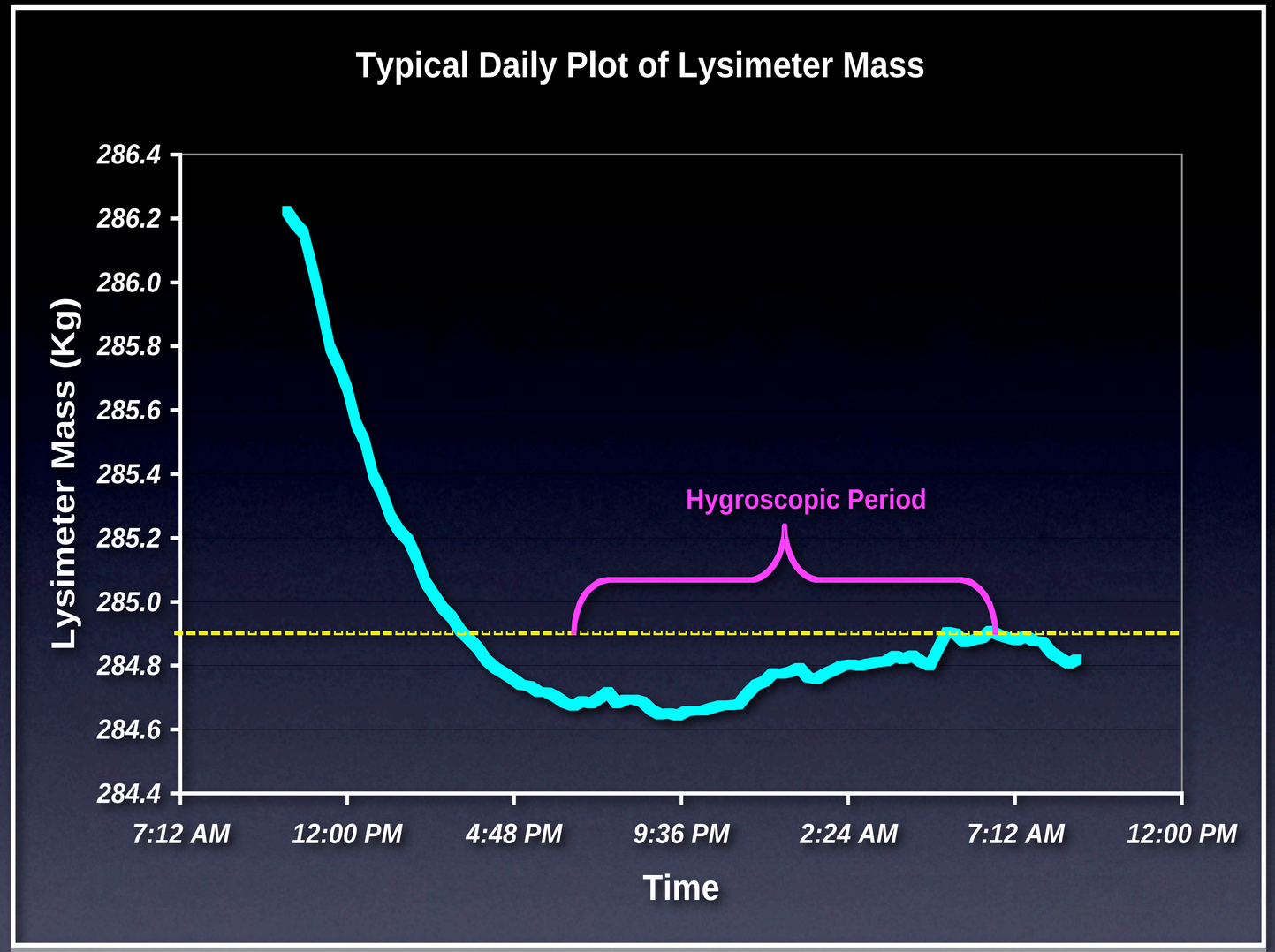



MARCH 31, 2006


25 September 2000

# The Evening Dust Peak - Why?

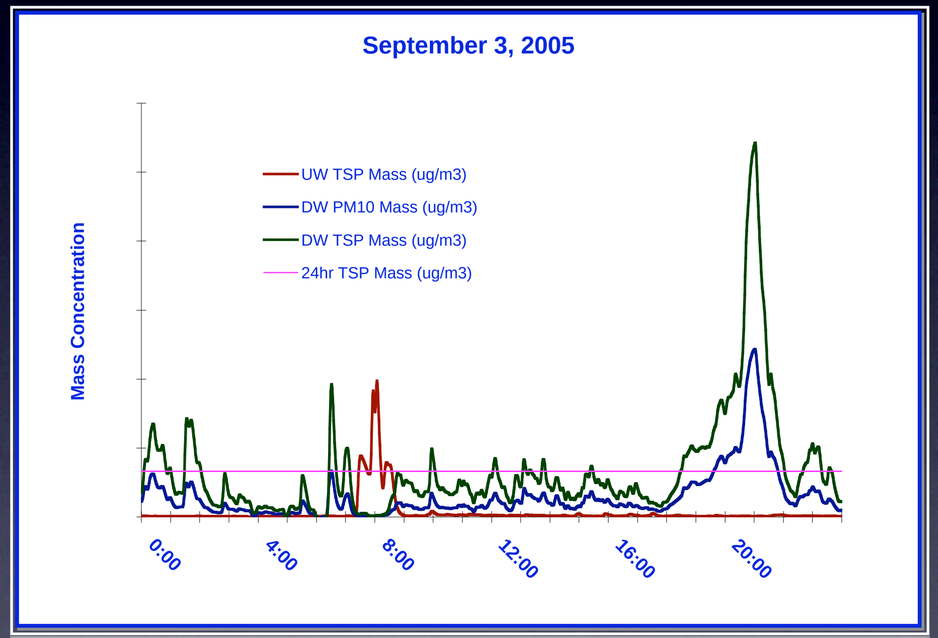
- Animal activity increases in the early evening as compared to midday
- Uncompacted manure is at its driest in the early evening



