
There's plenty of room for all God's creatures.
Right next to the mashed potatoes.
SASKATOON
STEAKS • FISH • WILD GAME
477 HAYWOOD ROAD
FAIRWAY

Introduction to Open-Path Transmissometry as a Surrogate Measure of Ambient PM at Cattle Feedyards

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Meeting the Environmental Challenges of Texas' Livestock and Poultry Industries with Engineering, Education and Professional Development

Difficulties Posed by Ambient PM_x Monitoring

1. Labor-intensive, esp. in research mode
2. Time resolution amplifies labor issue
3. Size-selective inlets not aerodynamically robust
4. PM_x not an intuitive concept to the masses
5. Not well suited to spatially chaotic plumes

What We Want

1. Reduce labor requirements;
2. Permit time-resolved measurements;
3. Avoid biases of inertial, size-selective inlets;
4. Deliver an intuitive and reliable surrogate for PM_x as a dust measure; and
5. Integrate measurement along a line transverse to plume drift

Candidate Methods

- TSP + PSD = PM_x
  - Best suited for regulatory applications where MMD>>x
  - Assumes PSD method is accurate in AED ranges of interest
  - Does not reduce labor intensity
- Tapered-Element Oscillating Microbalance
  - Time-resolved data
  - Still a point measure
  - Still has S-SI bias problem
- LIght Detection And Ranging
  - Won’t be long until it’s affordable! (maybe)
  - Can shoot a plume approximately in 3-D
  - This one got us thinking about optical methods

Where Doth Transmissometry Fit?

- Potentially:
  - ✓ Reduces labor requirements;
  - ✓ Permits time-resolved measurements;
  - ✓ Avoids biases of inertial, size-selective inlets *(sort of);*
  - ? Delivers an intuitive and reliable surrogate for PM_x as a dust measure; and
  - ✓ Integrates measurement along a line transverse to plume drift

Caveat

Like substitutes for dynamic, forced-choice olfactometry, visibility data have little regulatory meaning *without being anchored to the accepted methods*:

Odor: Human panelists

PM_x: Federal Reference Methods

Motivation (Reprise)

- We're NOT interested in:
  - Shouting matches (or worse) over "preferred methods" ; NOR
  - Slaying *Sacred Cows*™
- We ARE interested in:
  - Adding to the monitoring toolkit for agricultural PM
  - Visibility measurements for their own sake

Principles of Visibility

- Image strength can be attenuated by reflection, refraction, absorption
- Contrast is modified by wavelength dependence of attenuating processes
- Instruments can differentiate among scattering processes, but...
- ...our eyes and brains respond to the *integration* of those processes

Components of Total Atmospheric Extinction

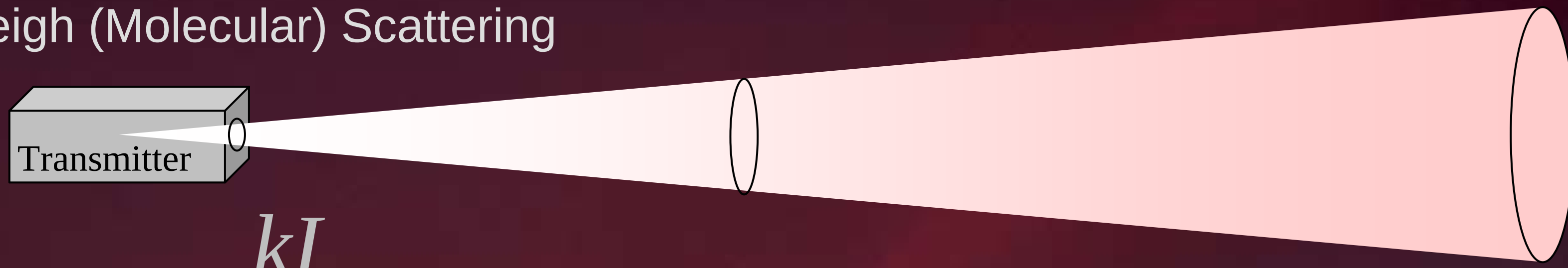
Scattering Absorption

Particles

Gases

Total Extinction

Rayleigh (Molecular) Scattering



$$I_R(x) = \frac{kI_o}{x^2} e^{-\alpha_R x}; \lim_{P \to 0} \alpha_R = 0$$

$$I_T(x) = \frac{kI_o}{x^2} e^{-\alpha_T x}; \alpha_T = f(C_{PM}, C_{gas} \ldots)$$

Molecular <u>and Particle</u> Scattering and Absorption

Transmissometry Equation

$$f = \left\{ \frac{k_j}{r^2} \frac{I_{o,j}}{I_j(r)} \right\}^{1/r} = e^{-\alpha_j}$$

