TEXAS A&M AGRILIFE RESEARCH

Some Research Highlights: Cattle Feeding & Environmental Quality

Texas A&M AgriLife Research & Extension

Amarillo TX

December 10, 2013

<u>Significant multi-year funding has included:</u>

State & Federal

- **USDA-NIFA, Air quality: Reducing Emissions from Cattle Feedlots & Dairies** (TX & KS), 2002-13 (8-years funding).
- **TX A&M AgriLife Research—State Air Quality** initiative, 1999-2015.
- **USDA- ARS: DG research program,**~2005-13
- **TX A&M AgriLife: WDG/Cattle Feeding state** initiative, 2007-15.
- **USDOE-Golden: Bioenergy, cattle manure**, 2006-2012.

USDA-NIFA Federal Air Quality Initiative (FAQI)

- **Objectives (4):**

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

- **Research Partners:**

TX A&M AgriLife Research & Extension; KSU; WTAMU; USDA-ARS; UN-L Ext.

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

Texas A&M AgriLife Research & Extension

- **Amarillo/Vernon faculty** has included:
  - Brent Auvermann
  - Steve Amosson
  - Mike Brown (WT & AgriLife
  - Ken Casey
  - Kay Ledbetter
  - Jim McDonald (AgriLife & WT; now UN-L)
  - Ted McCollum
  - Seong Park (Vernon & AMA)
  - Bill Pinchak (Vernon)
  - Pablo Pinedo
- **College Station faculty:**
  - Brock Faulkner
  - Calvin Parnell
  - Sergio Capareda
  - Saqib Mukhtar.

Approaches to Emission Sampling

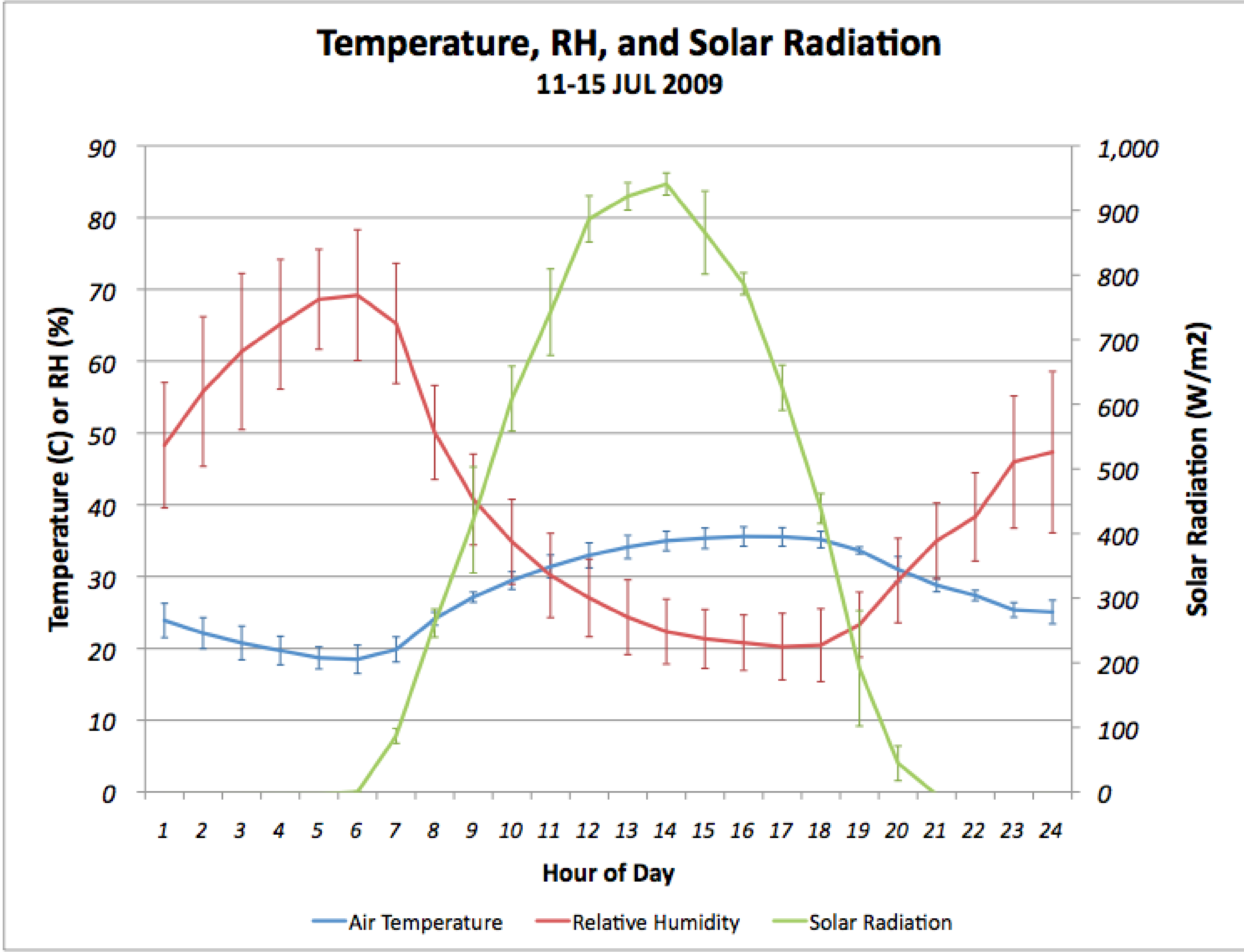
- **Source-specific:**
- Examples:
  - Flux chambers
  - Wind tunnels
- Comment:
  - Multiple, indiv. sources.
  - Semi-invasive;
  - Important for relative comparisons;
  - High precision;
  - Short-term comparisons.
  - Accuracy “depends”, viz: equip., protocols, sampling intensity, etc.