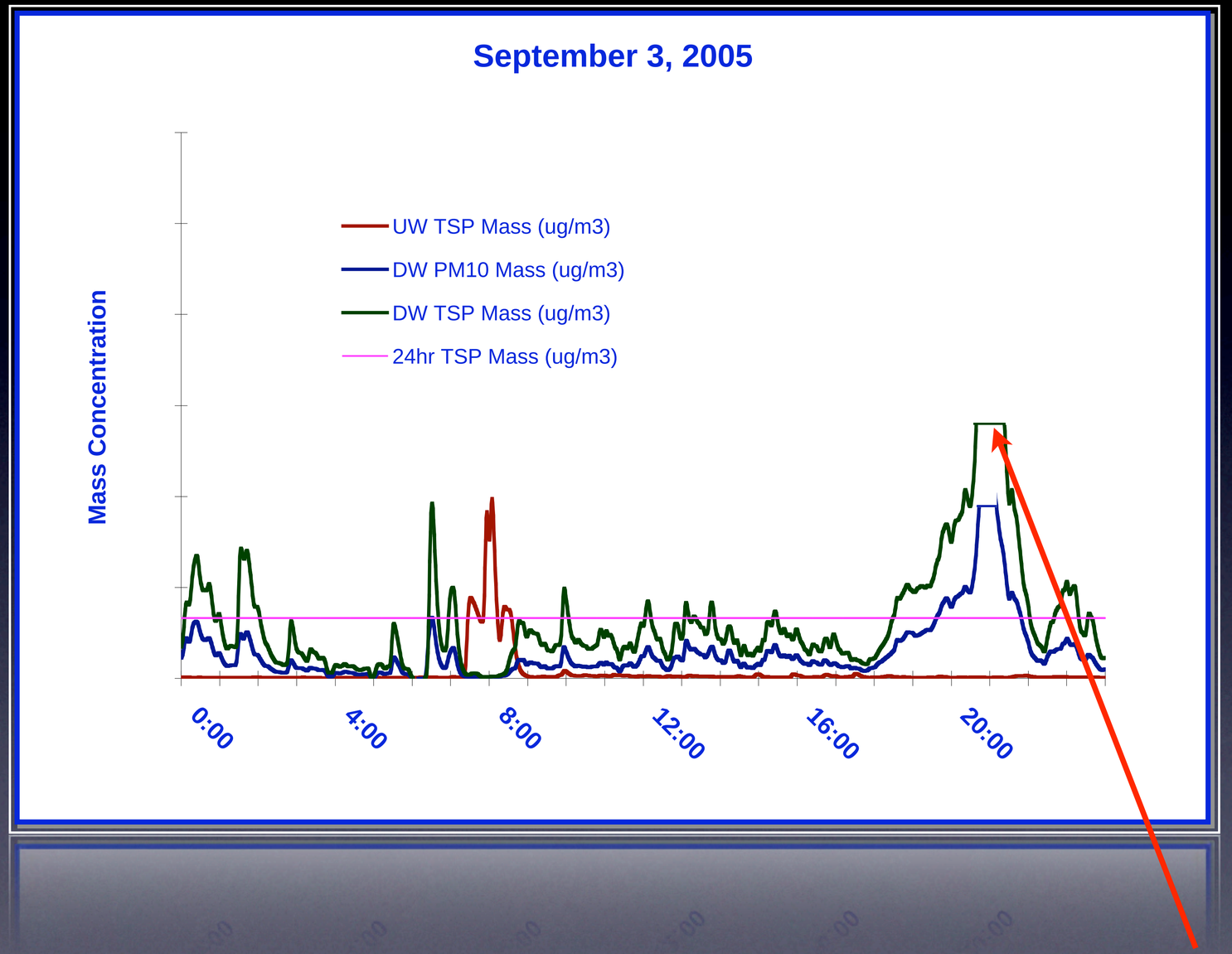

# Measuring Feedyard Evaporation

# The Evening Dust Peak - Why?

- Animal activity increases in the early evening as compared to midday
- Uncompacted manure is at its driest in the early evening
- Atmospheric stability at ground level usually increases at dusk




# Atmospheric Stability Usually Increases at Dusk




Primary Dust-Management Objective: *Clip the Peaks*

# Options for “Clipping the Peak”

- Modify animal behavior to reduce activity from dusk to midnight
- Reduce the dust-emission potential of the corral surface

# Estimating PM Emissions Arising from Horizontal-Mode Hoof Action

Jack Bush and Brent W. Auvermann
Texas AgriLife Research-Amarillo

Ronaldo Maghirang
Kansas State University



OL' DUSTY

Photo courtesy Dr. Rick Todd, USDA-ARS

# Measurement Techniques - Gases

- Surface isolation flux chambers
- Indirect techniques using downwind concentration measurements and appropriate models
- Mass-balance techniques

# “Inverse” Methods

- Measurements do not interfere with the governing microclimate
- Techniques integrate entire contributing source area
- Isolate source types by judicious selection of monitoring location

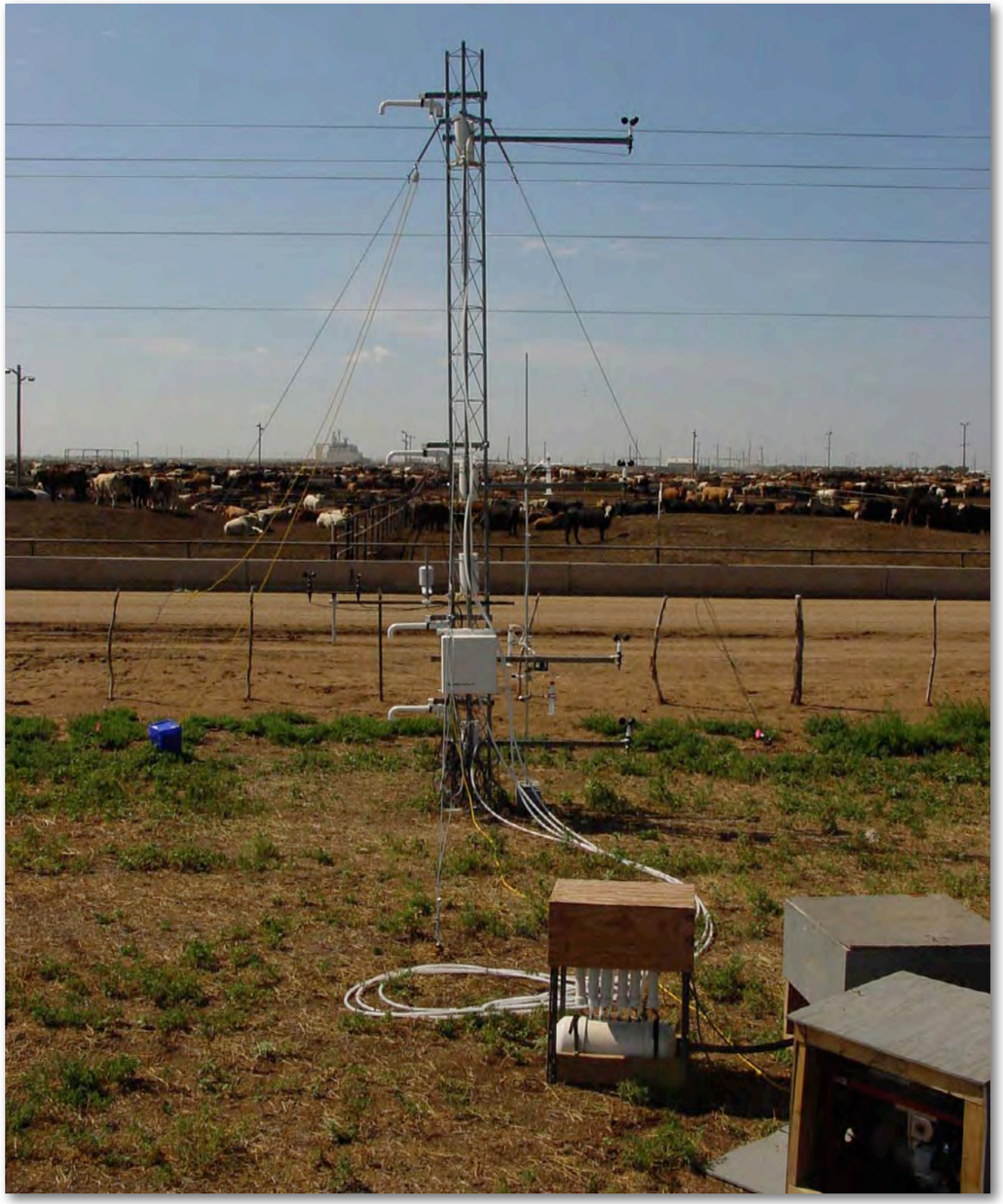
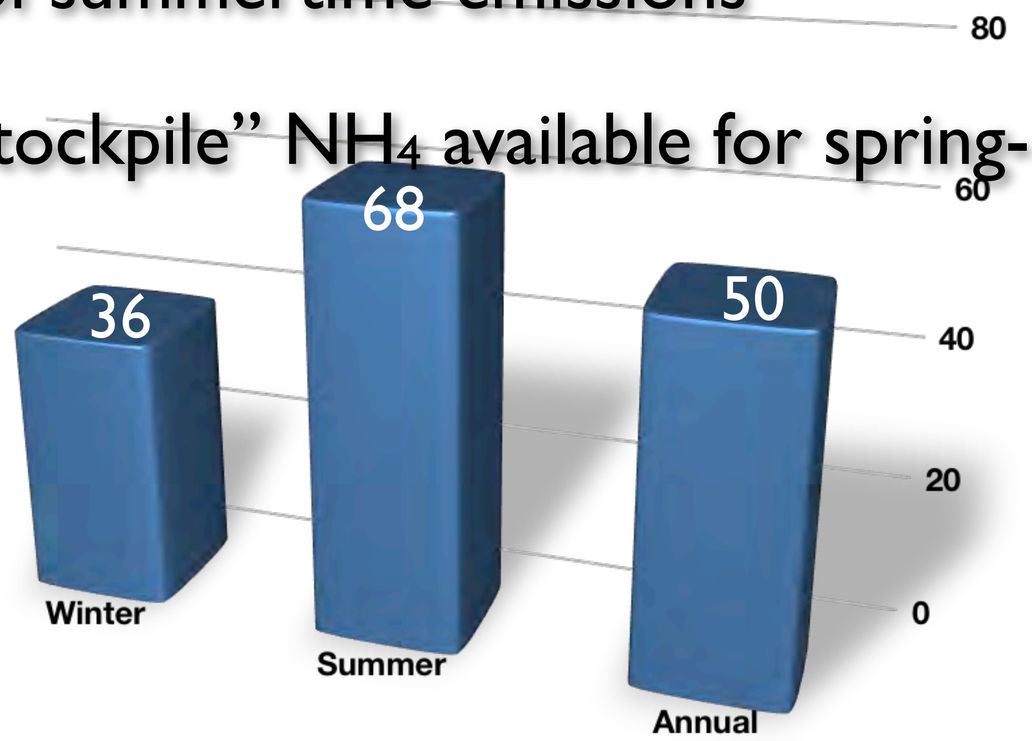


