TEXAS A&M AGRILIFE RESEARCH

Cattle Feeding & Environmental Air Quality

Some Research Highlights from the 2002-2013 USDA-NIFA Special Research Project:

"Air Quality: Reducing Emissions from Cattle Feedlots & Dairies (TX & KS)"

Reported by

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Texas A&M AgriLife Research & Extension Center

Amarillo TX

Presented to:

USDA-Agricultural Air Quality Task Force

College Station, TX

August 21, 2014

Significant multi-year funding has included:

Federal, State & Private

- ***Primary Funding:***
- **USDA-NIFA, Air Quality: Reducing Emissions from Cattle Feedlots & Dairies** (TX & KS), 2002-13 (8-years funding).
- Other NIFA-AFRI & NSF spinoff grants: n~10

- ***Important co-funding has included:***
- **TX A&M AgriLife *Research*—***State Air Quality Legislative exceptional item, 1999-present.*
- **KSU**– *similar parallel State funding.*
- **USDA- ARS: Distillers Grains cattle feeding research program**,~2005-present. *Included Cooperative Agreements with TX A&M AgriLife Research & WTAMU.*
- **TX A&M AgriLife: WDG/Cattle Feeding,** State *Legislative exceptional item, 2007-present.*
- **USDOE-Golden CO: Bioenergy from dairy & cattle feedlot manure**, *2006-2012.*
- **Private industry & commodity assn. grants** *(several)***:** TX, CA, NM.
- **Regulatory agencies:** TCEQ, others.

USDA-NIFA Federal Air Quality Initiative (FAQI):

"Air Quality: Reducing Emissions from Cattle Feedlots & Dairies (TX & KS)"

- **Objectives (4):**

A. Abatement measures & receptor impacts.
B. Process-based emission models.
C. Dispersion modeling, regulation & emission factors.
D. Technology transfer to stakeholders.

- **Research Partnering agencies/universities:**

TX A&M AgriLife Research *(lead agency)*; TX A&M AgriLife Extension; KSU; WTAMU; USDA-ARS. *Collaborator: UN-L Extension.*

- **Industry Partners**: *Stakeholder Advisory Committee*
  - TCFA, KLA, NCBA, TFB, TAD, USDA-NRCS, TCEQ, USEPA Reg. 6&7.

USDA-NIFA Federal Air Quality Initiative (FAQI):

Project team

Texas A&M AgriLife Research/Extension

- Amarillo/Vernon faculty:
  - Brent Auvermann
  - Steve Amosson
  - Ken Casey
  - Kay Ledbetter
  - Jim McDonald (AgriLife & WT)
  - Ted McCollum
  - Seong Park (Vernon & AMA)
  - Bill Pinchak (Vernon)
  - J. Osterstock/Pablo Pinedo
- BAEN College Station faculty:
  - Calvin Parnell
  - Brock Faulkner
  - Sergio Capareda
  - Saqib Mukhtar
  - Bryan Shaw
  - Ron Lacey
  - Russell McGee

Subcontractors:

- Kansas State University
  - Ronaldo Maghirang
  - J. Pat Murphy
  - Joe Harner
- USDA-ARS/Bushland:
  - Andy Cole
  - Richard Todd
- West Texas A&M University:
  - Mike Brown (WT & AgriLife)
  - David Parker
  - Marty Rhoades
- Univ. of Nebraska-Lincoln:
  - Richard Stowell
- **Administrative Advisors**
  - Ray Knighton, USDA-NIFA
  - Ron Lacewell, TX A&M AgriLife

Approaches to Emission Sampling

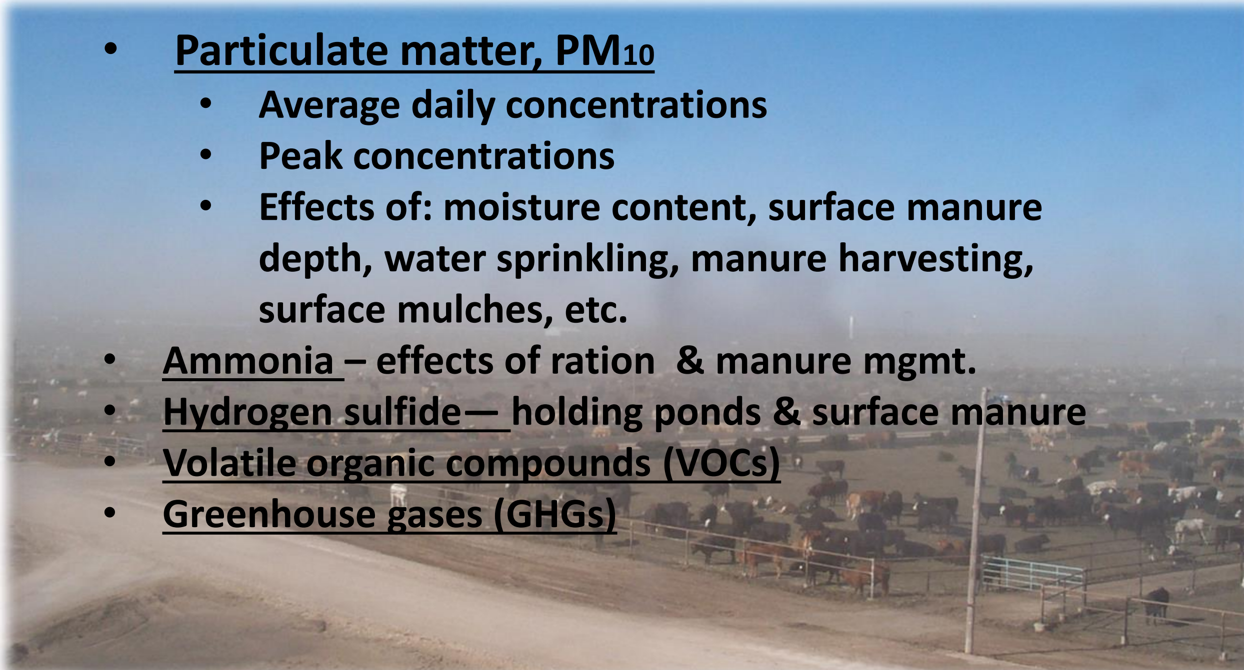
- Source-specific:
- Examples:
  - Flux chambers
  - Wind tunnels
  - Calorimetry chambers.
- Comment:
  - Multiple, indiv. sources.
  - Semi-invasive;
  - Important for *relative or short-term* comparisons;
  - Fairly high precision;
  - Accuracy *depends* on: protocols & instrumentation for sampling & analysis, frequency, intensity, scale, etc.

- Source-integrated:
- Examples--
  - PM_{10} sampler array.
  - Open path lasers, TDLAS
  - Open path FTIR.
- Comment:
  - Integrates across multiple sources.
  - Non-invasive.
  - Seeks *absolute* values.
  - Accounts for spatial & temporal variability.
  - Ambient air or open paths.

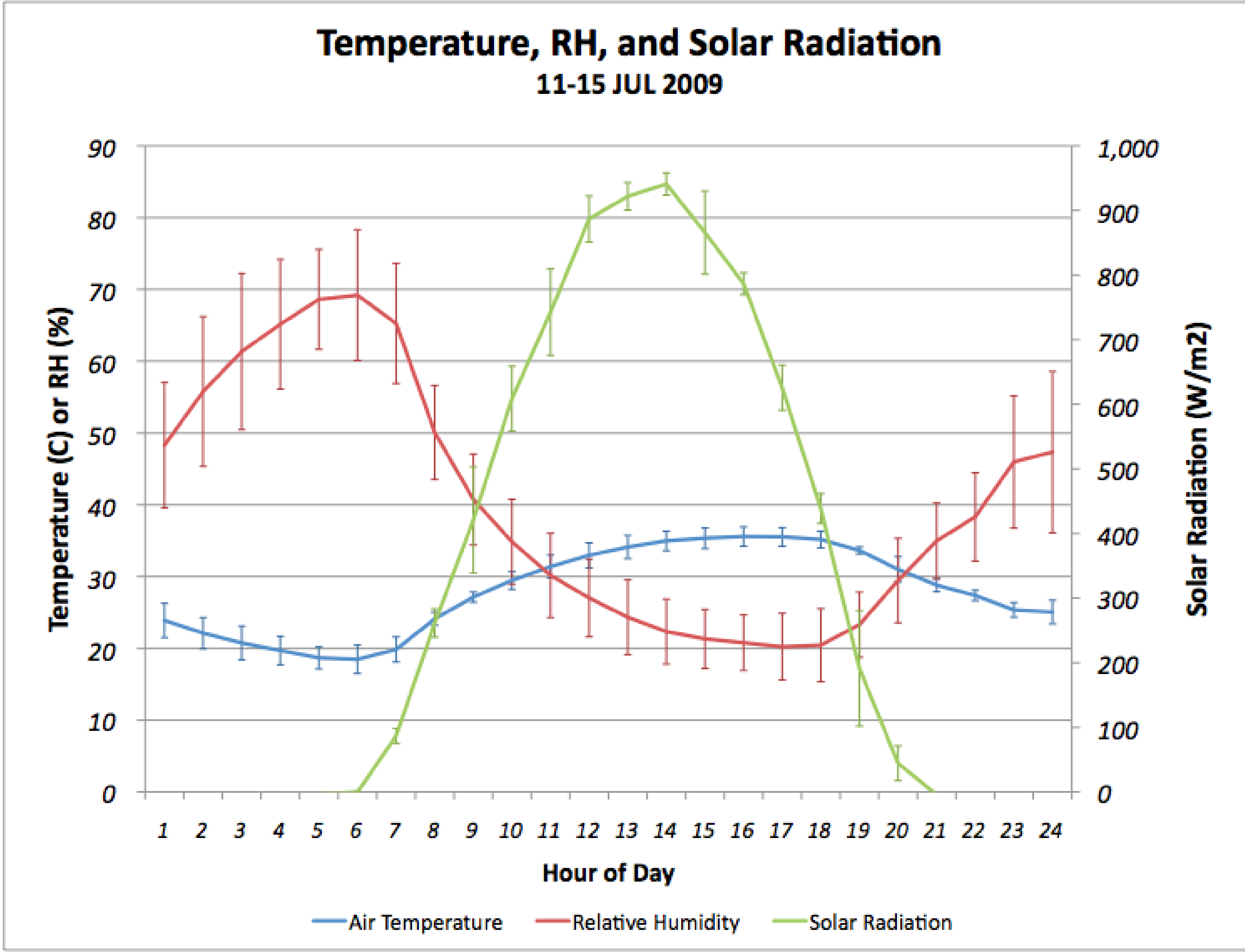
Common Emission Expressions

- **Emission concentrations**:
  - mass/volume (μg/m^3)
  - Volume/volume, ppmv or ppbv.
- ***With inverse dispersion modeling***, measured concentrations are used to produce calculated values for:
  - **Emission rate**, mass/time, μg/sec, or kg/day .
  - **Emission flux**, mass/area/time: μg/m^2/sec, or kg/m^2/yr.
  - **Emission factor**, mass/time/unit of production or throughput: e.g. lbs/day/1,000 hd cattle.