- **Source-integrated:**
- Examples--
  - PM gravimetric samplers.
  - Open path lasers, TDLAS
  - Open path FTIR.
  - Calorimetry chambers.
- Comment:
  - Integrates across multiple sources.
  - Accounts for spatial & temporal variability.
  - Ambient air or open paths.
  - Non-invasive.
  - Seeks absolute values.

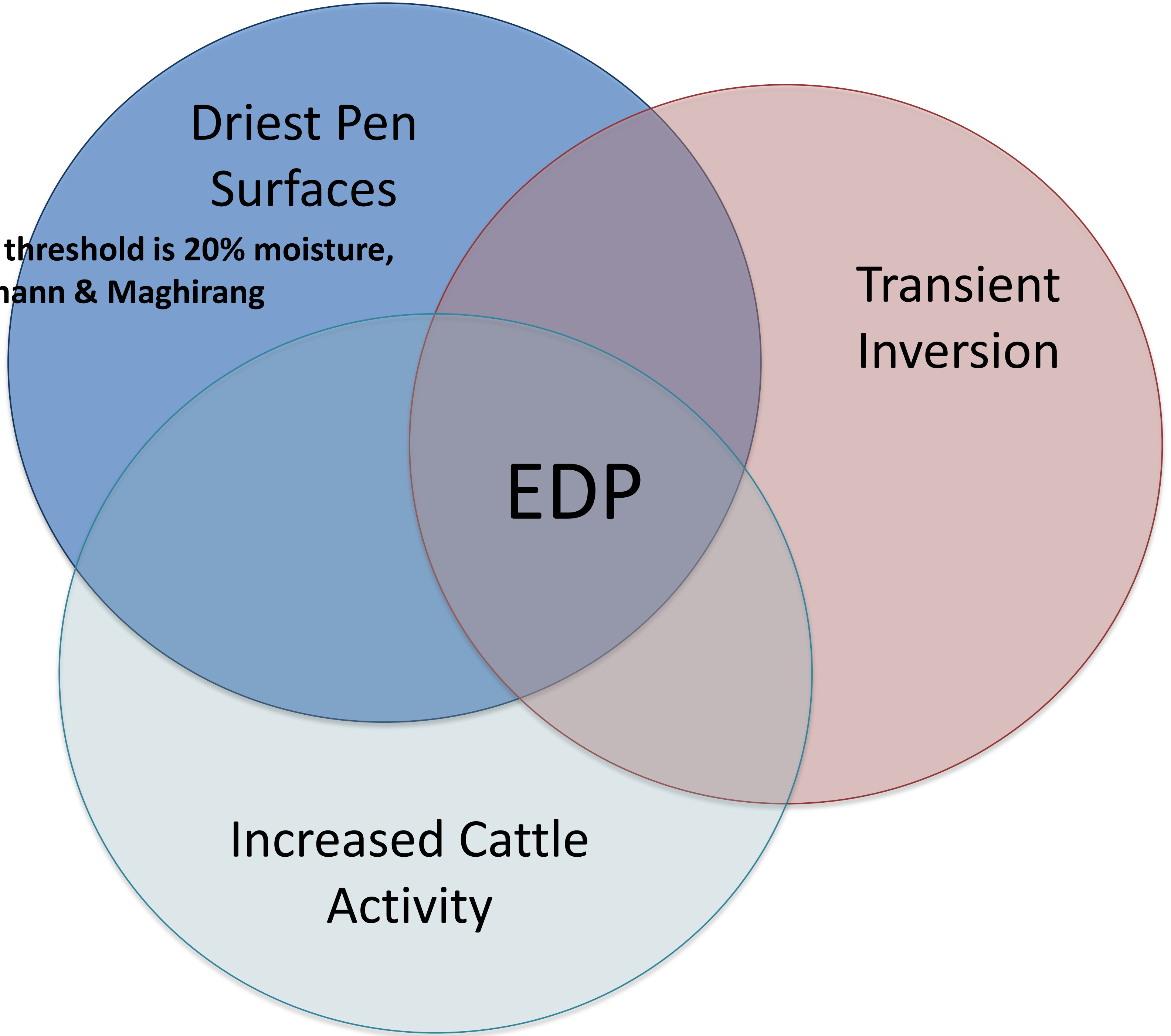
Common Emission Expressions

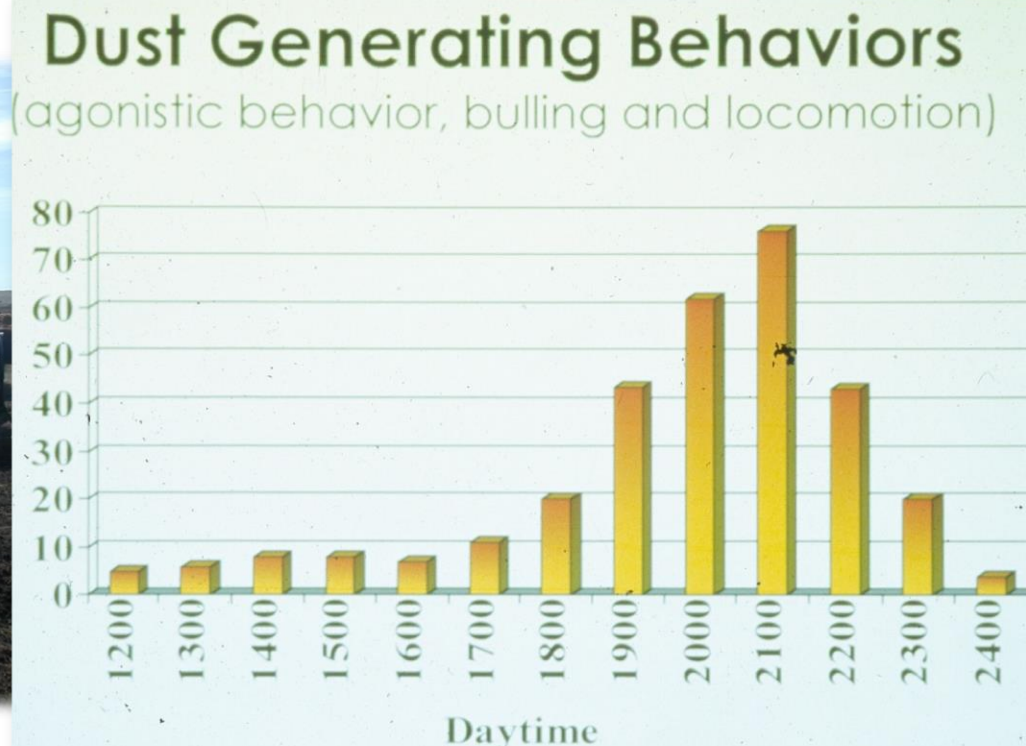
- **Emission concentrations**:
  - mass/volume (µg/m^3)
  - mass/mass, ppm or ppb.
- ***With inverse dispersion modeling***, measured concentrations are used to produce calculated values for:
  - **Emission rate**, mass/time, µg/sec, or kg/day .
  - **Emission flux rate**, mass/area/time: µg/m^2/sec,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

Objective A. Abatement Measures & Receptor Impacts



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


Driest Pen Surfaces
Critical threshold is 20% moisture, Auvermann & Maghirang
Transient Inversion
EDP
Increased Cattle Activity