Photo courtesy Dr. Rick Todd, USDA-ARS

# $NH_3$ Emission Rates - Summary

- $NH_3$ emissions vary diurnally and seasonally
- Wintertime emissions ~1/2 of summertime emissions
- Low wintertime emissions "stockpile" $NH_4$ available for spring-summer release
- As a proportion of N fed:



# Objective 2:
# Abatement Measures and BMPs

Objective Coordinator: Brent Auvermann, Texas AgriLife Research-Amarillo

# Scheduling Sprinkler Dust Control to Maximize its Effectiveness

Gary W. Marek and Brent W. Auvermann
Texas AgriLife Research-Amarillo

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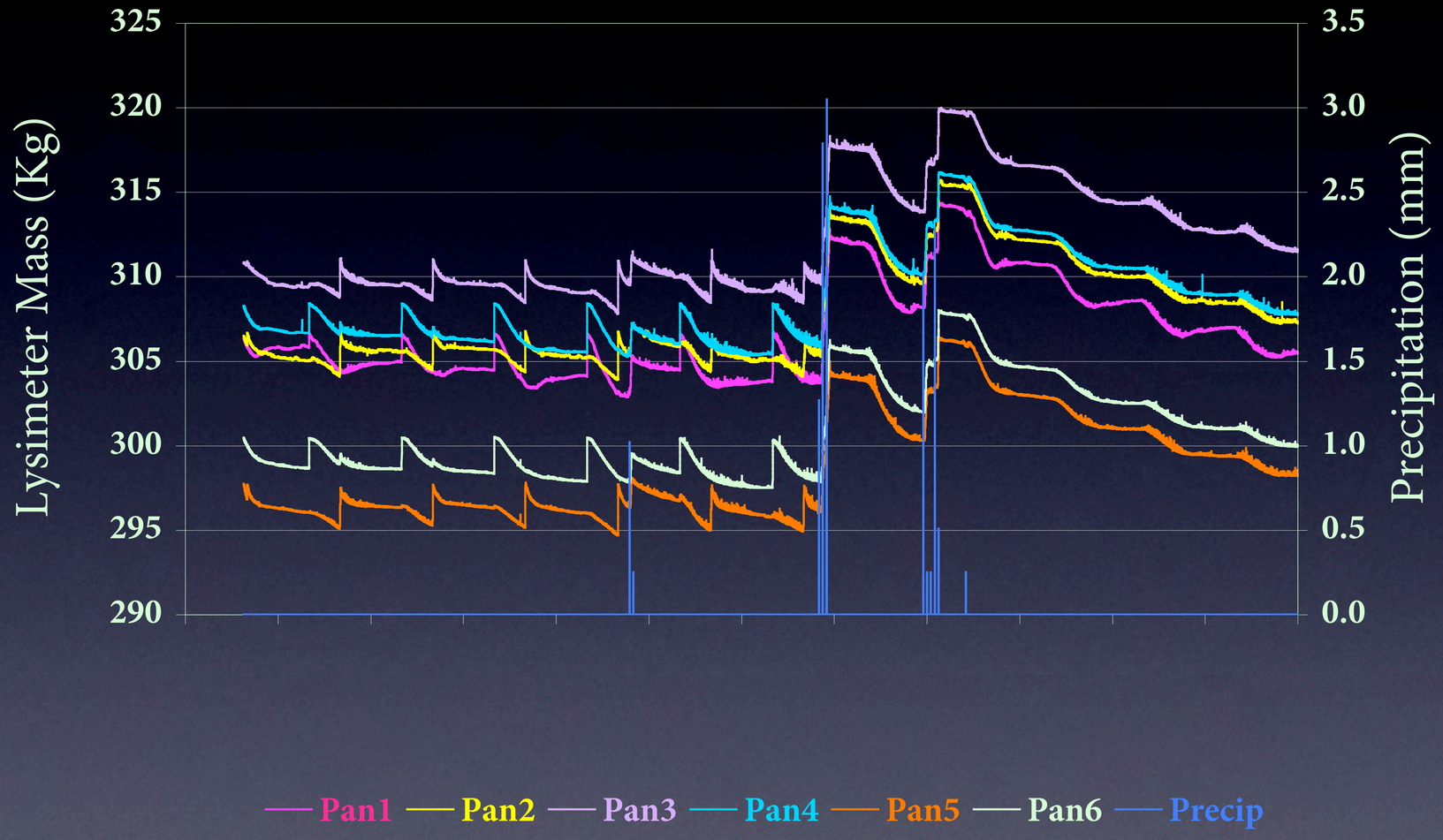
# Lysimeter Data, August 2007