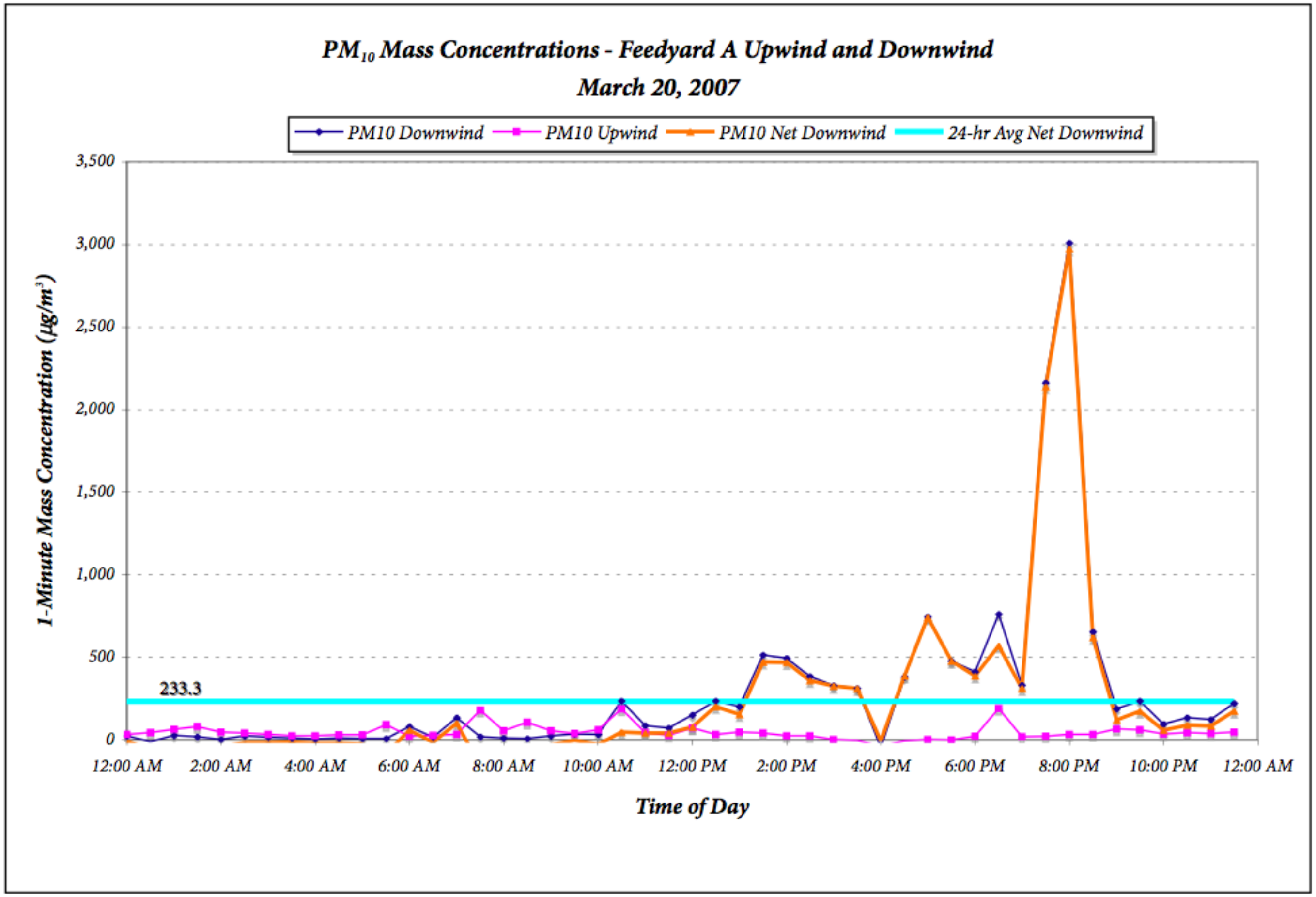
Objective A. Abatement Measures & Receptor Impacts



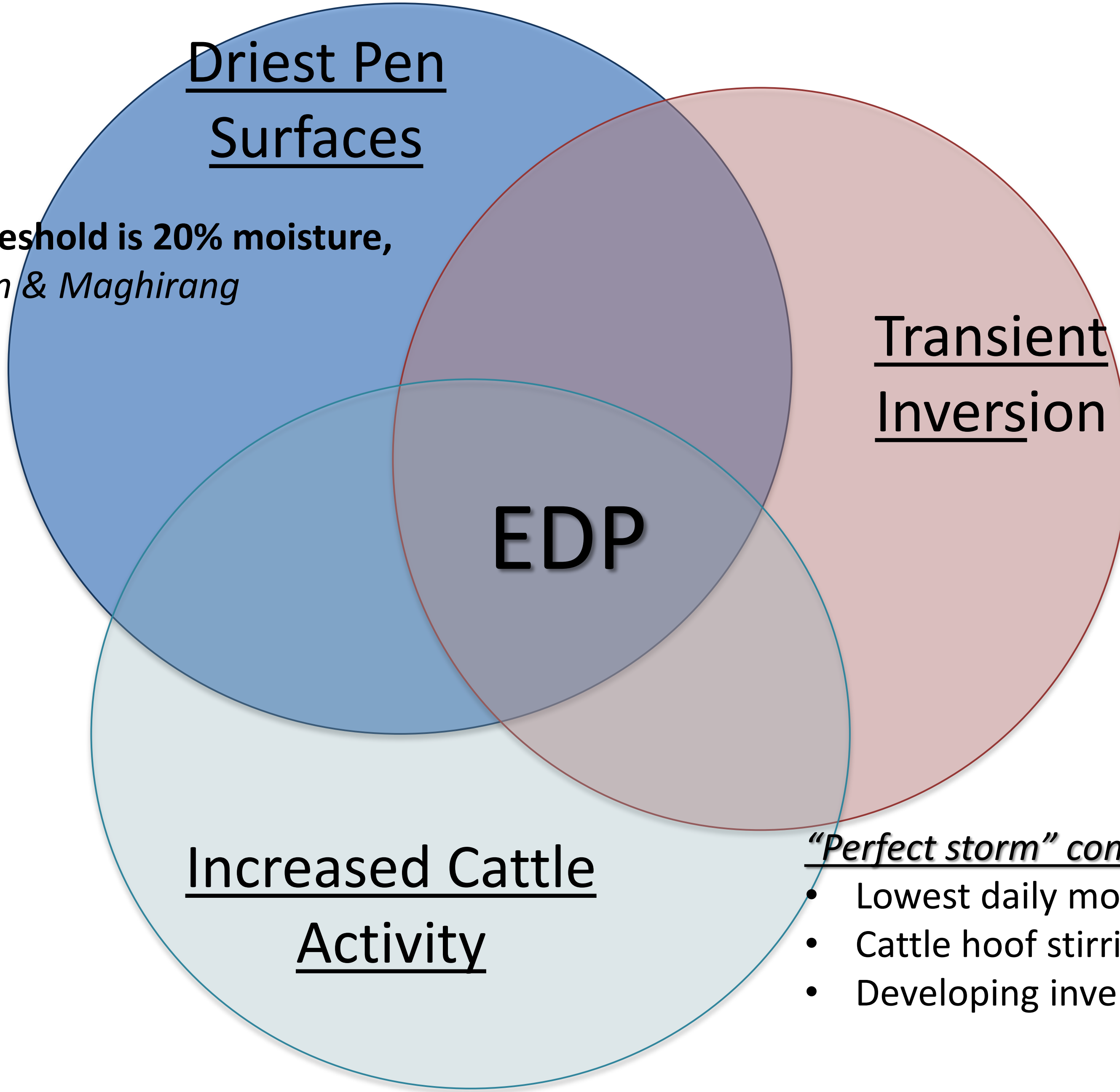
- Particulate matter, PM_{10}
  - Average daily concentrations
  - Peak concentrations
  - Effects of: moisture content, surface manure depth, water sprinkling, manure harvesting, surface mulches, etc.
- Ammonia – effects of ration & manure mgmt.
- Hydrogen sulfide— holding ponds & surface manure
- Volatile organic compounds (VOCs)
- Greenhouse gases (GHGs)


Temperature, RH, and Solar Radiation
11-15 JUL 2009
Temperature (C) or RH (%)
Solar Radiation (W/m2)
Hour of Day
90
80
70
60
50
40
30
20
10
0
1,000
900
800
700
600
500
400
300
200
100
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Air Temperature
Relative Humidity
Solar Radiation

PM10 MASS Concentration vs. Time of Day



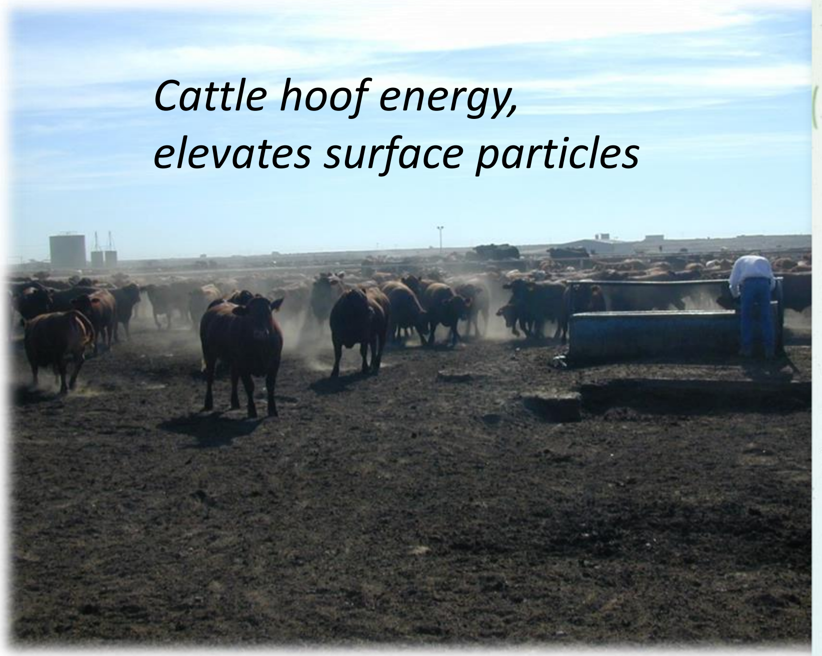
Evening Dust (PM) Peak (EDP)

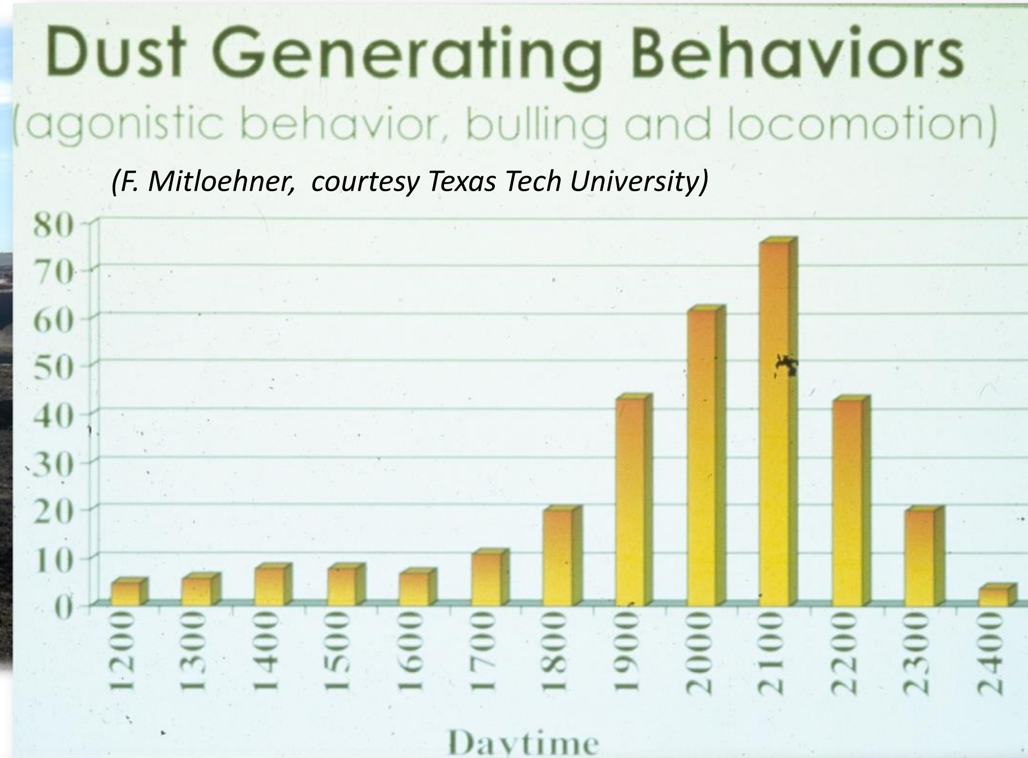


Critical threshold is 20% moisture,
Auvermann & Maghirang

"Perfect storm" conditions:

- Lowest daily moisture;
- Cattle hoof stirring
- Developing inversion condition.