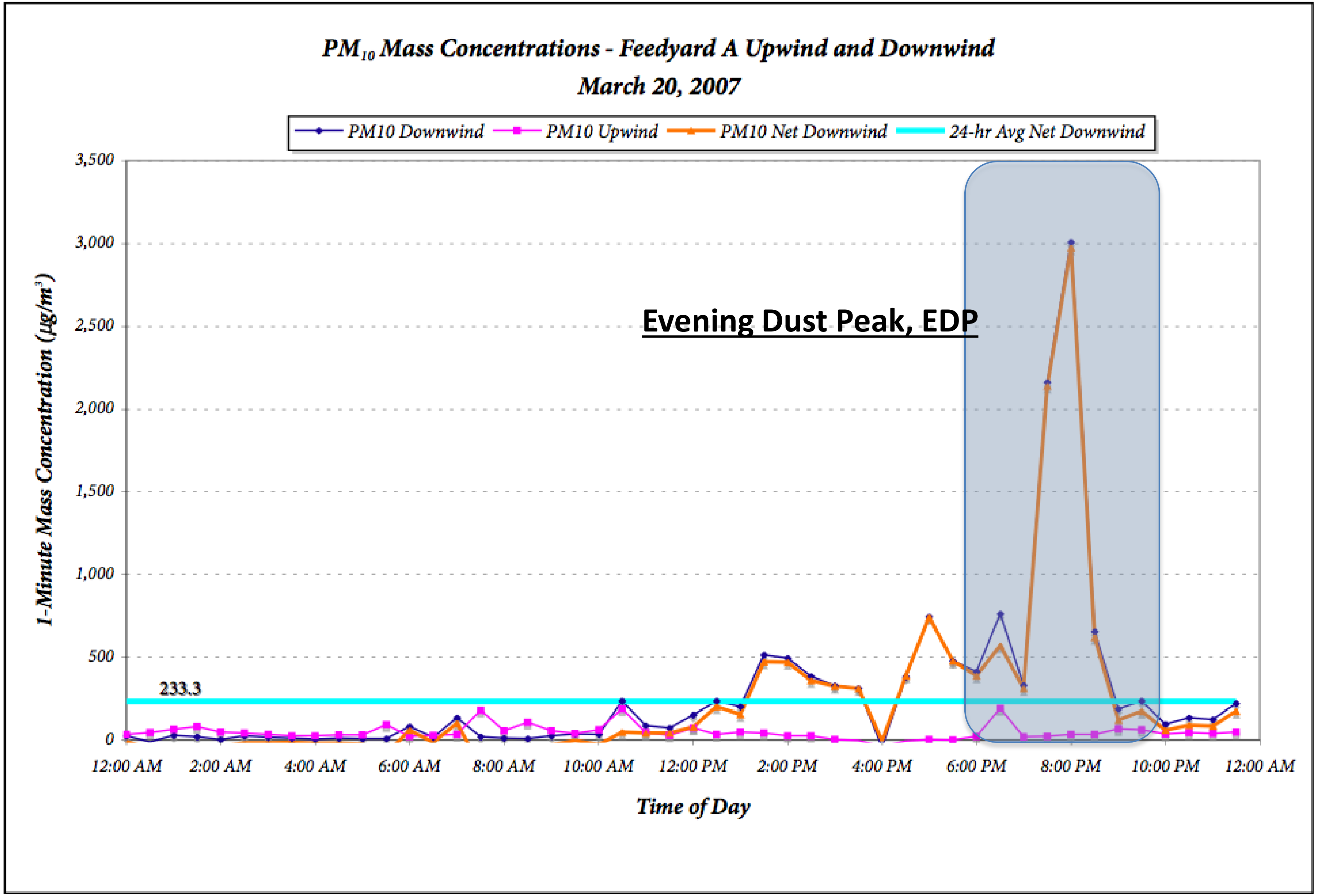


<u>Conceptual model</u> *<u>(Auvermann):</u>*

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
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

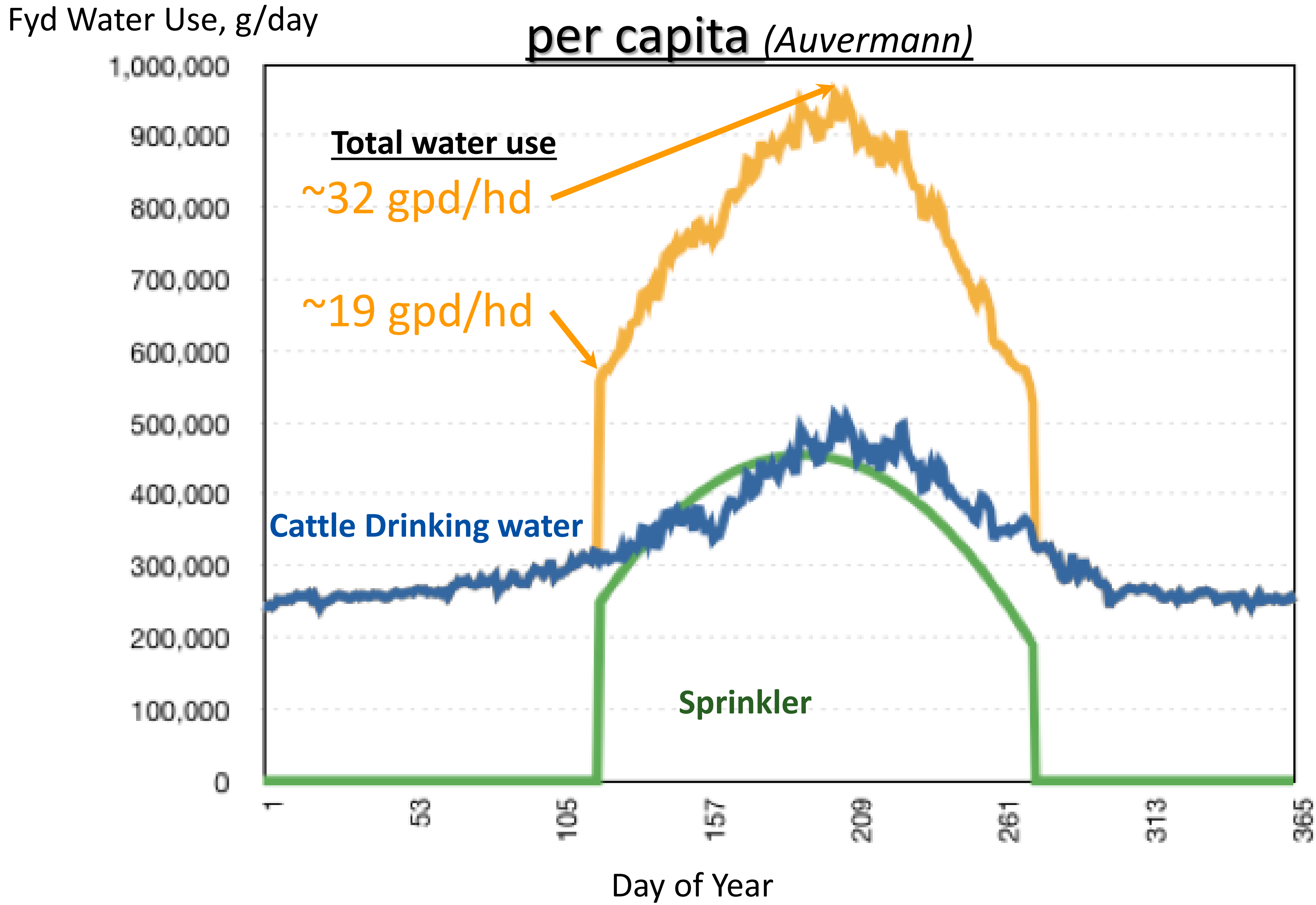
- **Solid-set sprinklers** *(Auvermann & Maghirang)*
  - 50-80% effectiveness
  - Cost/benefit ~ \$0.75-1.00/lb PM_{10}
- **Manure harvesting**
  - Including increased frequency.
- **Stocking density manipulation**
  - Reduces water requirements
  - Extends rainfall effects
  - Must preserve bunk space per head
  - >50% effectiveness (not yet published)