Pans 1, 4, & 6 watered at 8:00 AM,  Pans 2, 3, & 5 watered at 4:00 PM



# Continuous PM Monitoring at Feedyards A and E: Preliminary Data

Jack Bush and Brent W. Auvermann
Texas AgriLife Research-Amarillo

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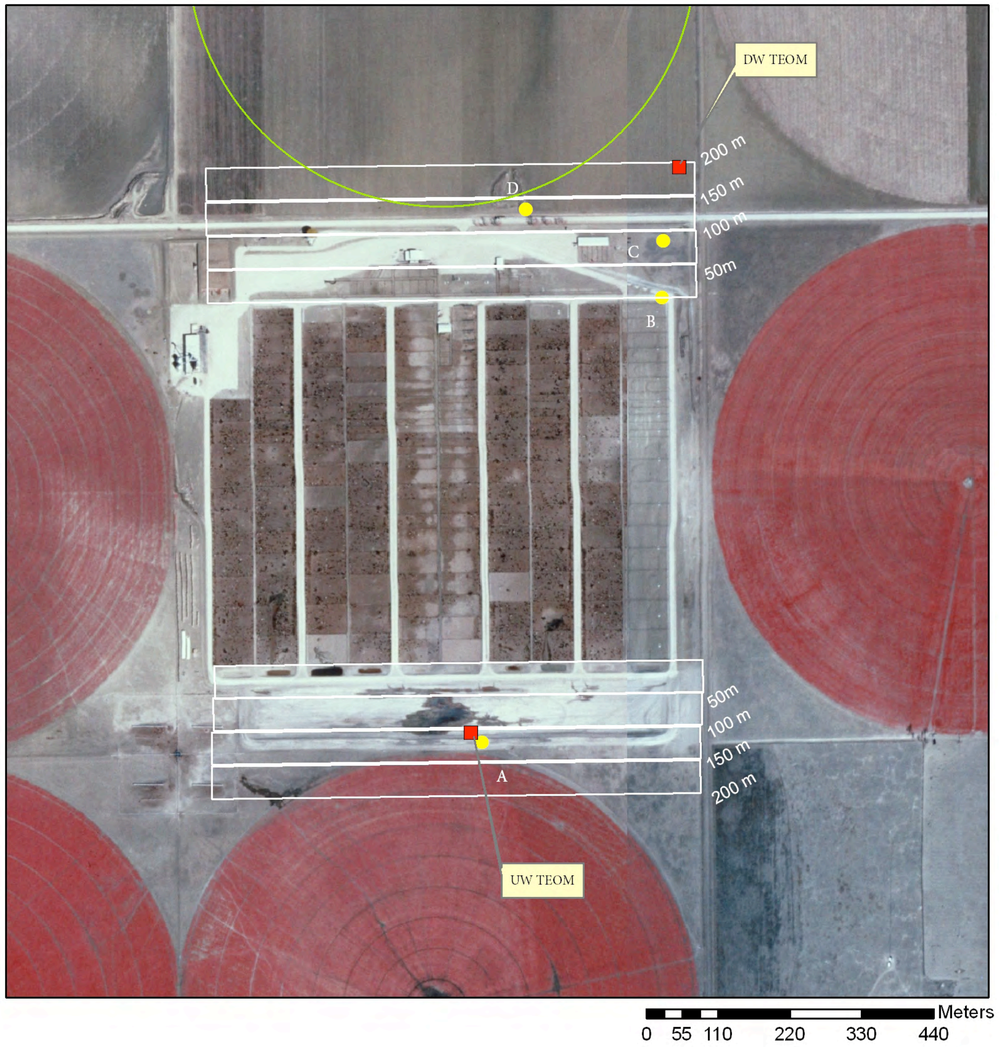



# FeedYard E
# Proposed PM Sampling Sites

N

Texas Agricultural Experiment Station
THE TEXAS A&M UNIVERSITY SYSTEM


# FeedYard A
# Proposed PM Sampling Sites

N

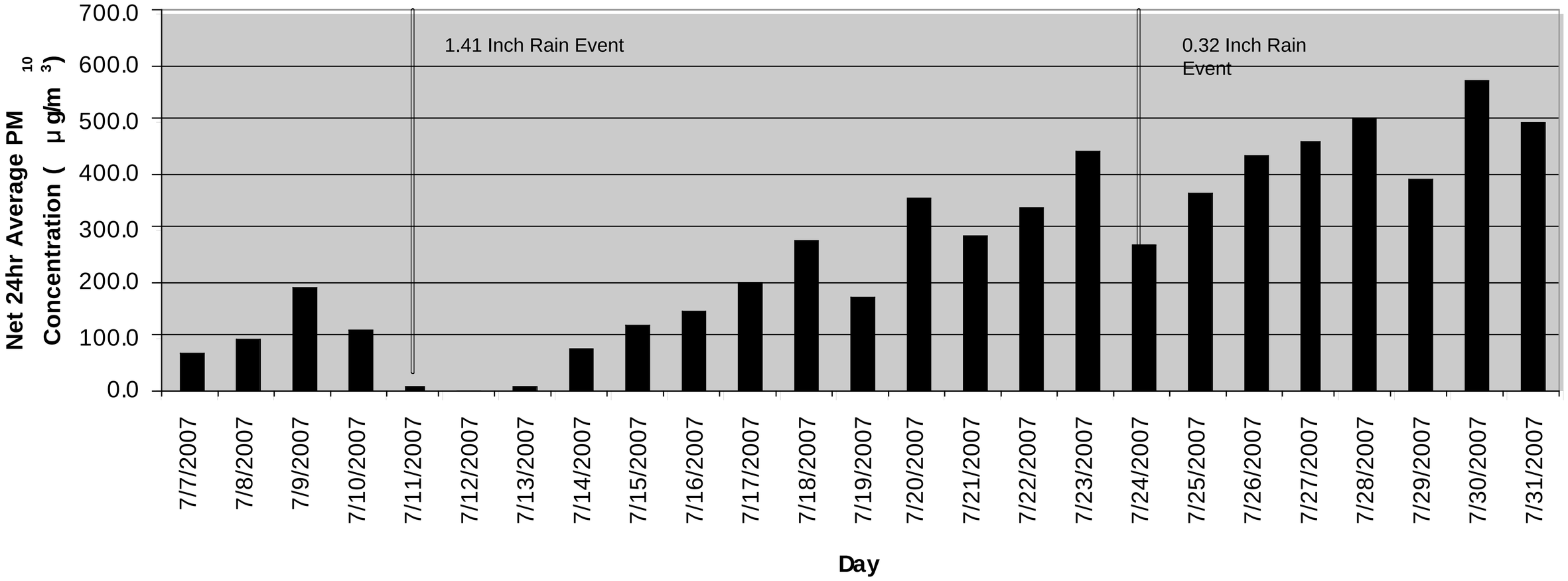
Texas Agricultural Experiment Station
THE TEXAS A&M UNIVERSITY SYSTEM