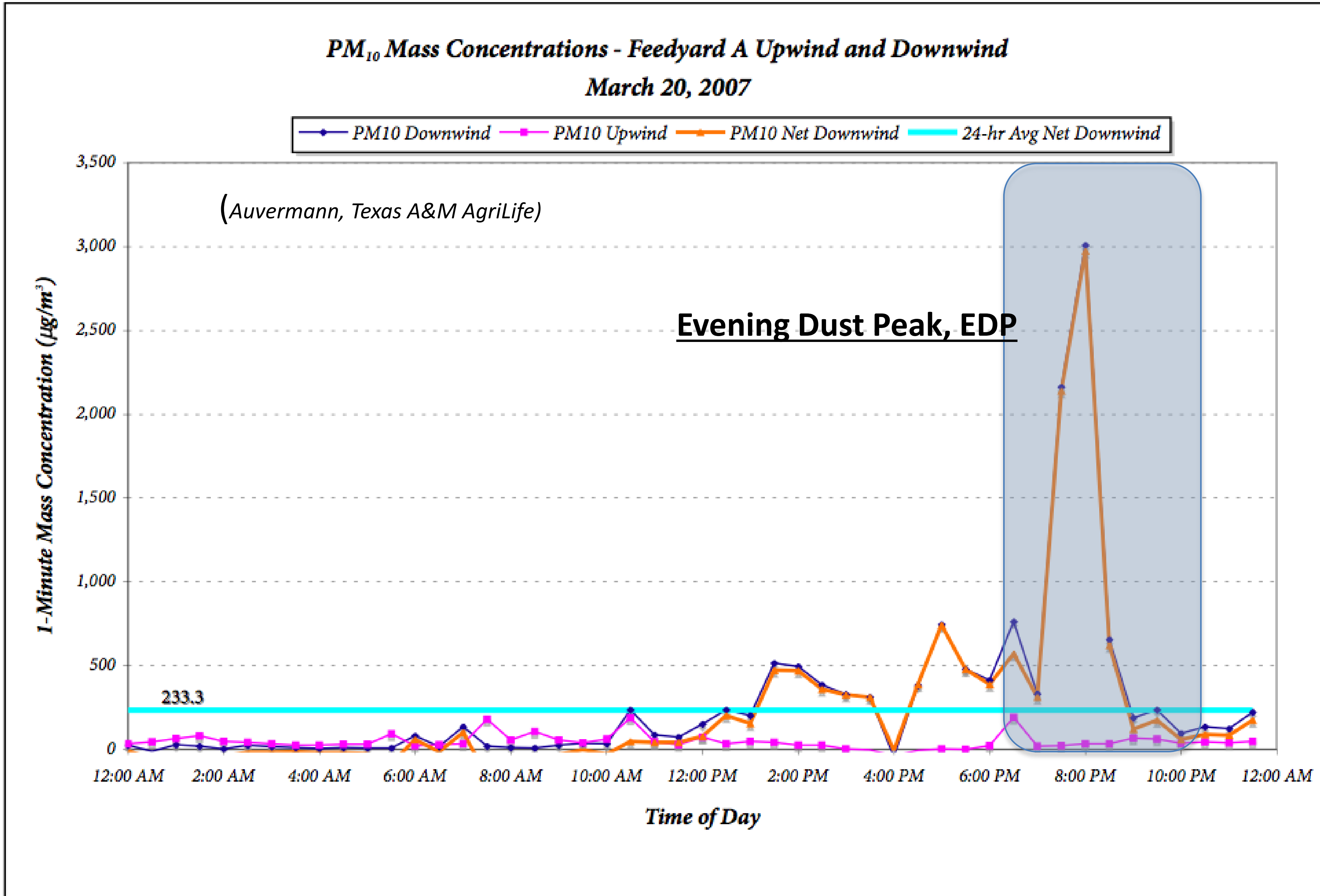


<u>Conceptual model</u> *<u>(Auvermann):</u>*

Emission Factor, EF (g/hd/d) =

Pen Surface Dustiness, S (g/kJ)

X Animal Activity, AA (kJ/hd/d)



PM10 Mass Concentrations - Feedyard A Upwind and Downwind
March 20, 2007
PM10 Downwind
PM10 Upwind
PM10 Net Downwind
24-hr Avg Net Downwind
(Auvermann, Texas A&M AgriLife)
Evening Dust Peak, EDP
233.3
1-Minute Mass Concentration (µg/m³)
3,500
3,000
2,500
2,000
1,500
1,000
500
0
12:00 AM
2:00 AM
4:00 AM
6:00 AM
8:00 AM
10:00 AM
12:00 PM
2:00 PM
4:00 PM
6:00 PM
8:00 PM
10:00 PM
12:00 AM
Time of Day

Abatement Measures: PM_{10}

- **Critical moisture threshold** **is 20% surface manure moisture (Auvermann & Maghirang)**
- **Abatement measures:**
- **Solid-set sprinklers** *(Auvermann & Maghirang)*
  - 50-80% measured effectiveness
  - Cost/benefit, depending on assumed EF ~ \$0.75-1.00/lb PM_{10}
  - *Higher EF yields improved cost/benefit, and vice versa.*
- **Manure harvesting**
  - Including increased harvest frequency.
- **Stocking density manipulation**
  - Reduces water requirements
  - Extends rainfall effects
  - Must preserve bunk space per head, re: cattle performance.
  - >50% effectiveness *(Bush et al., Appl. Eng. Agric., 2014)*

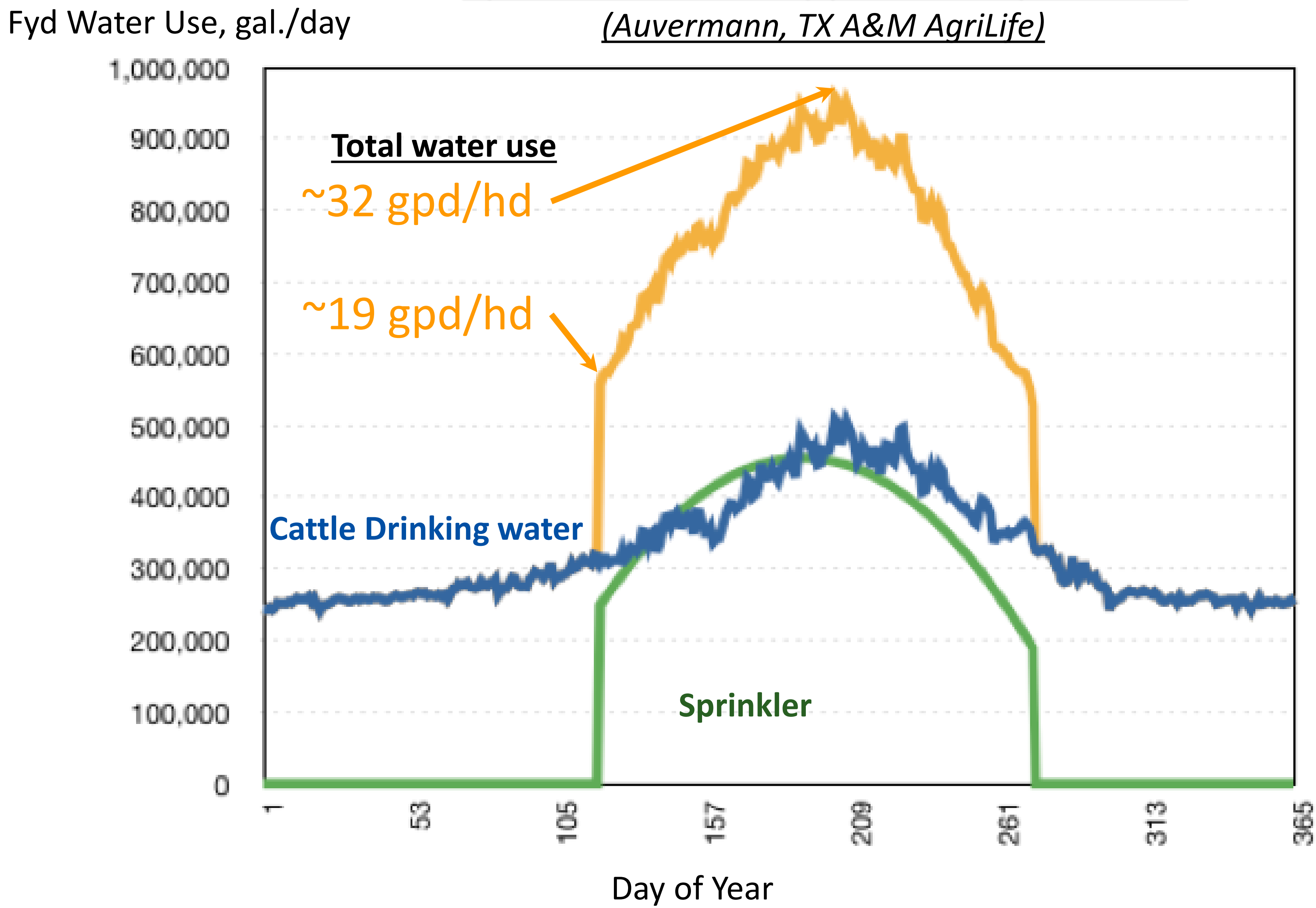
Obj. A-- Abatement Measures & Receptor Impacts