Koschmieder Equation

$$VR = \frac{3.912}{\alpha}$$

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Wyoming Visibility Monitoring Network

Wyoming
Department of Environmental Quality

Live Sites

Campbell County
Cloud Peak
Thunder Basin
All Sites

Image Gallery

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Teton Wilderness
Yellowstone National Park

Campbell County
Cloud Peak
Green River Basin
Thunder Basin

Cloud Peak

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Image Updated Every 15 Minutes

Meteorology

Temperature	71°F	Humidity	54%
Wind Speed	8 mph	Wind Direction	ESE

Air Quality Information

Visual Range ~ 94 miles

Wyoming

Extinction Efficiency of Air Pollutants

$$\beta_i = \frac{\partial \alpha_T}{\partial C_i}$$

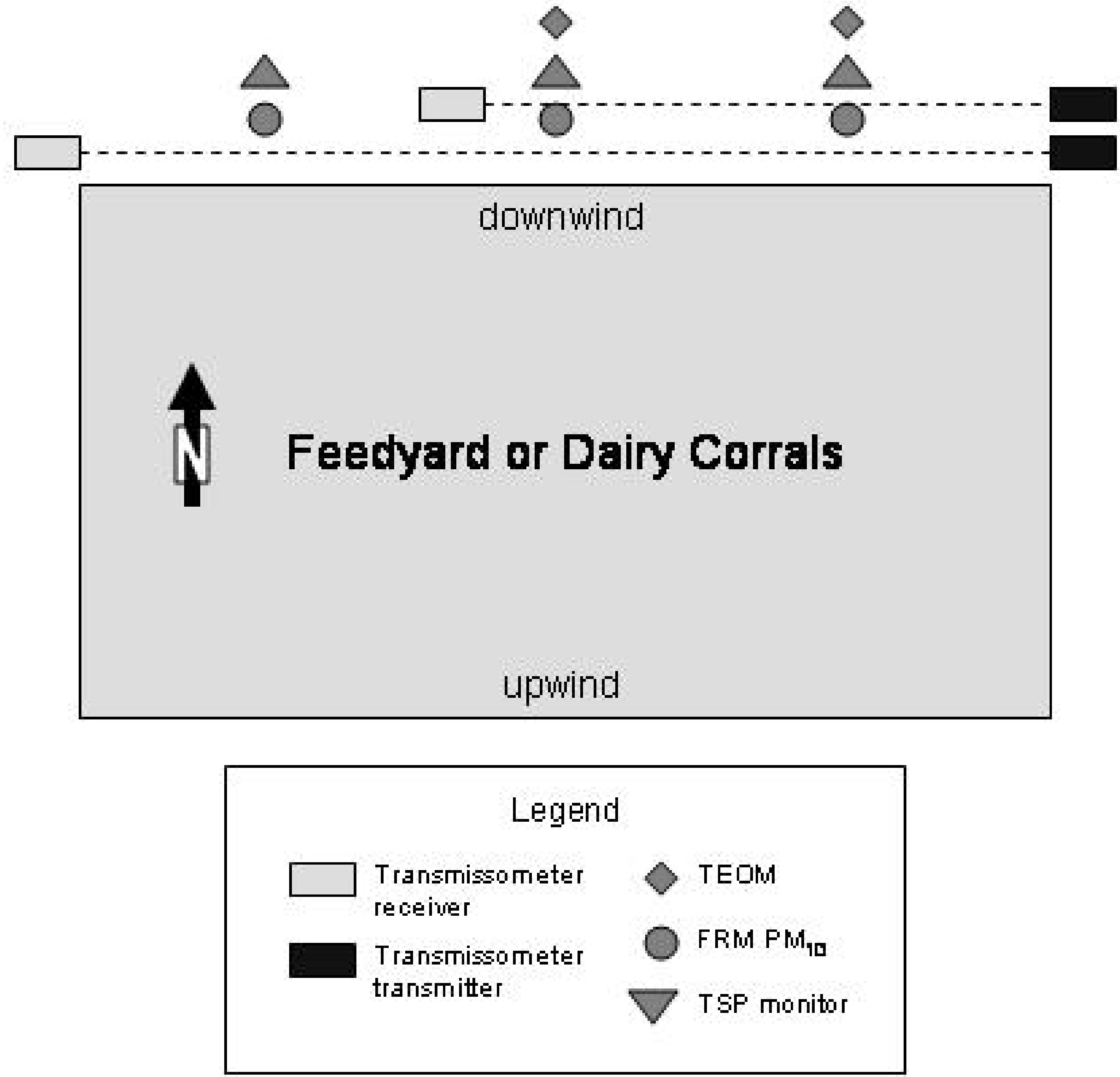
Units: $L^{-1}\ L^{3}\ M^{-1} = L^{2}\ M^{-1}$