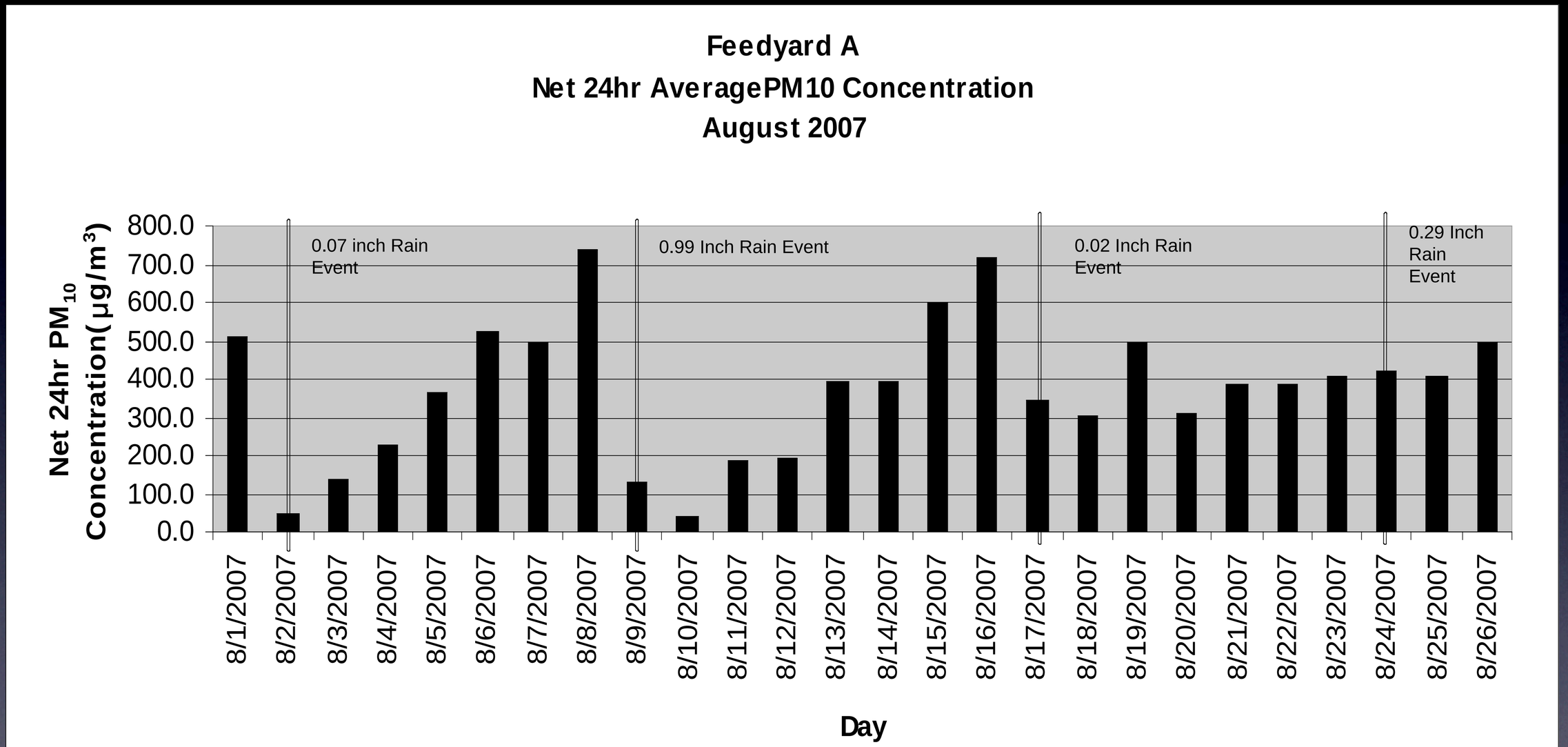

Upwind
Upwind Avg
Downwind
Downwind Avg
Mass Concentration
(µg/m3)
4500
4000
3500
3000
2500
2000
1500
1000
500
0
0:00
2:00
4:00
6:00
8:00
10:00
12:00
14:00
16:00
18:00
20:00
22:00
Time

**Feedyard A**

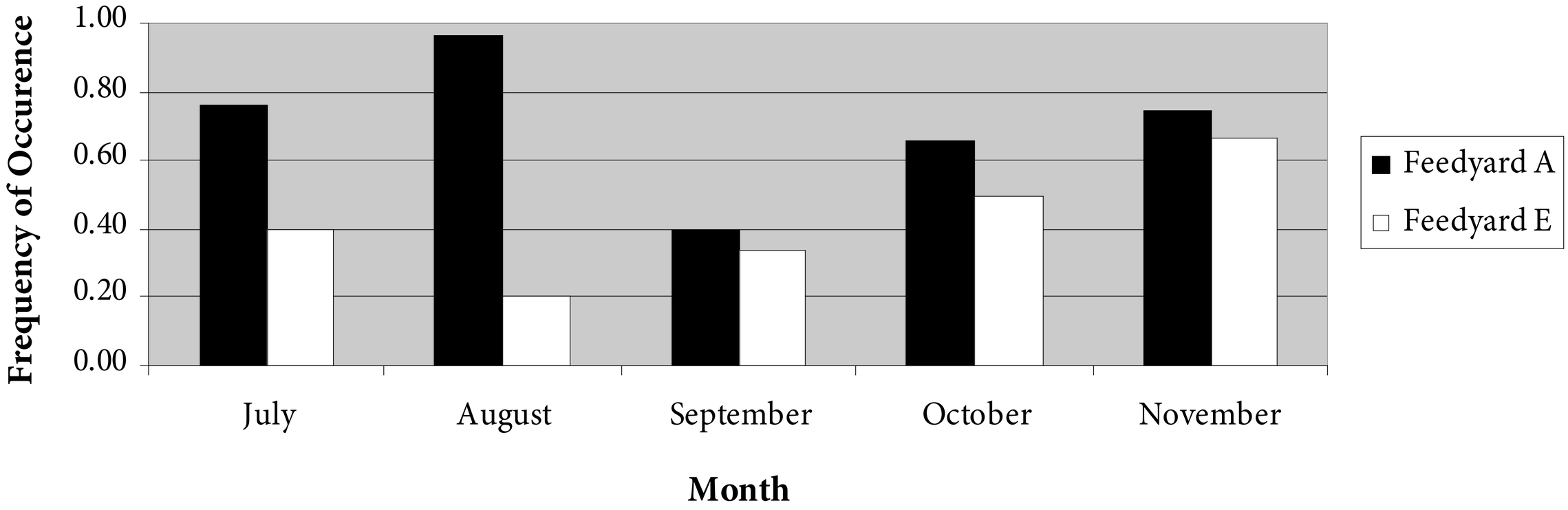
**24hr Average PM 10 Concentration**

**July 2007**




Feedyard A
Net 24hr AveragePM10 Concentration
August 2007
Net 24hr PM10 Concentration(µg/m3)
800.0
700.0
600.0
500.0
400.0
300.0
200.0
100.0
0.0
0.07 inch Rain Event
0.99 Inch Rain Event
0.02 Inch Rain Event
0.29 Inch Rain Event
8/1/2007
8/2/2007
8/3/2007
8/4/2007
8/5/2007
8/6/2007
8/7/2007
8/8/2007
8/9/2007
8/10/2007
8/11/2007
8/12/2007
8/13/2007
8/14/2007
8/15/2007
8/16/2007
8/17/2007
8/18/2007
8/19/2007
8/20/2007
8/21/2007
8/22/2007
8/23/2007
8/24/2007
8/25/2007
8/26/2007
Day

# Frequency of Evening Dust Peak



- In 2005, the latest meaningful rainfall was around 9/1
- Some feedyards rolled the dice:
  - Winterized sprinkler systems in September in anticipation of the October freeze (SOP)
  - Built wintertime mounds using what they had available: *dry, uncompacted manure*
  - Banked on some timely rainfall to ensure compaction
  - Didn't get it
  - September diesel fuel ($$$) and labor costs ($$$) were wasted

# Take-Home Messages

- Applying water to an open-lot surface, either passively or actively, is not a cure-all
- Frequent manure harvesting (>1 per turn) will decrease water requirements and increase water effectiveness
- Use the off-season to get ready
- Prioritize within the yard *and* the corral

# Take-Home Messages

- Manure harvesting and moisture control will have a synergistic effect
- Building mounds with dry manure doesn't work; needs 25-30% moisture for compaction
- Manure harvesting makes supplemental water go further (Auvermann, 2003; Razote et al., 2006)