- **Solid-set sprinklers:**
- PM10 control efficiency (24-hr values): *(Maghirang, KSU)*
- Sprinkled feedyard (KS1):
  - PM10 concentration reductions: mean = 53% (range = 32-80%).
  - PM10 emission rates 24-hr reduced: mean = 49% (range=12-92%)
  - PM10 emission rates for EDP reduced: mean = 61% (range = 21-93%).
  - Sprinkler effect lasted one day. Improved w/higher application.
- Rainfall effect for sprinkled vs. unsprinkled (KS2) feedyards:
  - means --KS1 = 77%; KS2 = 76%;
  - range = 60 - ~100% both feedyards.
  - Rainfall effect lasted 3-7 days, per amount & intensity.
- Cost/benefit of sprinkling, EF-dependent~ $0.75-1.00/lb PM_{10}$

(B. W. Auvermann & S. Park, TX A&M AgriLife)

Sprinkler Water Application, per head

(Auvermann, TX A&M AgriLife)



Water Application for Feedyard Dust Control

- **Suggestions:**
- Don't rely on water ALONE if uncompacted manure is deeper than ½"-1"
- Longer sprinkler sets rather than more numerous, IF POSSIBLE
- The last set of the day should be the downwind set, if layout permits.
  - *B. W. Auvermann*

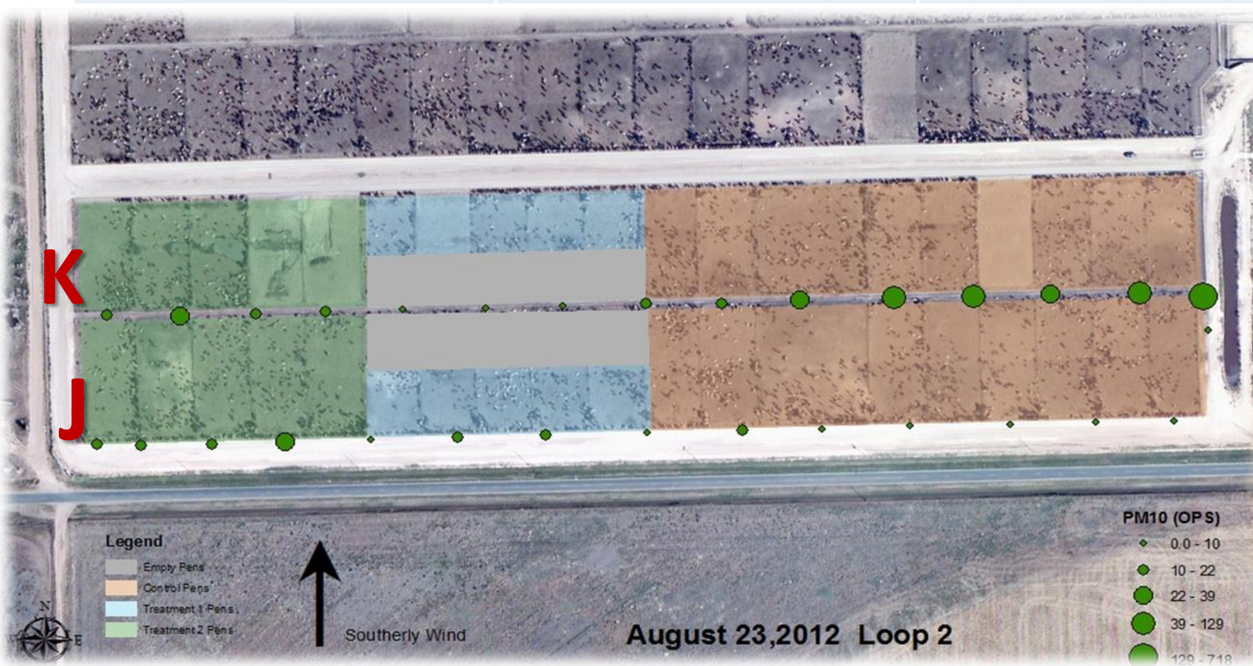
Obj. A. Abatement Measures & Receptor Impacts

- Frequent pen scraping/manure harvest:
- **PM10 control efficiency (24-hr values):** *(Maghirang, KSU; Auvermann, TX AgriLife)*
  - PM_{10} concentrations, before vs. after scraping
  - Reductions: mean = 40%; range = 11-61%.
- Prioritize & focus harvesting operations:
  - Begin downwind side, work upwind.
  - Cattle nearest slaughter weight
  - Operate when sun is highest
  - Remove manure immediately or compact to reduce redistribution.

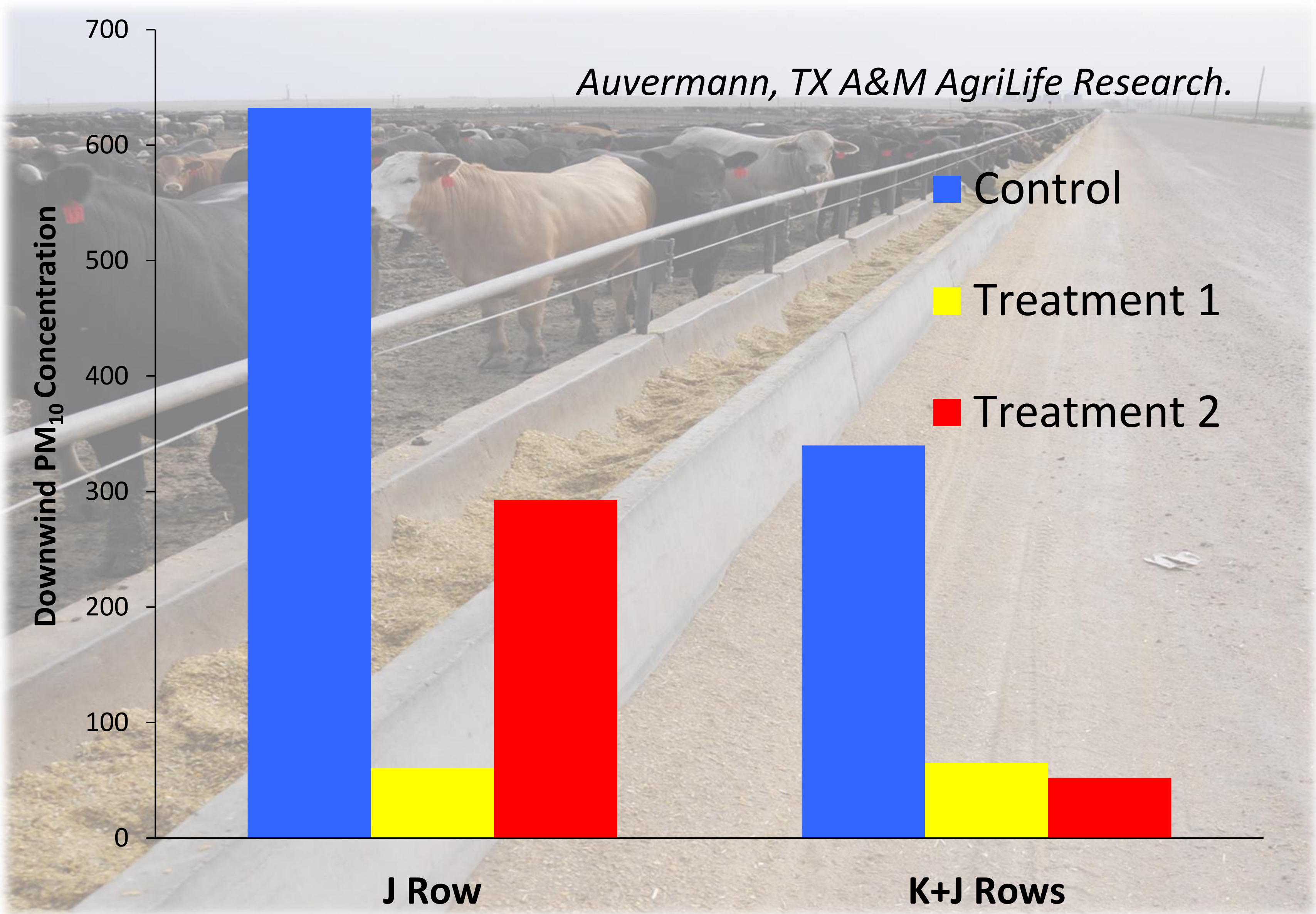
Obj. A. Abatement Measures & Receptor Impacts

Stocking Density Treatments *(Auvermann)*

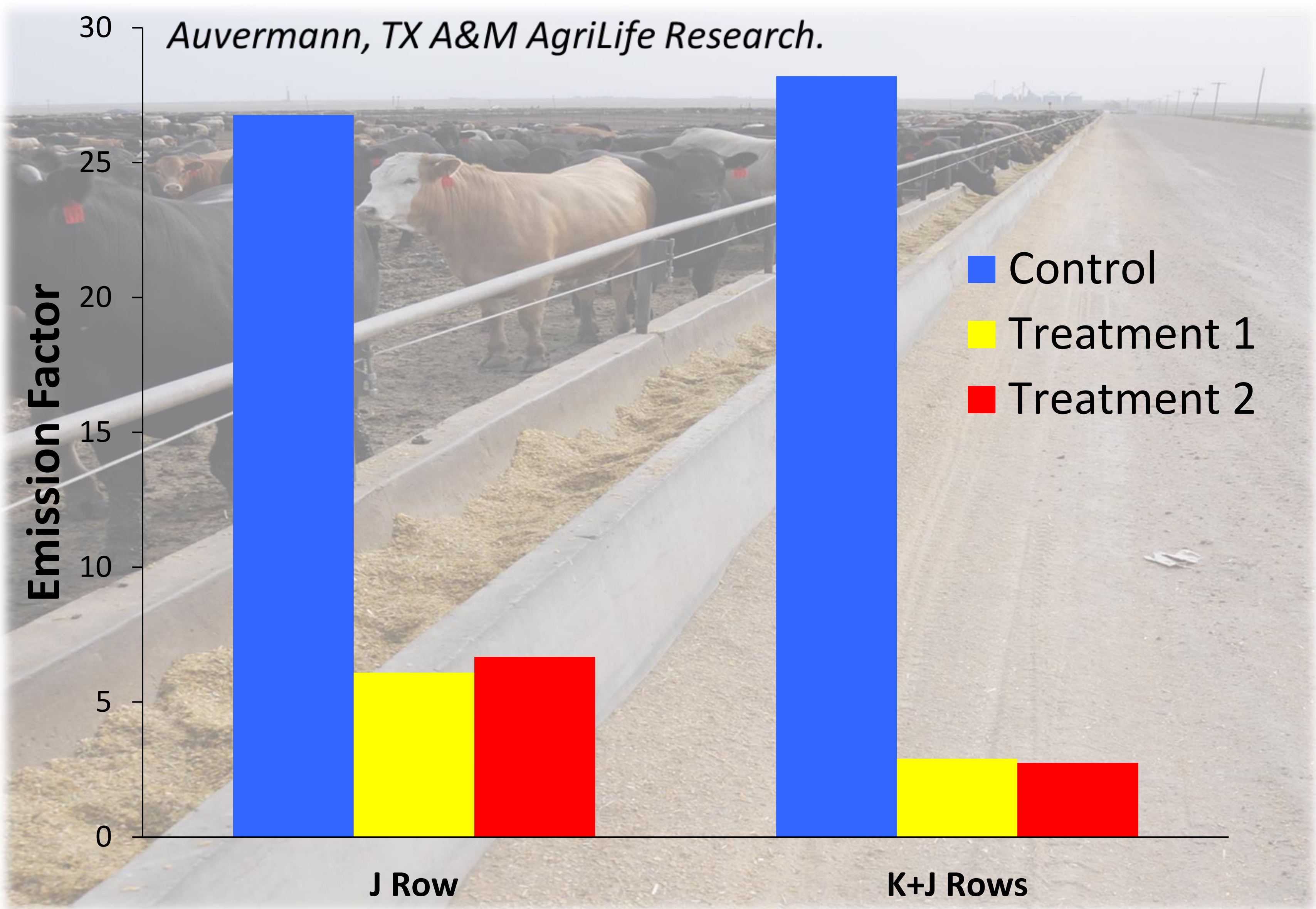
Treatment	Control	TRT 1	TRT 2
J-Row Block	Pens J11-J19	Pens J6-J10	Pens J1-J5
K-Row Block	Pens K11-K19	Pens K6-K10	Pens K1-K5
Cattle Spacing	150 sq. ft./hd.	75 sq. ft./hd.	75 sq.ft./hd.
Method	Industry standard	Pen Area Reduced 50% by fence	Doubled Cattle Numbers per Pen



Effect of Stocking Density on PM_{10} Concentrations, µg/m³



Effect of Stocking Density on PM10 Emission Factor, lbs/day/1,000 hd



Objective B.
Process-based emission models.