Note: critical threshold is 20% surface moisture (Auvermann & Maghirang)

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 ~ \$0.75-1.00/lb PM_{10} *(Brent Auvermann & Seong Park)*

Sprinkler Water Application, per capita *(Auvermann)*



Water Application

- **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*

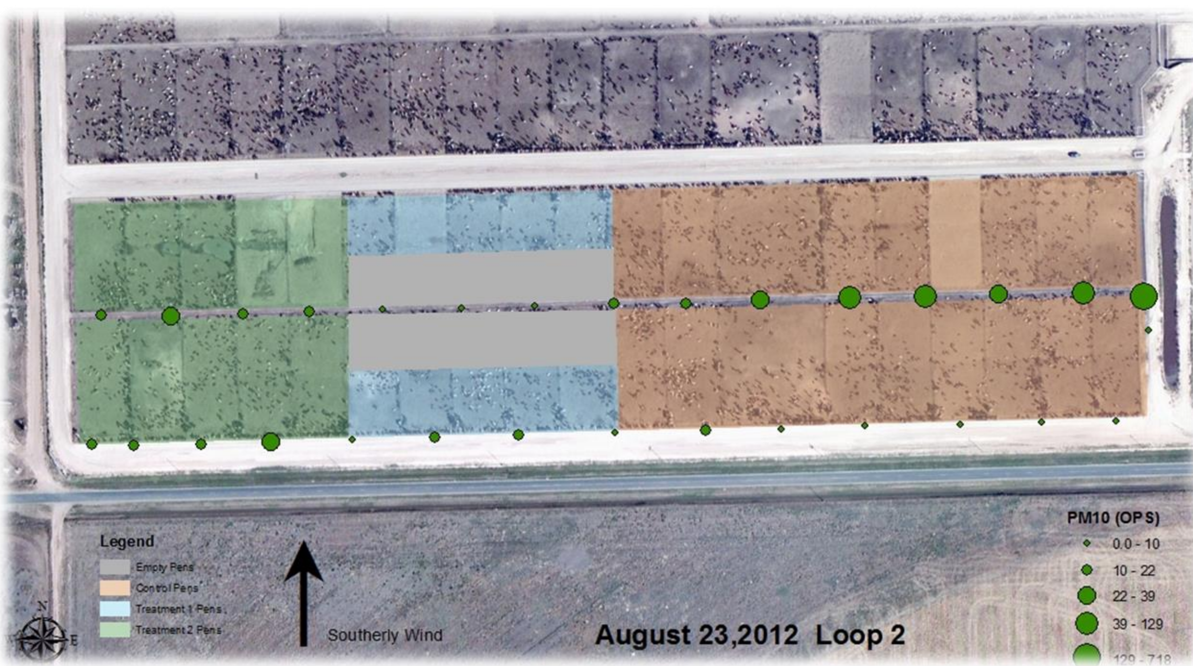
Obj. A. Abatement Measures & Receptor Impacts

- 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 and focus operations?
  - Begin downwind side, work upwind.
  - Cattle nearest slaughter weight
  - Operate when sun is highest
  - Remove manure immediately or compact to reduce redistribution.