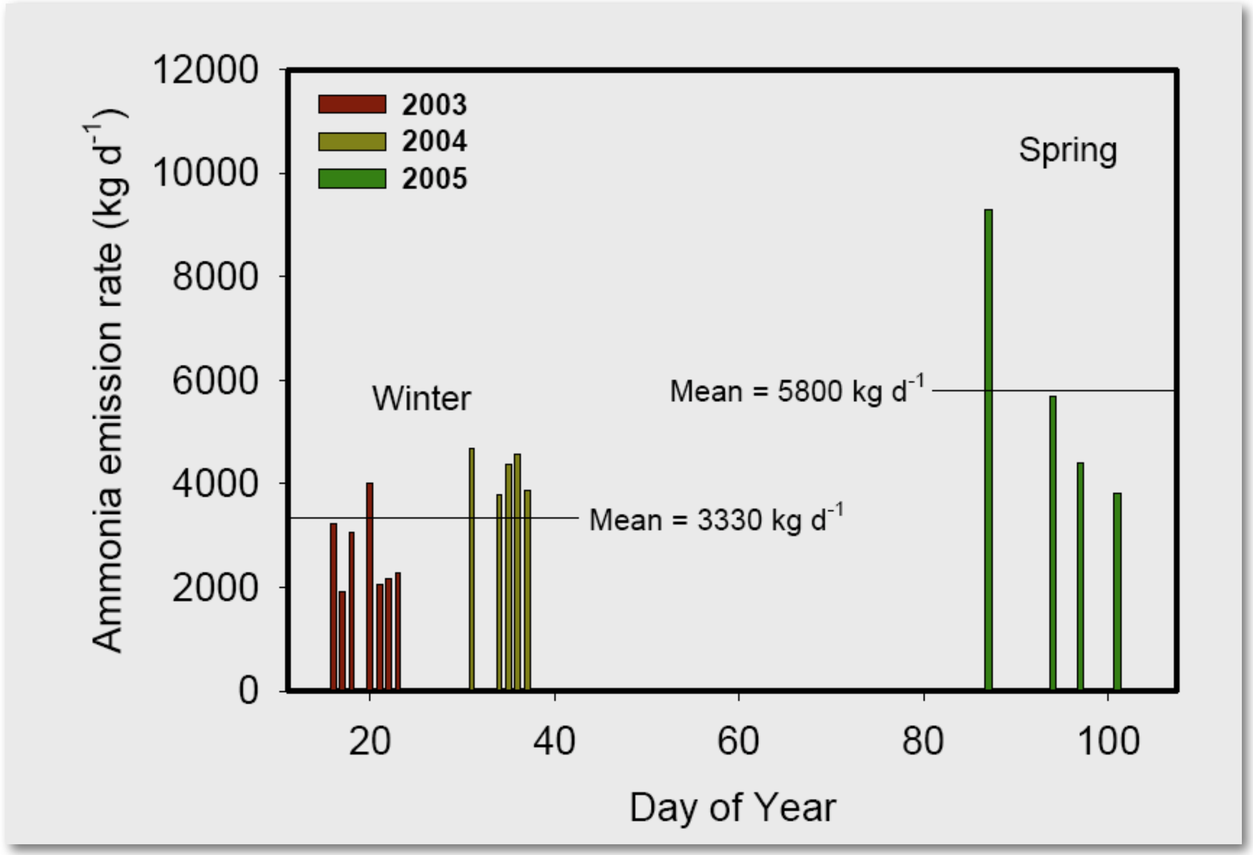

# Manure Harve$ting

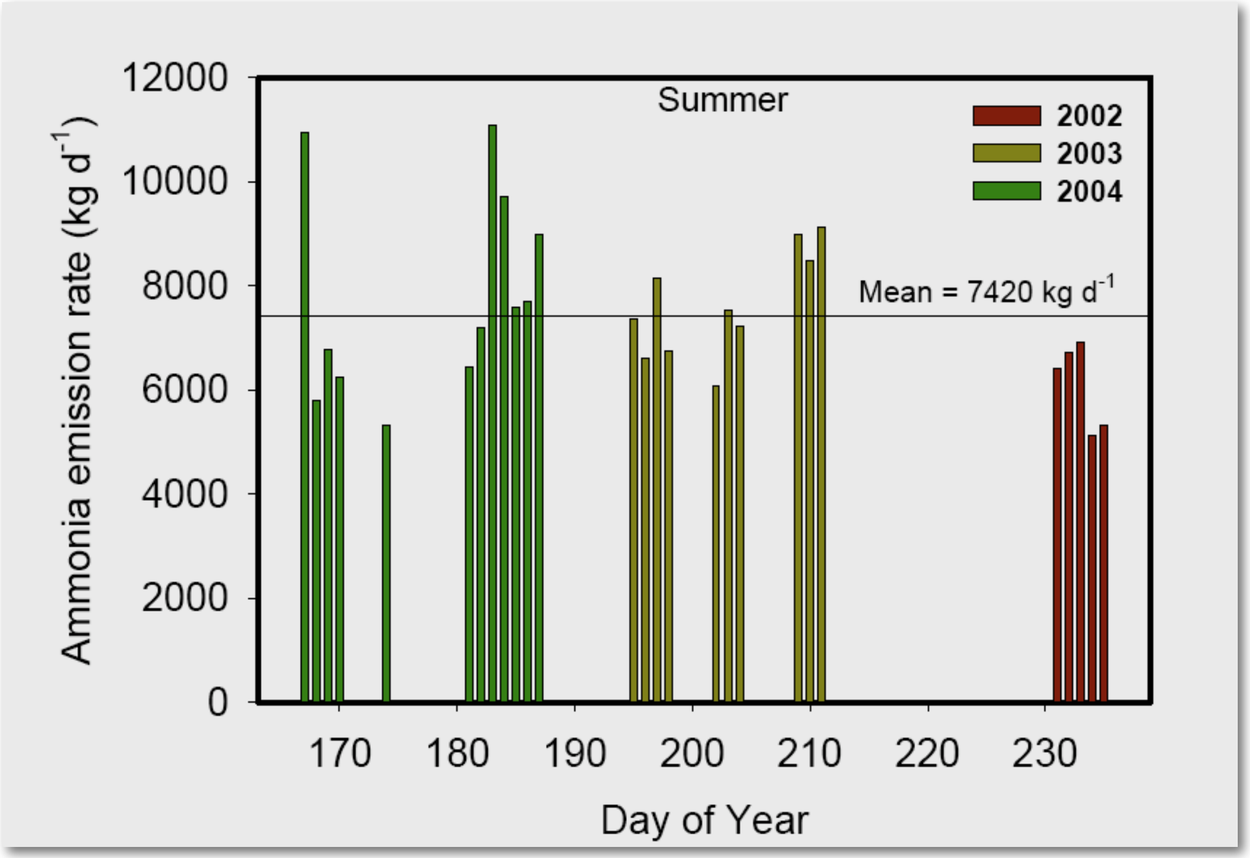

(Incidentally, this dry material probably
contains 3,500 BTU/lb, as-is.)

# Objective 3: Emission Factors, Dispersion Modeling, and Regulations

Objective Coordinator: Dr. Calvin B. Parnell, Jr., Texas A&M University

130-240 lb $NH_3$-N/1000 hd-d



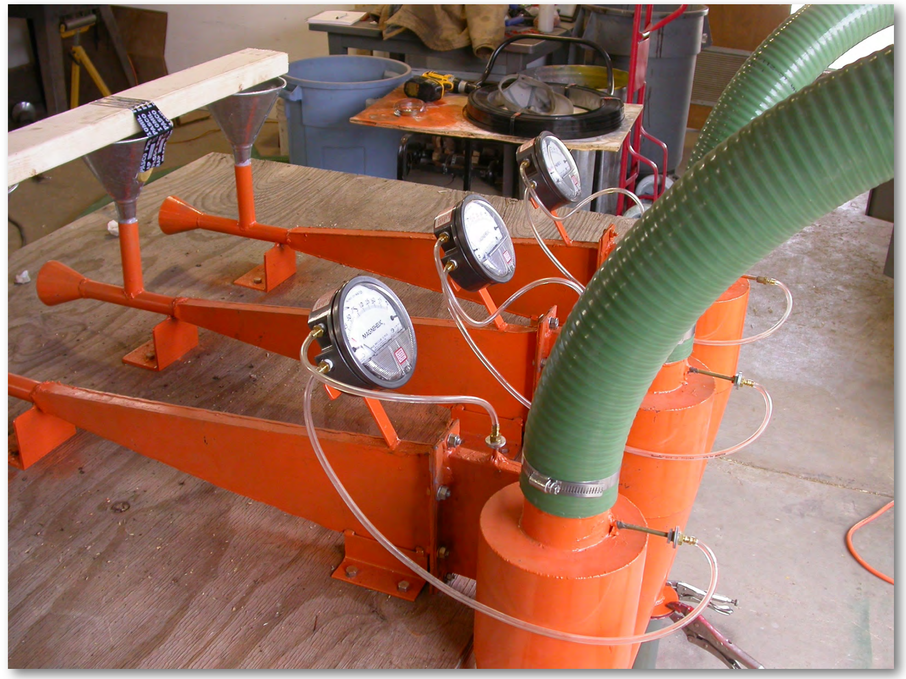




280-300 lb $NH_3$-N/1000 hd-d

Charts courtesy Dr. Rick Todd, USDA-ARS

# Objective 4:
# Animal Health

Objective Coordinator:  Dr. Andy Cole, USDA/ARS-Bushland



# Years 6 and Beyond

- Emissions Processes and Measurement Techniques
- Abatement Measures
- Emission Factors, Dispersion Modeling, and Regulations
- Animal Health
- Technology Transfer