- **Process-based modeling**:
  - Mathematical expressions based on good understanding of emission source(s) & causal mechanisms.
- Hypothetically:
  - *Modeling* prediction/evaluation is generally *cheaper* than in-field *monitoring*; but it requires *robust* models.
- Major recent focus:
  - Particulate matter, PM_{10} (dust) *(Maghirang & Auvermann)*
  - Ammonia *(Todd, Cole & Waldrip)*
  - Hydrogen sulfide *(Casey)*
  - Greenhouse gases: N_2O, CH_4, CO_2 *(Casey, Faulkner, Cole, Todd, Waldrip, Capareda, Mukhtar, Maghirang).*

PM$_{10}$ Conceptual Model, an example *(Auvermann)*

PM$_{10}$ Emission Factor, EF (g/hd/d) =

Pen Surface Dustiness, S (g/kJ)

X Animal Activity, AA (kJ/hd/d)

In which:

- S = “[Intrinsic] dust susceptibility”
- Key Factors Affecting S: Varies spatially & temporally through 3 surface layer properties:
  - Moisture content
  - Bulk density
  - Depth
- USDA-NRCS Standard
  375 addresses all three.
- Pen surface assessment tool,
  - Condition A, B, C, …
  - Descriptors.

Obj. B. Process-based emission models.

- Measurement of GHG Fluxes from Feedyard Pens using non-flow-through/non-steady-state (NFT-NSS) chamber techniques *(K.D. Casey, TX A&M AgriLife Research)*
- Objectives:
- Develop understanding of spatial, temporal and seasonal variations in N_2O and CH_4 fluxes from feedyard pen surfaces
- Collaborate with modelling community and ***contribute to improving models*** of GHGs from CAFOs.
    - Working with Heidi Waldrip USDA-ARS et al.

Non-Flow-Through(NFT)/Non-Steady-State (NSS) Flux Chambers

Advantages:

- Dominant technique used by scientists for measurement of GHG fluxes from other land and crop systems.
- Well developed methodology and well supported in the scientific literature
- Very useful for developing an understanding of the emission processes

Disadvantages:

- Small area measured by each chamber may not be representative of a large highly spatially-varied area for determining overall emission rates
  - Integrative techniques such as eddy correlation (EC) and open path measurement :
    - face significant operational challenges in the feedlot environment
    - Instrumentation to continuously measure N_2O at required speed and resolution is very expensive, has limited field deployment potential and is only just becoming available
    - Provides limited information for developing a understanding of the emission processes because the spatial variability masks the response of individual areas

GHG Sample Collection and Analysis

NFT-NSS chamber with top installed and sealing skirt rolled up.

Two rows of five NFT-NSS chambers installed in a pen at Feedyard-C.

GHG Sample Collection and Analysis

K.D. Casey

Air sample collected from NFT-NSS chamber being injected into an evacuated vial.

Gas chromatograph used for analysis of GHG samples.

Methane and nitrous oxide flux rates for different pen areas *(K.D. Casey)*

Oct.-Dec, 2012

Feedlot	Greenhouse Gas Flux Rates (mg m^{-2} h^{-1})											
	Overall		Near Feed Bunk		On Mound		Near Water Trough		Mound Edge		Visually Wetter Area	
	CH_4	N_2O	CH_4	N_2O	CH_4	N_2O	CH_4	N_2O	CH_4	N_2O	CH_4	N_2O
Fyd-C – Oct 12	10.96	0.03	17.80	0.03	5.98	0.04	12.24	0.03	2.95	0.06	33.63	0.00
Fyd-A – Nov 12	4.85	9.85	7.66	46.57	2.95	4.05	2.91	1.32	--	--	2.27	2.04
Fyd-C – Nov 12	1.40	0.15	1.82	0.01	0.10	0.45	0.74	0.26	0.17	0.14	--	--
Fyd-C – Dec 12	2.03	0.13	0.90	0.02	0.08	0.05	1.03	0.15	1.35	0.29	6.79	0.04

Average methane and nitrous oxide flux rates

for Fyds. A & C, mg m^{-2} h^{-1}

(K.D. Casey)

	Feedyard-A		Feedyard-C					
	5-9 Nov 2012		21-25 Oct 2012		26-30 Nov 2012		10-14 Dec 2012	
	CH_4 Flux	N_2O Flux	CH_4 Flux	N_2O Flux	CH_4 Flux	N_2O Flux	CH_4 Flux	N_2O Flux
Avg.	4.85	9.85	10.96	0.03	1.40	0.15	2.03	0.13
s.d.	3.26	32.55	11.96	0.04	1.35	0.23	6.31	0.34

Tentative Observations, CH4 & N2O flux rates *(K.D. Casey)*

- **Methane flux rates:**
  - Reduced with the seasonal decline in ambient temperature.
  - Highest from areas where the manure pack was visually more moist, including near the feed bunk and wet patches.
- **Nitrous oxide flux rates** were much higher at Feedyard-A than at Feedyard-C.
  - This variation could result from the different manure management practices at the feedyards, with Feedyard-A harvesting manure from the pens twice per year whereas manure removal was performed annually at Feedyard-C.
  - Highest at sampling positions on a manure mound, on the edges of manure mounds and near the water trough.
- **Manure pack temperature** at 50 mm (2 inches) depth generally follows ambient temperature for the same interval.
  - Flux rates respond quickly to changes in temperature
  - Implying the generation process is in the surface layer of the manure pack
- **Overall**--Considerable **spatial variability** in emission fluxes within each pen.

Open-Path FTIR , Methane & Nitrous oxide emissions *(W.B. Faulkner & K.D. Casey)*

- **Goal** - develop baseline greenhouse gas (GHG) emissions data from a Texas cattle feeding operations

- **Issues**
  - Dust obscured optics
  - Alignment issues
  - Inter-instrument bias

OP-FTIR Installation at Feedyard C

Spatially Averaged Greenhouse Gas Emissions

- **Premise:** Different areas of feedyard pen emit at different rates: near feed-bunk, near water trough, mounds, drains, other pen area
- Emissions vary seasonally, temporally, with management activities and with episodic weather events
- **Promise:** Open-path FTIR systems offer *potential* to obtain spatially integrated measurements over significant time periods suitable for determining emission factors.
- **Protocol:**
  - Two, open-path FTIR systems deployed at Feedyard C to measure N_2O and CH_4 emissions.
  - First unit was located on predominant downwind edge of feedyard while the second unit was located on predominant upwind edge of feedyard
- **Realization:**
  - Relatively long path lengths were necessary to obtain sufficient sensitivity as measured concentration were not substantially greater than background concentration.
  - Background concentration (~320 ppb) potentially varied with activities on adjacent *land areas.*
  - *Expected increase across the feedyard was perhaps 10%.*
  - *Measured increases across the feedyard were too variable to report with confidence/comfort at this time.*
  - **Simultaneous use of both source-specific & source-integrated sampling, may improve accuracy of determining GHG emission factors. (*Faulkner & Casey*)**

OP-FTIR System Experience

- **Installation/set-up challenges**
  - Small foundation/structural movements can significantly affect signal strength over required long paths
- **Technically Challenging**
  - FTIR measurement and spectral processing for N_2O in agricultural environments not well defined
  - Performance differences between two otherwise identical FTIR system posed problems when computing emissions based on the measurements by the two systems. Relatively few hours of co-extensive data collected.
- **Significant learning curve**
  - Instrumentation and processing software
- **Maintenance challenges**
  - *Hostile* monitoring environment
    - Constant dust coating of optics reduces signal strength
    - Atmospheric gases and compounds attached to dust particles corrode the coatings on optical mirrors and lens
  - Maintenance items are very expensive
  - On-going maintenance and reliability issues with downwind FTIR system posed problems when both systems had to operate concurrently for valid measurements
- **Financially Challenging**
  - High capital, operating and maintenance budget requirements

Summation: While much has been learnt about making measurement with this system under these conditions, limited useable emissions data has been obtained to date.

Beef Cattle Air Quality Research Review: USDA- ARS – Conservation & Production Research Laboratory, Bushland, TX