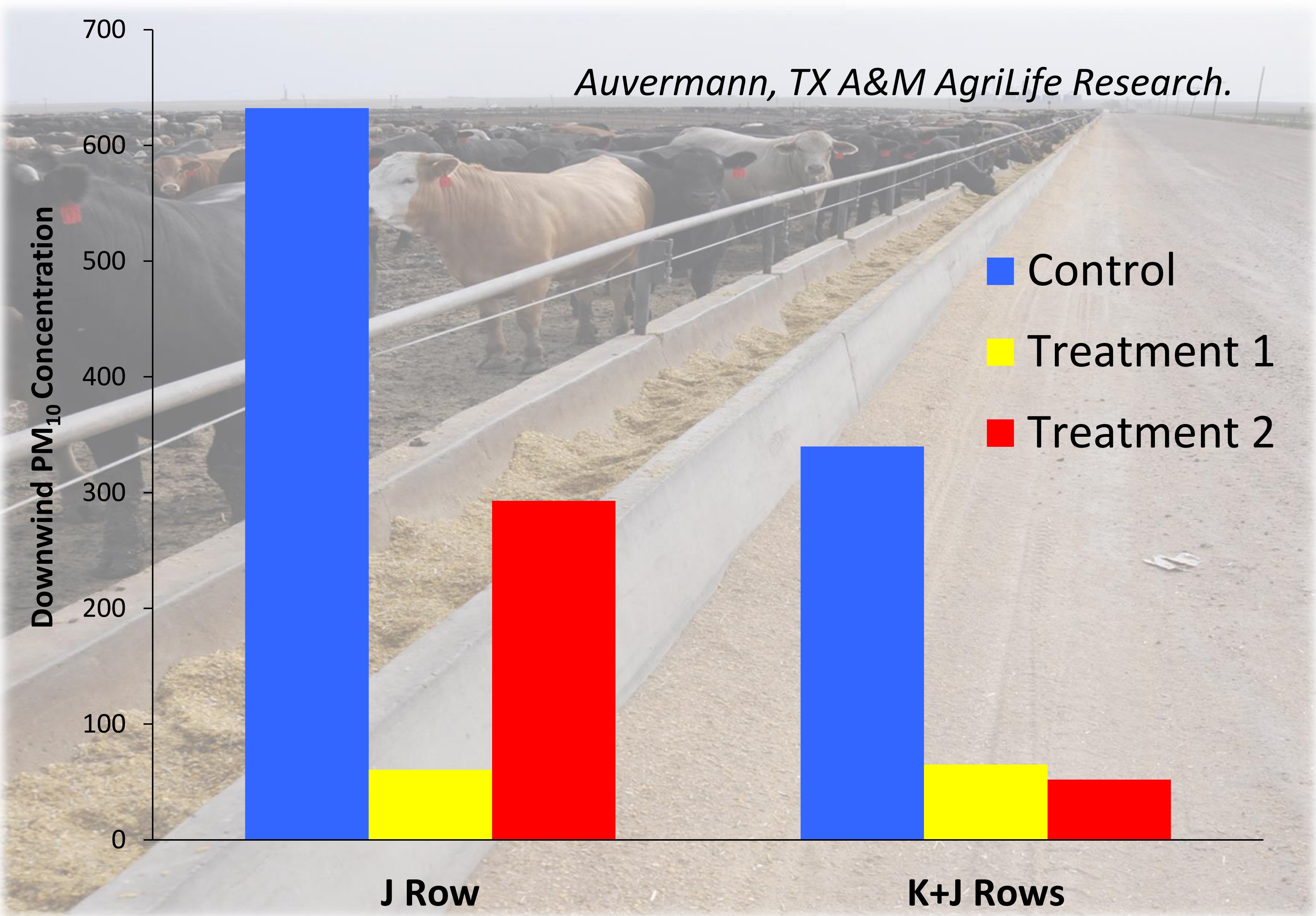
Obj. A. Abatement Measures & Receptor Impacts