- Process-Based Modeling (NRC, 2003)
- Abatement Measures and Receptor Impacts
- Emission Factors, Dispersion Modeling, and Regulations

# Process-Based Modeling (NRC, 2003)

- $NH_3$:  process models have mushroomed in the past 5-10 years; adapt, assemble, validate
- PM:  animal behavior * surface condition
- More precise source resolution
- Validate against indirect methods of emission measurement

# Abatement Measures & Receptor Impacts

- Abatement Measures
  - Sprinklers:  continue paired-feedyard experiment, lysimetry/timing, use of effluent
  - Manure harvesting:  commercial-scale evaluation, extend to biofuel- and fertilizer-value implications
  - Surface treatments:  benchtop evaluations

# Bushland Experimental Feedyard

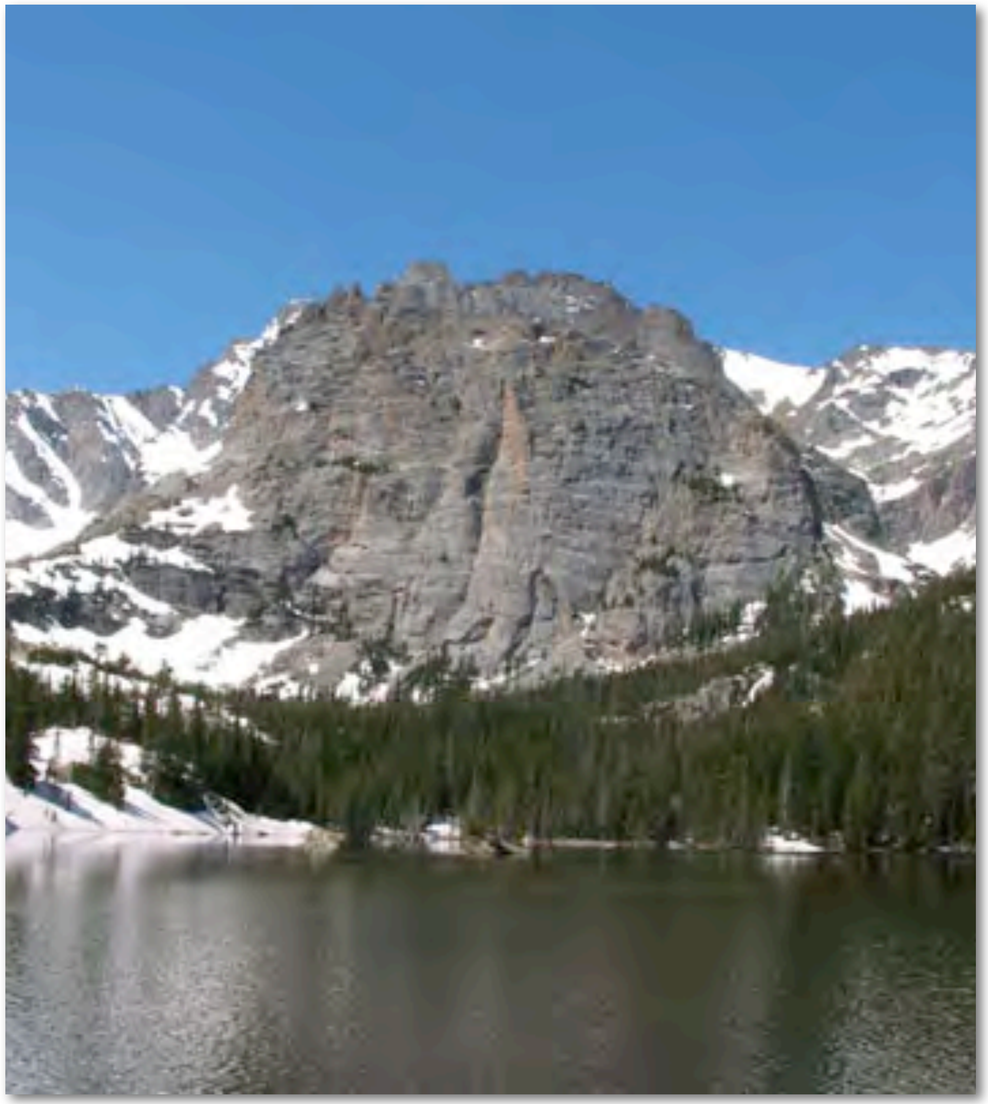
- Small-scale validation of sprinkler system effectiveness, surface treatments, nutritional strategies
- Adapt sprinkler system to blend holding-pond effluent with fresh water
- Compare higher heating value (HHV) of manure harvested from paved, unpaved pens

# Abatement Measures & Receptor Impacts

- Receptor Impacts
  - Nitrogen deposition to sensitive ecosystems
  - Animal health
  - Odor “footprint”

# N Deposition: The Basic Idea

- Pristine RMNP ecosystems evolved with low nutrient inputs
- These ecosystems now exhibit signs of ecological shifts
- The shifts are consistent with nutrient enrichment (primarily N)
- Wet deposition of N appears to have increased in the Park over the past couple of decades
- Hypothesis: Increased wet deposition of N is responsible for irreversible shifts in high alpine ecosystems
- Corollary: Reducing wet deposition of N would head off those ecological shifts



# Ecological Effects of Alpine N Enrichment

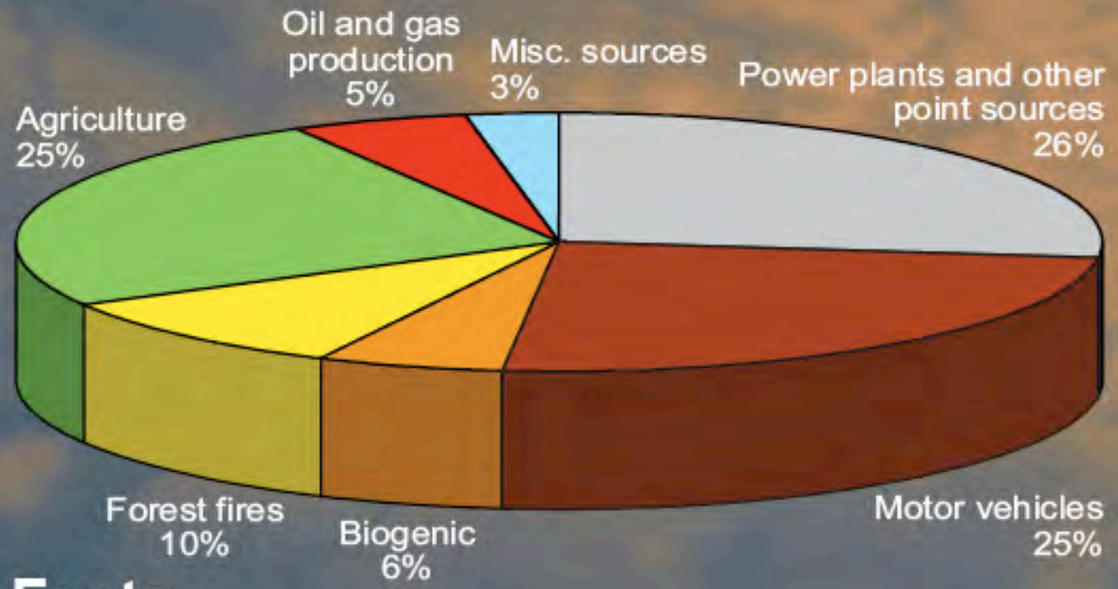
- Water quality: increased N concentrations in streams and lakes
  - Eutrophication
  - Change in microbial flora (diatoms)
- Vegetation: From wildflowers to grasses and sedges
- Soil acidification as $NH_4$ oxidized to $NO_3$

Source: Baron et al. (2005)

# Sources

Nitrogen compounds (e.g., $NO_X$, ammonia) and sulfur compounds are emitted into the atmosphere from a variety of air pollution sources, including automobiles, power plants, industry, agriculture, and fires. Colorado's Front Range is an area of rapid population growth, escalating urbanization, oil and gas development, and agricultural production. Increases in these activities result in corresponding increases in nitrogen deposition in mountain ecosystems.