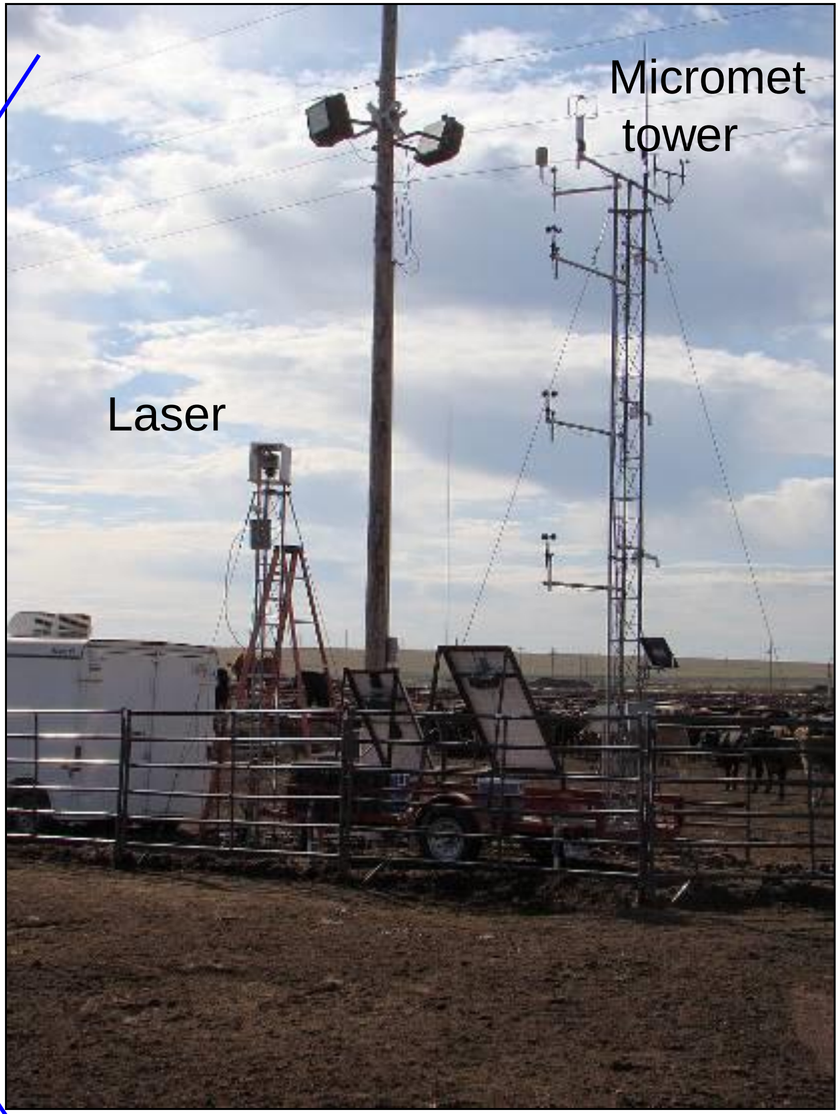
Rick W. Todd, Soil Scientist

N. Andy Cole, Animal Nutritionist & RL

Heidi Waldrip, Chemist

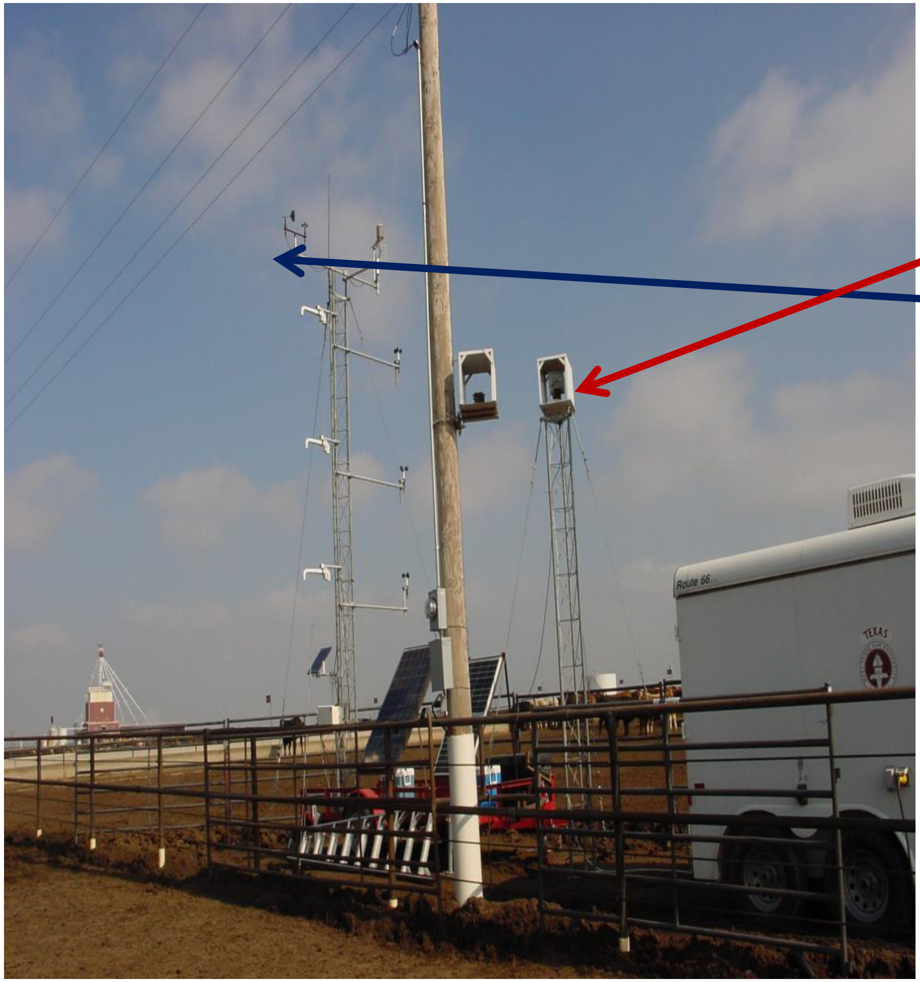
Kristin Hales, Animal Nutritionist

Measuring NH_3 & CH_4 Emissions at Feedyards



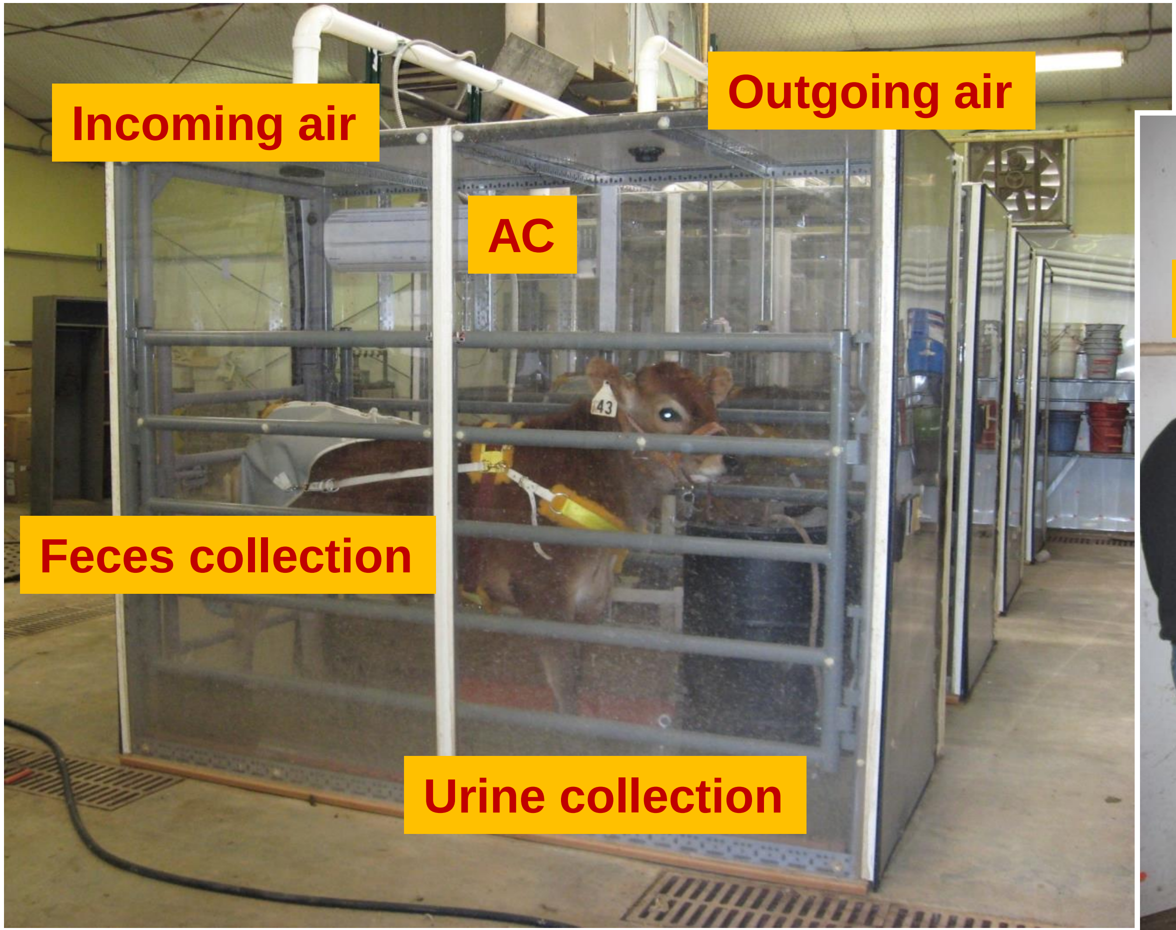
*** Emissions corroborated via total nitrogen balance**

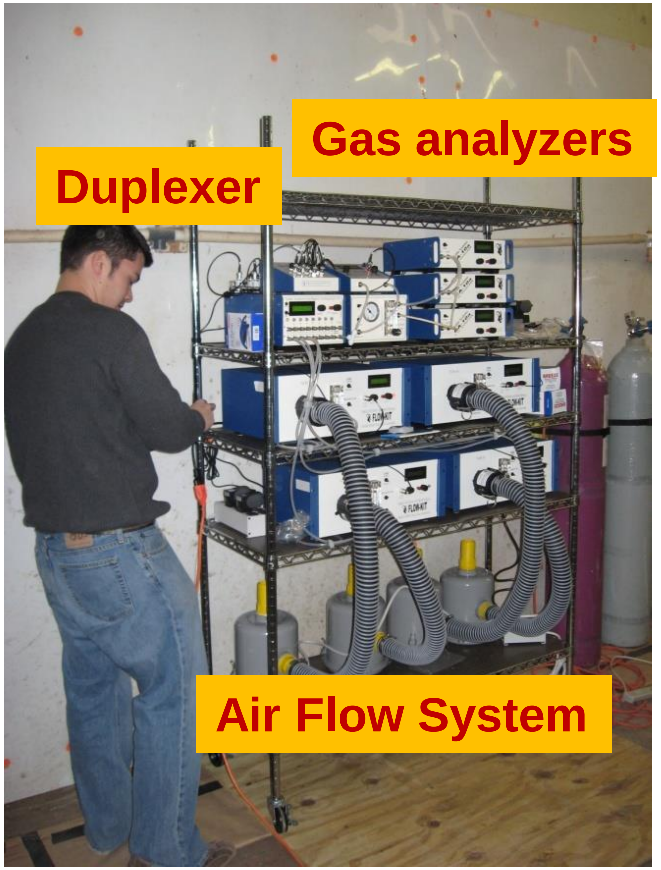
How Do We Estimate Emissions?