Extinction efficiencies by particle type (Malm, 1999)

Particle Type	*Dry Extinction Efficiency (m^2/g)*
Sulfates	3.0
Organics	3.0
Elemental Carbon	10.0
Nitrates	3.0
Soil Dust	1.25
Coarse Particles	0.6
Feedyard Dust	***????***

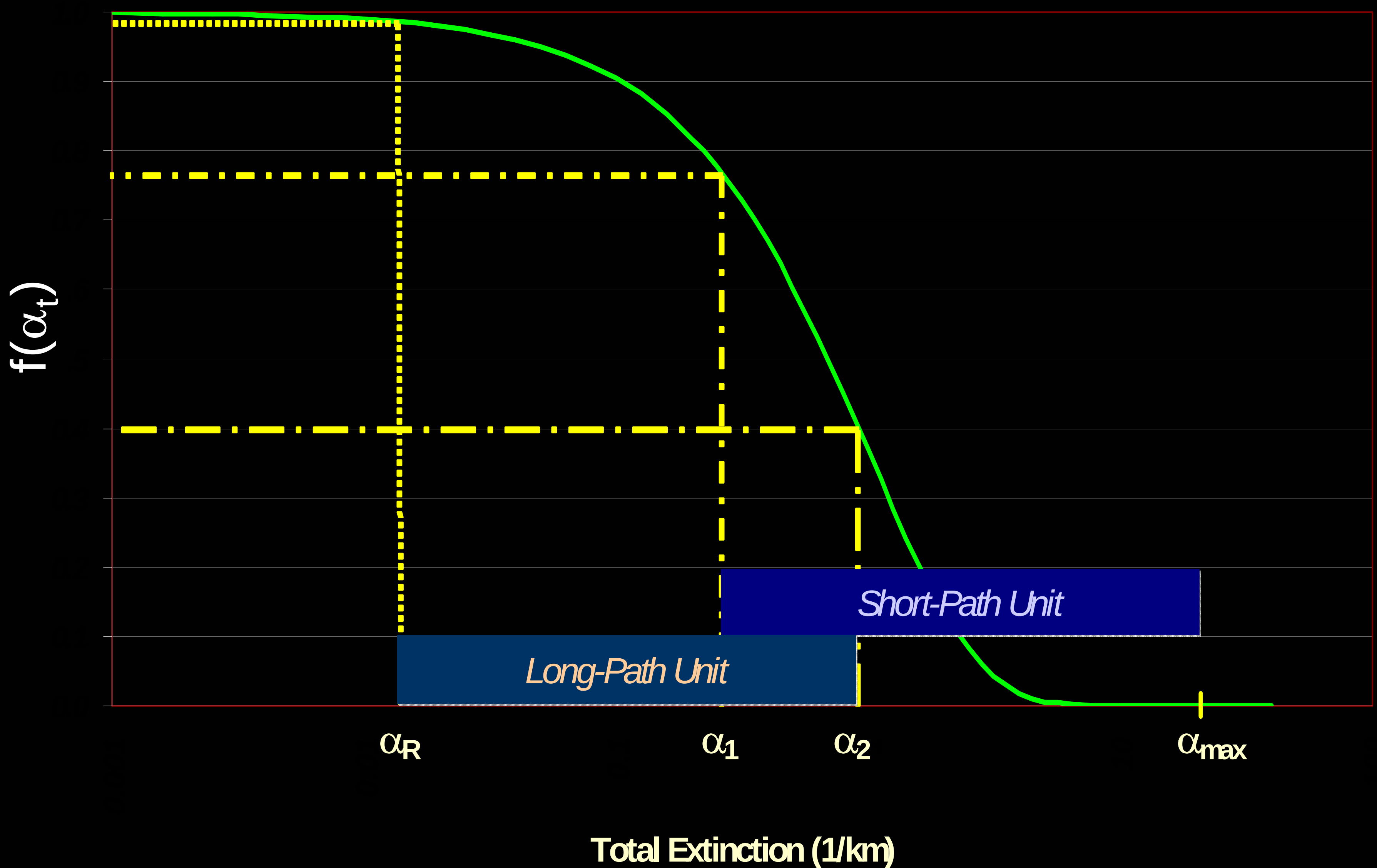
Objectives

1. Determine the open-path length at which one can measure the maximum extinction coefficient associated with severe feedyard dust events
2. Optimize path lengths and gain settings for a two-transmissometer system to measure worst-case to Rayleigh conditions
3. Determine the extinction efficiency of feedyard dust



downwind
N
Feedyard or Dairy Corrals
upwind
Legend
Transmissometer receiver
Transmissometer transmitter
TEOM
FRM PM_{10}
TSP monitor