## Nitrogen Emissions in Colorado




## Facts

- 2/3 of the state's population lives along the Front Range.
- Ammonium nitrate is a common crop fertilizer and results in emissions of ammonia.
- Some chemical transport models suggest that 25-30% of nitrate and 45-50% of sulfate is associated with emissions from within Colorado.

Source: Rocky Mountain Atmospheric Nitrogen and Sulfur (RoMANS) Brochure

# What Happens to Emitted $NH_3$?

- Atmospheric residence time of $NH_3$ gas is fairly short (<7 days) due to its high reactivity with surfaces, with water, and with acid gases
- $NH_3$ sources tend to be at ground level (i. e., not stack emissions)
- Dry deposition of gaseous $NH_3$ dominates near sources
- Wet deposition of particle-phase $NH_4^+$ dominates away from sources

Source: Asman et al. (1998)

# Watson et al. (1996)

- Northern Front Range Air Quality Study (NFRAQS)
- Seasonality, composition, and distribution of PM along the I-25 and US85 corridors
- Major conclusion: Study area is relatively enriched with respect to $NH_3$ as compared to $SO_x$ and $NO_x$
- Would changes in $NH_3$ concentration give rise to changes in secondary fine particles (sulfates and nitrates)?

# More NFRAQS Conclusions

- Virtually all of the sulfate and nitrate in the NFR can be accounted for as secondary ammonium salts ($PM_{2.5}$)
- If $NH_3$ levels were reduced by 50%...
  - ...most of the available $HNO_3$ would be neutralized
  - ...particle $NO_3$ would be reduced by only 15%
- Beyond 50% reduction in $NH_3$, particle $NO_3$ would decrease proportionately with $NH_3$

# Two Kinds of Deposition

- WET deposition - rainfall, snowfall, fog
  - Gases and particles dissolve into liquid phase to form solution
  - Solution deposits on surfaces (canopies, vegetation, soils, surface water) as fog, dew or precipitation
- DRY deposition - gases and particles impact or settle onto surfaces without assistance from condensing water

# Anatomy of an NADP Site

Deposition (kg/ha/yr) = Precipitation (mm/wk) * Concentration (mg/l) * 0.52

# NADP Sites in Rocky Mountain National Park



Google Maps

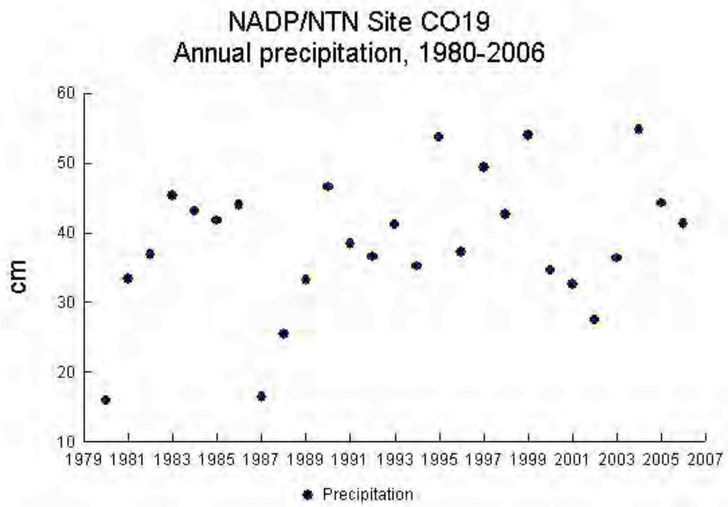
Address +40° 21' 50.04", -105° 34' 50.16"

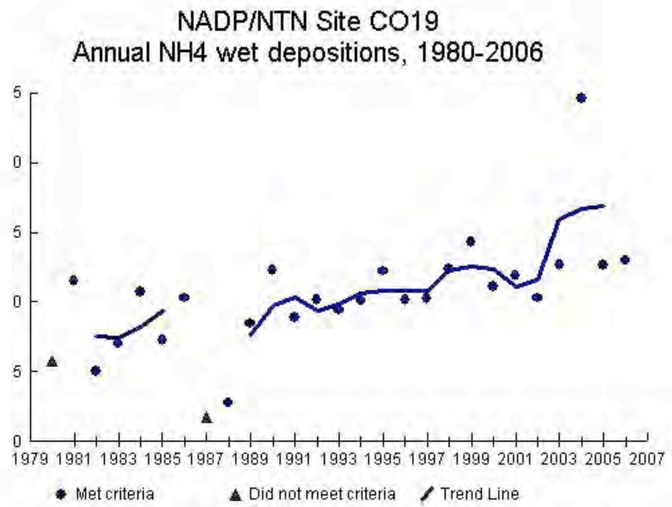


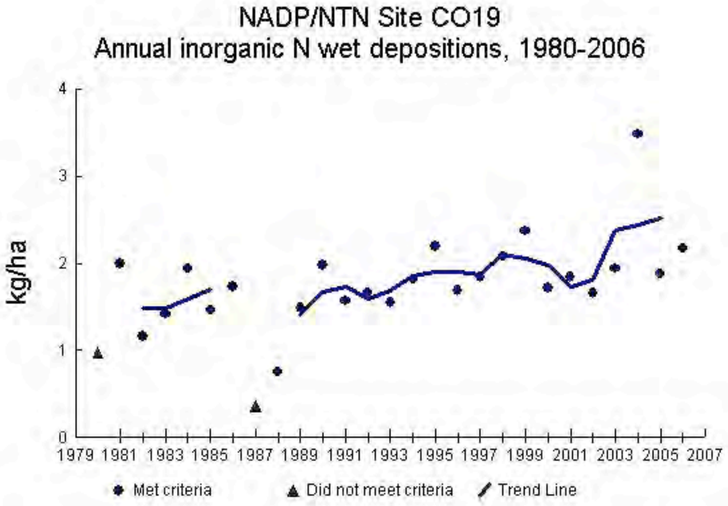
# NADP Site CO19 "Beaver Meadows"

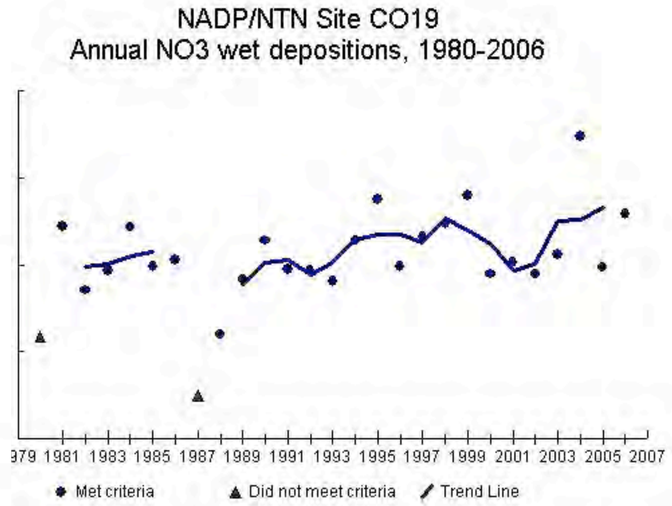
# NADP Site CO98 "Loch Vale"

# Deposition and Precipitation, CO19



# RoMANS:
## A Source-Apportionment Study

- Two models required
  - MM5 (wind fields, precipitation)
  - CAMx (chemical transport)
- Tracer sources inside and outside of CO
- Interim finding: 33% of $NH_3$ and 50% of $NO_x$ affecting RMNP are from CO sources

Source: Barna et al. (2007)

# $NH_4^+$ ion concentrations, 2004