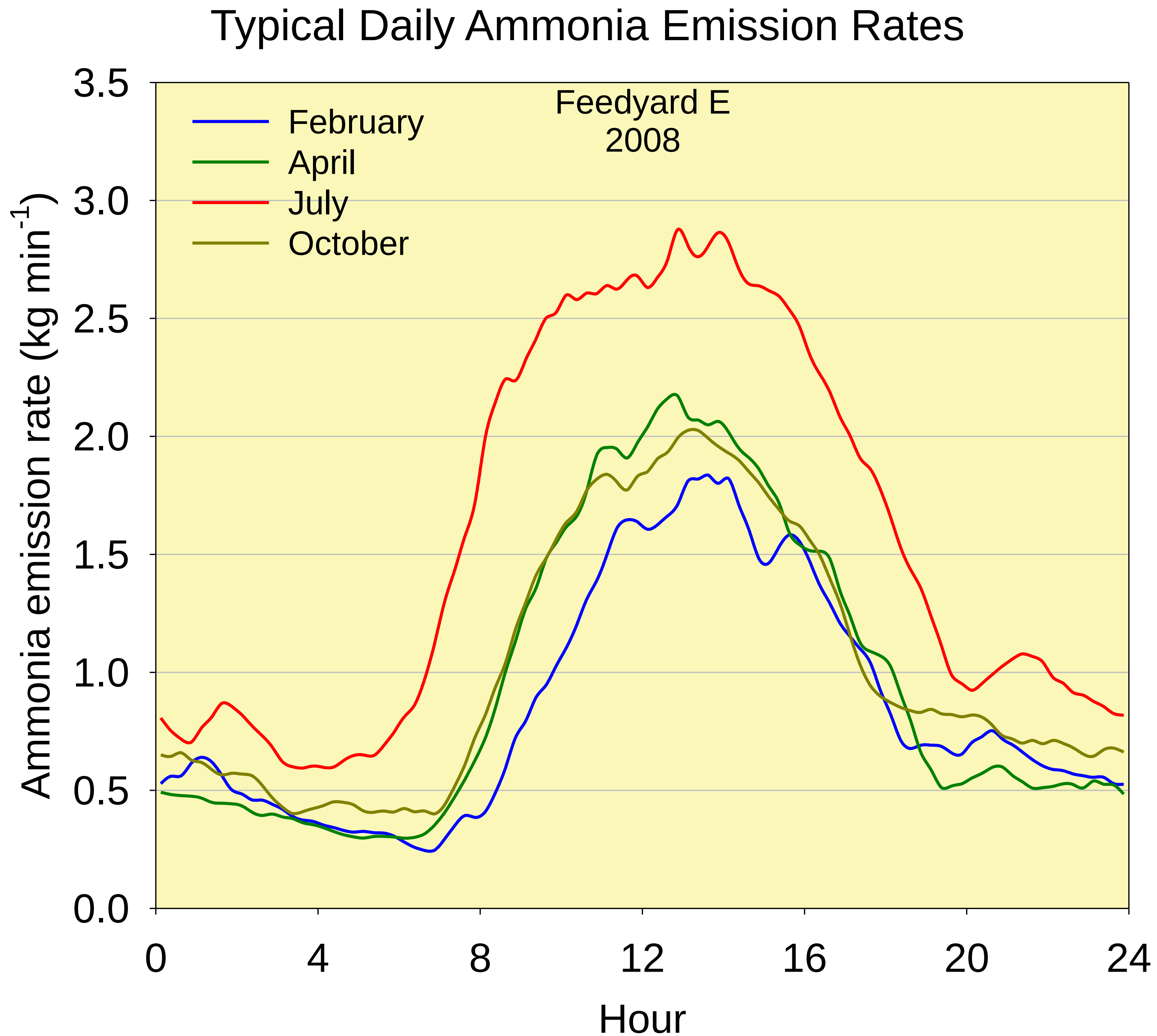


- Measure gas *concentrations* (using open path lasers) & *micrometeorology variables* (sonic anemometers) downwind;
- Use dispersion *model* (bLS) to calculate emissions.

Respiration Calorimetry System
To Measure GHG from Individual Cattle







Typical Daily Ammonia Emission Rates
Feedyard E
2008
February
April
July
October
Ammonia emission rate (kg min^{-1})
Hour
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
0
4
8
12
16
20
24

Fractional Ammonia Loss, 4-yrs data

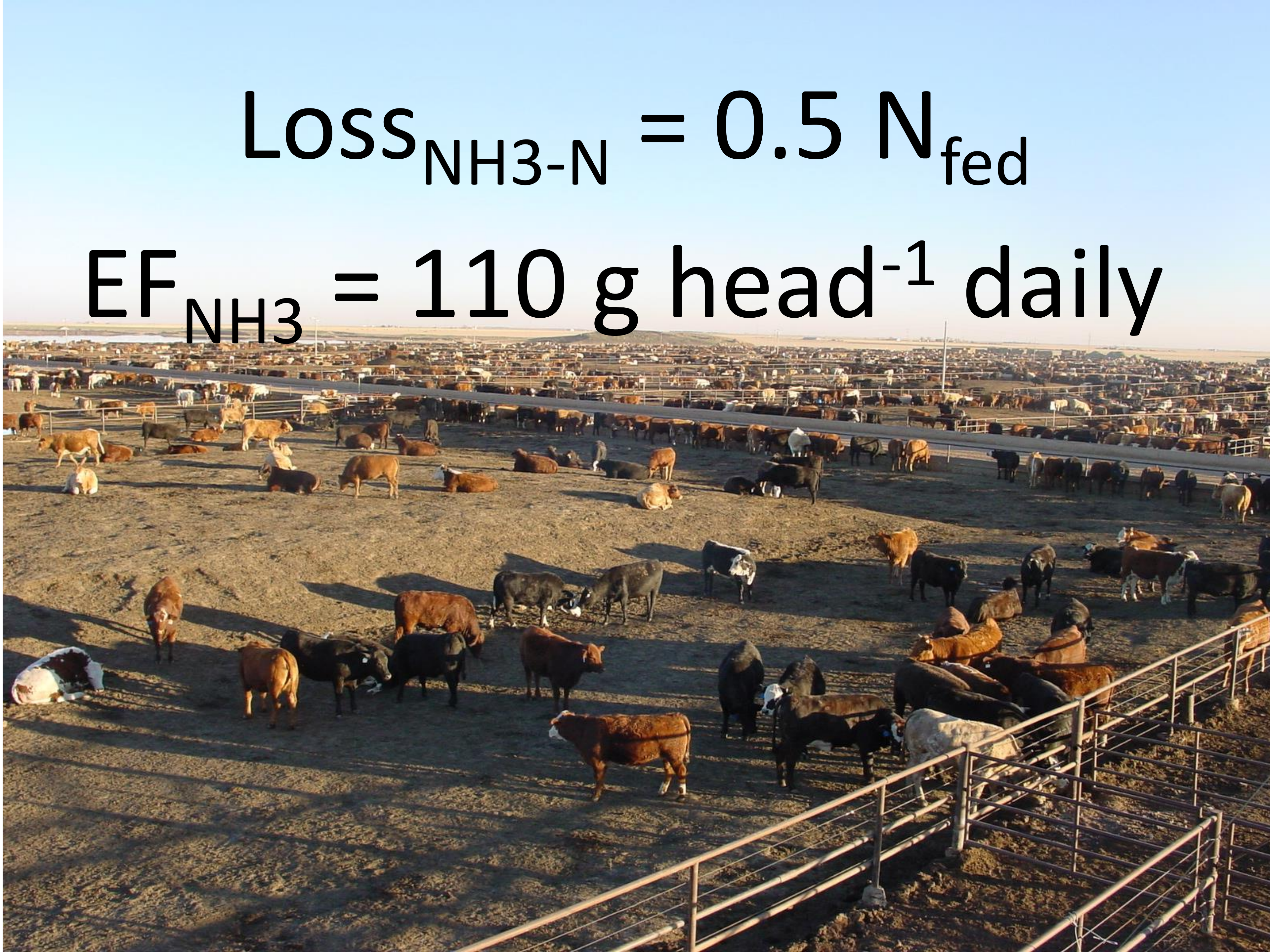
(% of fed N)

Feedyard	Summer	Winter	Annual
FYC	68	36	53
FYA	71	44	58†
FYE	68	42	52†

† Includes spring and autumn emissions;

$$\mathrm{Loss}_{\mathrm{NH3\text{-}N}} = 0.5\ \mathrm{N}_{\mathrm{fed}}$$

$$\mathrm{EF}_{\mathrm{NH3}} = 110\ \mathrm{g\ head}^{-1}\ \mathrm{daily}$$



(KEEP THIS WORKSHEET FOR FEEDYARD RECORDS)

Calculation Worksheet – Ammonia and Hydrogen Sulfide
Beef Cattle Feedyards
January 2009

The following emissions estimates for ammonia and hydrogen sulfide are based on research data collected by Texas AgriLife Research, Texas AgriLife Extension Service, Texas A&M University, USDA-Agricultural Research Service, and West Texas A&M University. Data has been collected as part of the USDA-CSREES-funded project, "Air Quality: Reducing Emissions from Cattle Feedlots and Dairies," between the years of 2003-2008. Field measurements are on-going and as such these values are a good faith estimate of air emissions based on currently available scientific information.

The final rule on EPCRA reporting issued by EPA on Dec. 18, 2008 and effective Jan. 20, 2009 requires reporting of ammonia or hydrogen sulfide **if** (1) the feedyard is 1,000 head or larger **and** (2) the ammonia exceeds 100 lbs/day **or** the hydrogen sulfide exceeds 100 lbs/day. **DO NOT report ammonia or hydrogen sulfide values if the "upper bound" is LESS THAN 100 lbs/day.**

Feedyard Name:____________________________________

AMMONIA (NH_3) EMISSIONS ESTIMATE

The emissions estimates provided below are inclusive of ammonia emissions from the feedyard pen surfaces and the runoff holding pond(s). Ammonia emission rates are generally lower in the winter and higher in the summer.

Ammonia (NH_3) Emissions Estimate					
	Lowest Head Count		NH_3 Emission Rate (pounds/hd/day)		**NH_3 Lower Bound** (pounds/day)
NH_3 Lower Bound =		x	**0.16**[a]	=	
			[a]winter emission rate from research data		
	Permitted Head Count		NH_3 Emission Rate (pounds/hd/day)		**NH_3 Upper Bound** (pounds/day)
NH_3 Upper Bound =		x	**0.48**[b]	=	
			[b]summer emission rate from research data		

Results Summary: USDA-ARS-CPRL

- On an annual basis – about 50% of fed N is lost as ammonia (NH_3) from feedyards
- Emissions are about 2x greater in summer than in winter
- NH_3 emissions have a diel pattern with lowest emissions at night (cooler, less animal activity)
- NH_3 emissions increases with increased dietary N (greater urinary N excretion)