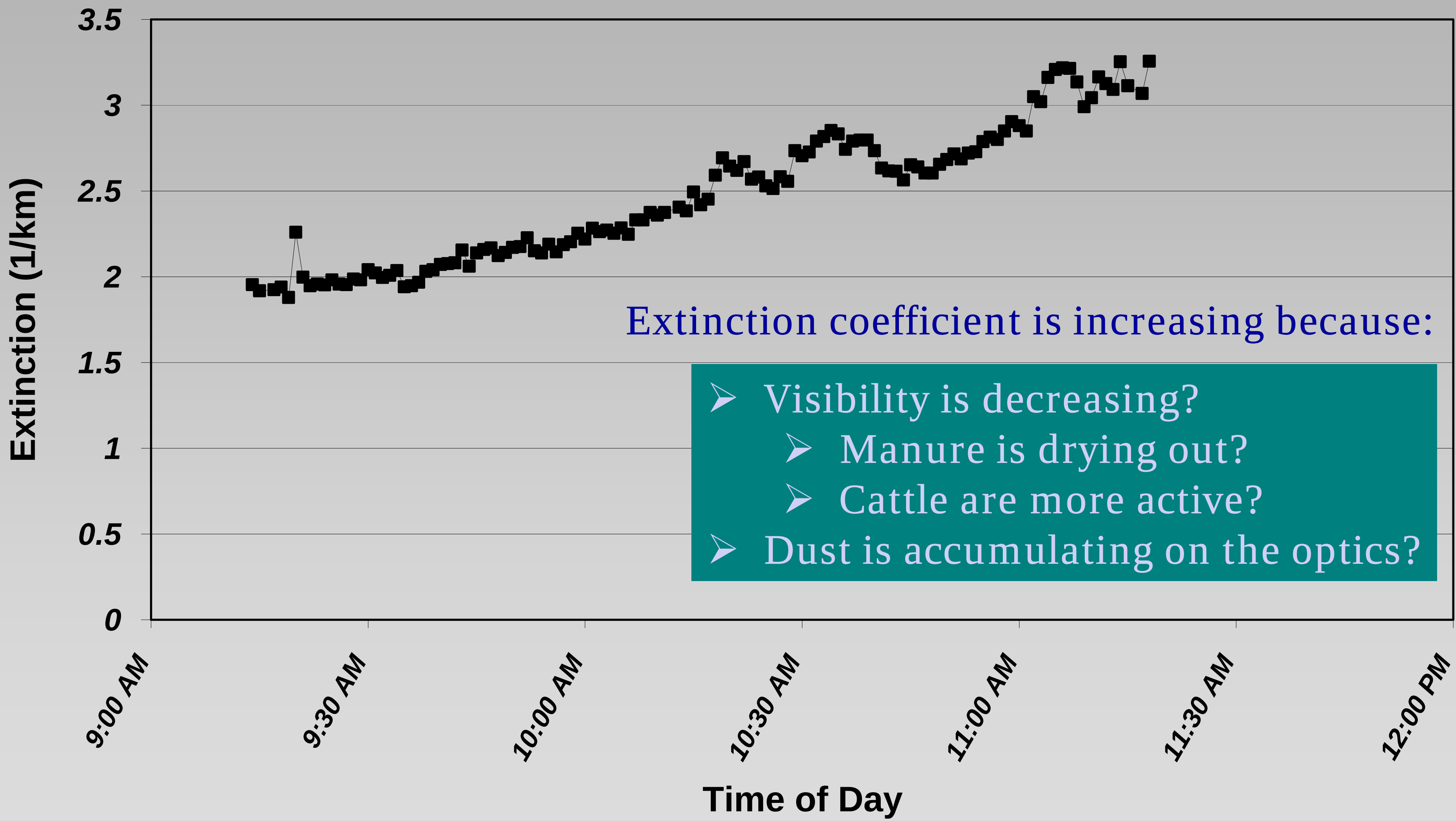
Two-Transmissometer Concept



Progress to Date

- Successfully calibrated the LPV-3 in the feedyard setting
- Successfully measured stable extinction values downwind of a commercial yard
- Predicted optimum path lengths from theory for two-unit system
- Rain, rain, go away!

Downwind Extinction Coefficient, Feedyard C
April 23, 2004



Extinction coefficient is increasing because:

- Visibility is decreasing?
  - Manure is drying out?
  - Cattle are more active?
- Dust is accumulating on the optics?

What Are the Remaining Challenges?

On flat terrain, elevations of transmitter and receiver must sum to 30’ per km of path length

Depth of dust plume (50’) limits us to about 3.0-3.6 km path length

Physical dimensions of feedyards limit us to 1.5-2.0 km path length

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