Stocking Density Treatments *(Auvermann)*

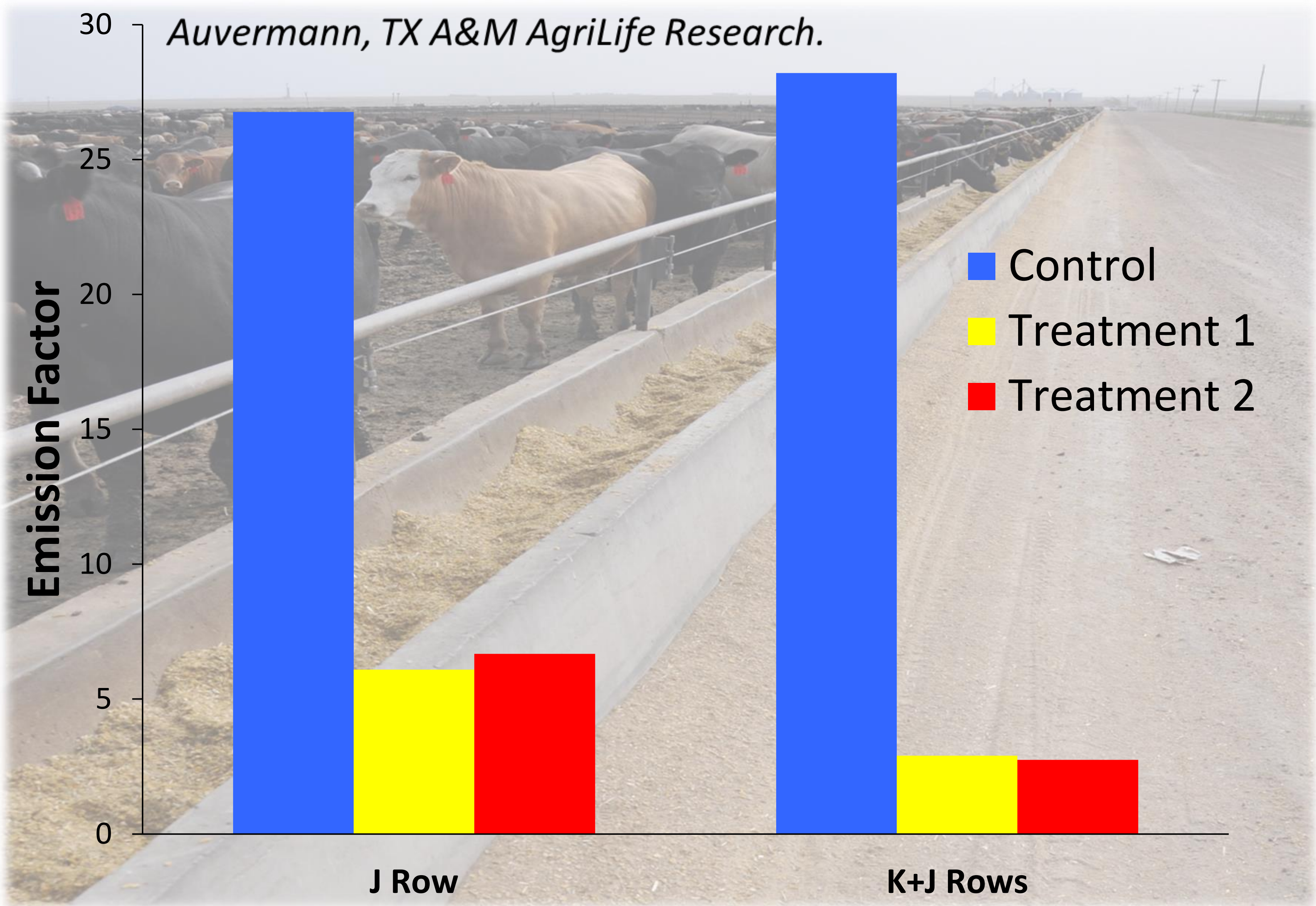
TREATMENT	CTRL	TRT1	TRT2
J-Row Block	Pens J11-J19	Pens J6-J10	Pens J1-J5
K-Row Block	Pens K11-K19	Pens K6-K10	Pens K1-K5
Cattle Spacing	150 $ft^2\ hd^{-1}$	75 $ft^2\ hd^{-1}$	75 $ft^2\ hd^{-1}$
Method	Industry Standard	Doubled Animal Numbers per Pen	Pen Area Reduced 50% by Fence



Effect of Stocking Density on PM_{10} Concentrations, $\mu g/m^3$



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.
- Hypothet:
  - Modeling prediction/evaluation is generally cheaper than in-field monitoring; but requires robust models.
- Major recent focus:
  - Ammonia *(Todd, Cole & Waldrip)*
  - Particulate matter, PM (dust) *(Maghirang & Auvermann)*
  - Greenhouse gases: N_2O, CH_4, CO_2. *(Casey, Faulkner, Cole, Todd, Waldrip, Capareda, Mukhtar, Maghirang).*

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

PM10 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.

Objective B.
Process-based emission models.

- Measurement of GHG Fluxes from Feedyard Pens using NFT-NSS Chamber Techniques *(Casey)*
- <u>Objectives:</u>
- 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 and through her with Al Rotz, Bill Salas et al.

Why Non-Flow-Through – Non-Steady-State 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)*

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 each study, mg m^{-2} h^{-1}

	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, CH_4 & N_2O 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.