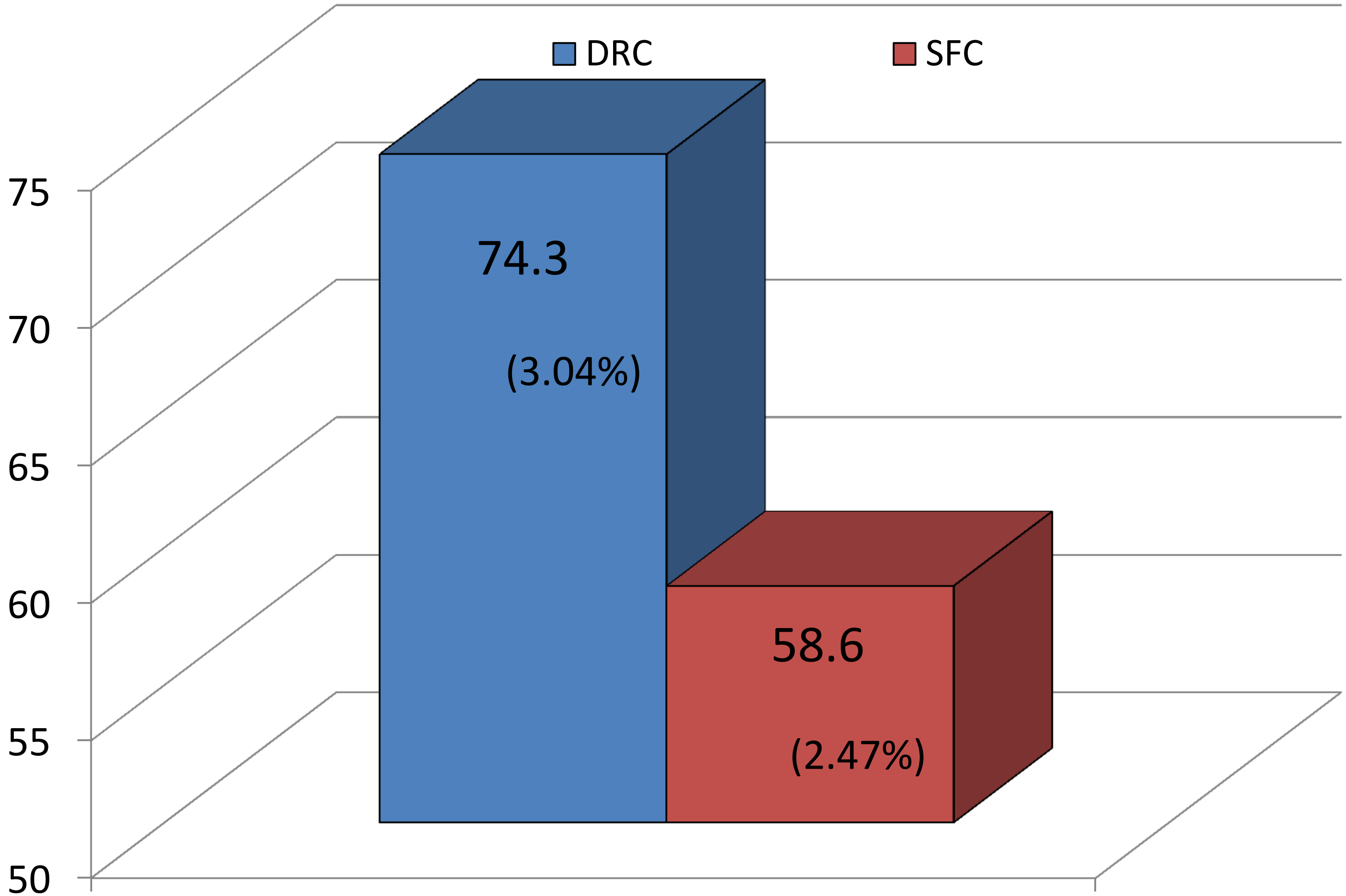
Grain Processing & C-Footprint

1.54Mcal NEg /kg

1.68 Mcal NEg /kg

Brown et al., 2008

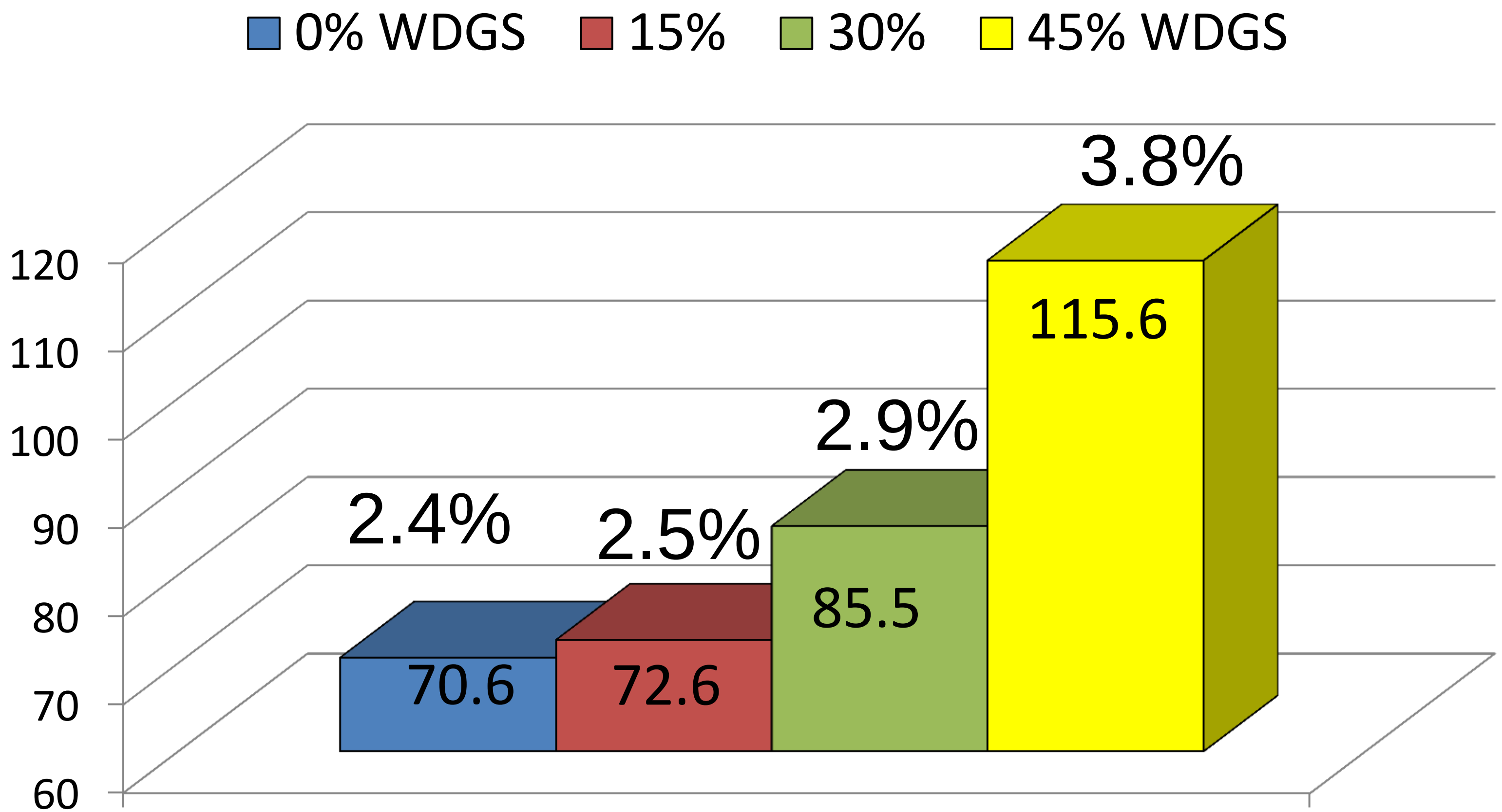
Enteric Methane, L/day (% of GE)



Hales, Cole, MacDonald, 2012

Distillers Grains and Enteric CH_4

g/day (% GEI) , Hales & Cole, 2012



Mean Monthly ***Methane*** Emissions, Feedyard A, 2010

USDA-ARS-CPRL/Bushland TX

Month	Methane Emission Rate	Methane Conversion Factor (Y_m)
	g animal^{-1} d^{-1}	%
January	84.0	2.7
February	85.2	2.9
May	85.9	3.3
June-July	93.4	3.1

Todd, R.W., M.B. Altman, N.A. Cole, and H.M. Waldrip. 2014.
Methane emissions from a beef cattle feedyard during winter and summer on the southern High Plains of Texas.
J. Environ. Qual. 43:1125-1130.

Methane Results Summary

USDA-ARS-CPRL/Bushland TX

- Feeding steam flaked corn (SFC) decreases enteric CH_4 emission by 25%, compared to feeding dry rolled corn (DRC).
- Feeding less than 30% wet distillers grain (WDGS) had no effect on CH_4.
- Feeding >30% WDGS increased enteric CH_4 production.
- CH_4 emissions from cattle fed SFC-based finishing diets ranged from 2.5 to 3.0% of GE intake (via both respiration calorimetry and bLS).

Objective C. Dispersion Modeling, Emission Factors, & Regulation

(Parnell, McGee Faulkner et al., TAMU)

- **PM sampler performance:**
- PM_{10} samplers were designed for use in urban areas where MMD is <10 um.
- Rural/ag PM is typically 20-30 um.
- Penetration of only a few large particles results in oversampling of 2X-5X.
- Can give misleading results & inaccurate regulatory interpretations.

Objective C. Dispersion Modeling, emission factors, and regulation:

(Parnell , McGee, Faulkner et al., TAMU)

- **PM-coarse (PM_c) regulation:**
- Subtraction method to determine coarse PM

-Problematic due to shifting cut points on samplers

-Rural/ag PM has large MMDs, negligible $PM_{2.5}$

-PM coarse NAAQs of 70 µg/m3 would effectively be a new PM_{10} NAAQS that is 50% lower than present.

Objective C. Dispersion modeling, emission factors & regulation.

- **Particulate matter, PM_{10}:**
- Developed ***correction factors*** for non-EDP conditions; translates measured concentrations from EPA's FRM vs. TEOM sampler types *(Parnell, Faulkner & Auvermann*).
  - For low PM_{10} concentration (<100 µg/m2) & small particles (<10 µg MMD): FRM concentrations = TEOM concentrations.
  - For high PM_{10} Conc. (>100 µg/m2) & larger MMD (>10 µm):
    - FRM conc. = 0.6 x TEOM results.
  - If oversampling bias due to very large PM sizes:
    - FRM conc. = 0.5 x TEOM results.
  - TEOM concentrations of PM_{10} at Fyd. C, non-EDP conditions (20 hrs/day), averaged: Sept. 169; Oct. 107; Nov. 43; & Dec. 63 µg/m2.
- **Derived Emission Factors** (non-EDP conditions) varied 3-36 lbs. PM_{10}/1,000 hd/day (11.5 average).

Objective C. <u>Dispersion modeling, emission factors & regulation.</u>

- **Feedyard GHG** *(Capareda et al.)*
- Flux chamber approach, discrete sources.
- Emitting surface areas: feedpens (89%), retention ponds (5%), compost windrows/piles (6%).
- **Aggregated GHG Emission Rates** (ERs) per head:
  - Methane, CH4 = 3.8 g/hd/day.
  - Nitrous oxide, N2O = 0.52 g/hd/day.
  - Carbon dioxide, CO2 = 1,192 g/hd/day .
- *Relative* contributions:
  - **Methane, CH_4**: pen surfaces (51%), retention ponds (48%), composting (1%).
  - **Nitrous oxide, N_2O**: pens (81%), retention ponds (2%), composting (17%).
- Feedyard values of ER were lower than dairy ER values.

Objective D- Technology Transfer to Stakeholders

- **2002-2013:**
- Industry/Stakeholder Advisory Committee, met w/investigators ~annually; added much value.
- Peer-reviewed journal articles (69);
- M.S./PhD theses/dissertations (22).
- Book Chapters (13)
- Scientific conference papers & abstracts (141);
- Invited presentations to stakeholders (~20+)
- Extension, TCFA & KLA feedyard management seminars (7)—So. Tx, So. Plains, Panhandle, SW Kansas.
- Extension fact sheets (22)— includes ***eXtension,*** UN-L/NLPELC & AgriLife Extension.
- Webinars, webcasts & videos (11)
- In-depth short courses conducted (8) for state regulators TX, KS, IA, OH, etc.
- Co-Funding: (0.9:1 leveraging of federal grant dollars).

Closing Comments

- Open-lot emissions not straight forward or especially easy to measure.
- USEPA “standard/reference methods” show breakdowns with feedlots and other agricultural sources of PM.
- Flux chamber methods are useful for relative emission values; results can vary with design/operation; standardization needed.
- Long term PM monitoring data bases have been developed at Feedyards C, A B.
- Dissimiliarities between open-lot cattle feedyards and open lot dairies; EDP is not a factor in dairies.
- Moisture is a main driver; so are ration and manure management.
- Diurnal effects– PM_{10}, NH_3, H_2S, N_2O, etc.
- Process-based emission models still under development.
- So are ER’s and EF’s.