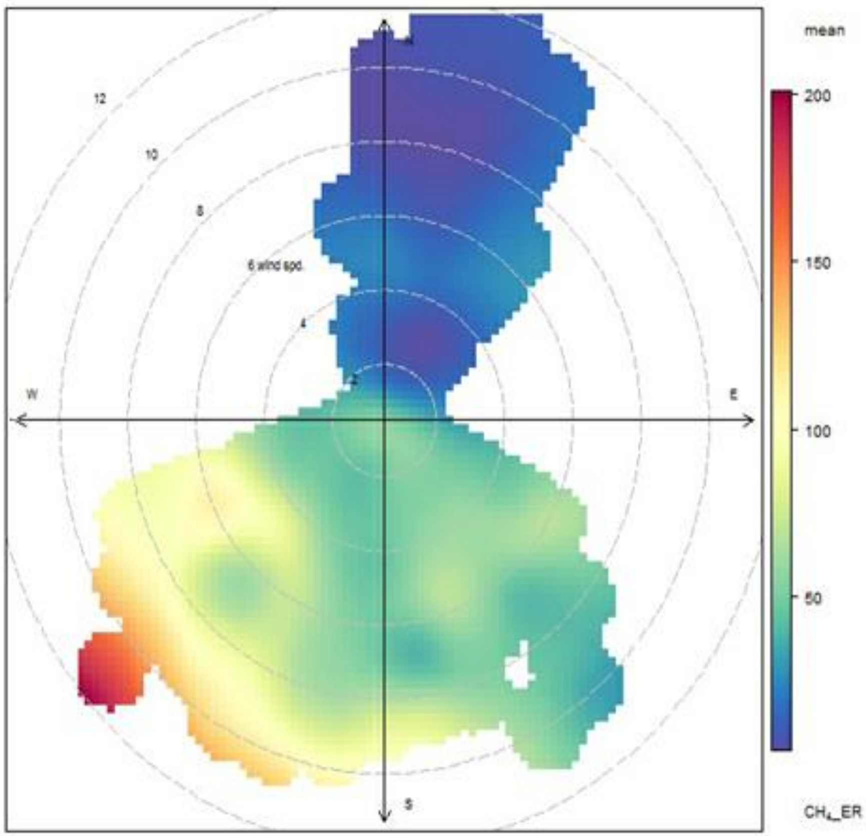
Open-Path FTIR , Methane & Nitrous oxide emissions *(W.B. Faulkner & K.D. Casey)*

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

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

Open-Path FTIR , Uncorrected Results

- Apparent bias between the two instruments must be addressed.
- No established calibration methods for open path bi-static systems.



Compound	Avg. Uncorrected Emission Rate
Methane (CH4)	45.7 µg/m2/s
Nitrous Oxide (N2O)	14.6 µg/m2/s

Next Steps Related to OP-FTIR

(Brock Faulkner)

- Send northern (downwind) FTIR to MIDAC for repair.
- Setup both FTIRs side-by-side.
- Determine if post-hoc data correction can be conducted.

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

- **<u>Particulate matter, PM10:</u>**
- Developed correction factors for non-EDP conditions; translates measured concentrations from EPA's FRM vs. TEOM sampler types *(Parnell, Faulkner & Auvermann*).
  - For low PM10 concentration (<100 µg/m2) & small particles (<10 µg MMD): FRM concentrations = TEOM concentrations.
  - For high PM10 Conc. (>100 µg/m2) & larger MMD (>10 µm): FRM= 0.6 x TEOM results.
  - If oversampling bias due to very large PM sizes:
    - FRM conc. = 0.5 x TEOM results.
  - TEOM concentrations of PM10 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/PM10/1,000 hd/day (11.5 average).

Objective C. **Dispersion modeling, emission factors & regulation.**

- **Greenhouse gases, GHG:**
- Open–path FTIR at Fyd. C to measure nitrous oxide (N_2O) emissions . Downwind vs. Upwind N_2O increased ~160 ppb across the feedyard. (*Faulkner & Casey*)
- Back-calculated emission rates were (*Faulkner & Casey*):
  - N_2O = 14.6 µg/m2/sec;
  - CH_4 = 45.7 µg/m2/sec.
- Flux chambers had higher uncertainty values than source-integrated OP-FTIR & required more labor. (*Faulkner & Casey*)
- OP-FTIR had equipment issues.
- Simultaneous use of both source-specific & source-integrated sampling, may improve accuracy of determining GHG emission factors. (*Faulkner & Casey*)

Objective C. **Dispersion modeling, emission factors & regulation.**

- **Feedyard GHG** *(Capareda et al.)*
- Flux chamber approach, discrete sources.
- Emitting surface areas: feedpens (89%), retention ponds (5%), compost windrows/piles (6%).
- Aggregated Emission Rates (ERs) per head:
  - Methane, CH_4 = 3.8 g/hd/day.
  - Nitrous oxide, N_2O = 0.52 g/hd/day.
  - Carbon dioxide, CO_2 = 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

- **Final-year report:**
- Stakeholder Advisory Committee, met w/investigators 2011 & 2012.
- In-depth short courses (8) for state regulators TX, KS, IA, etc.
- Annual updates to TCFA Research Committee.
- County Extension & TCFA feedyard management seminars (7), May 2013—So. Tx, So. Plains, Panhandle.
- Bulletins & fact sheets (10)— ***eXtension*** websites, UN-L/NLPELC & AgriLife Extension.
- Policy-relevant summaries—1 ready; 5 drafted.
- Webinars (8)– ditto.
- Co-Funding: $0.9 million, (0.9:1 leveraging of federal dollars).
- Presentations (22), prof. papers or abstracts (24); 32 peer-reviewed journal articles; M.S. theses (2).