

Extinction Efficiency of Feedyard Dust

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What We're After

An open-path means of estimating PM concentrations uniquely associated with emissions from open-lot livestock facilities (beef, dairy, sheep, goats)

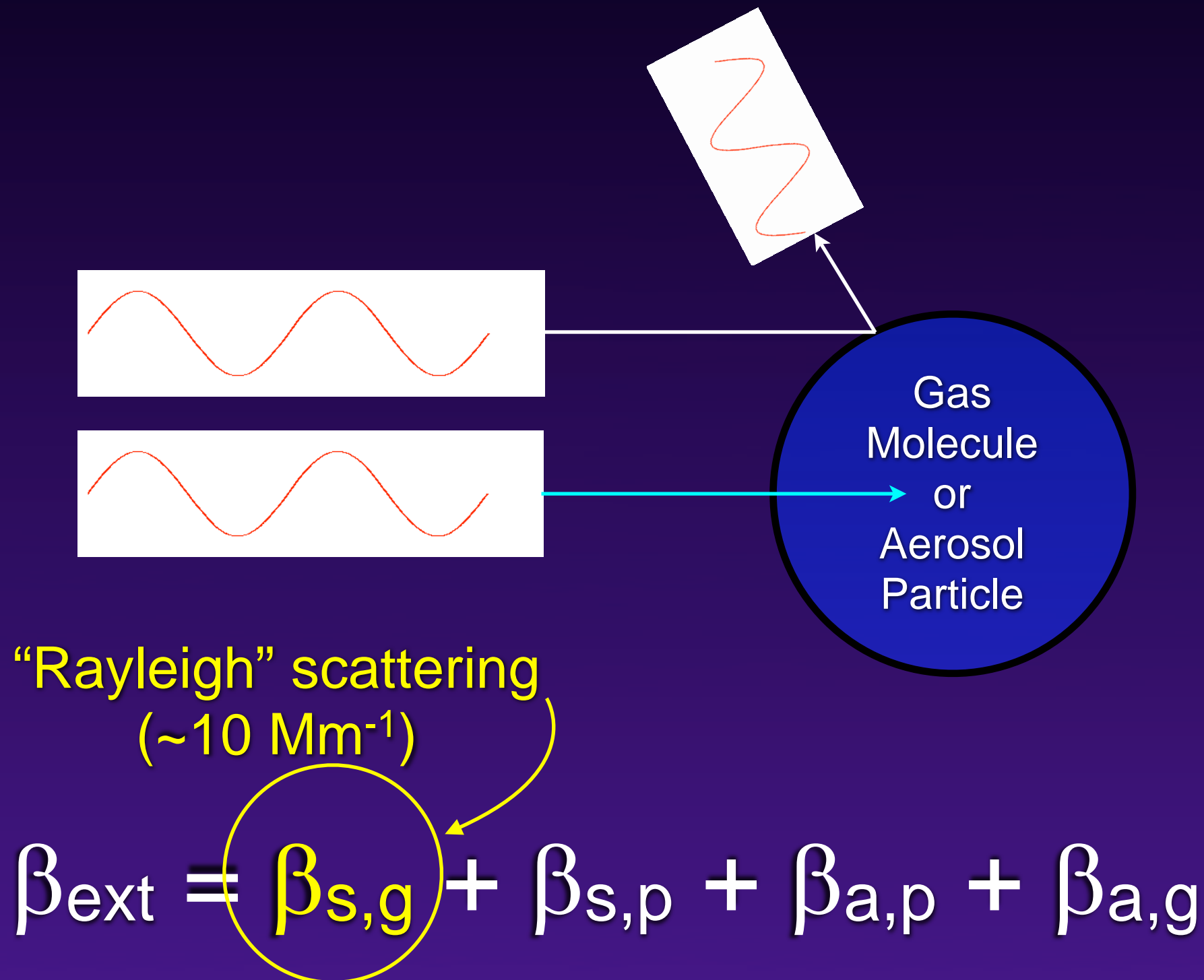
Why Transmissometry?

- Visibility corresponds to human experience in ways that $\mu\text{g}/\text{m}^3$ never will
- TCEQ gave us a transmissometer for free

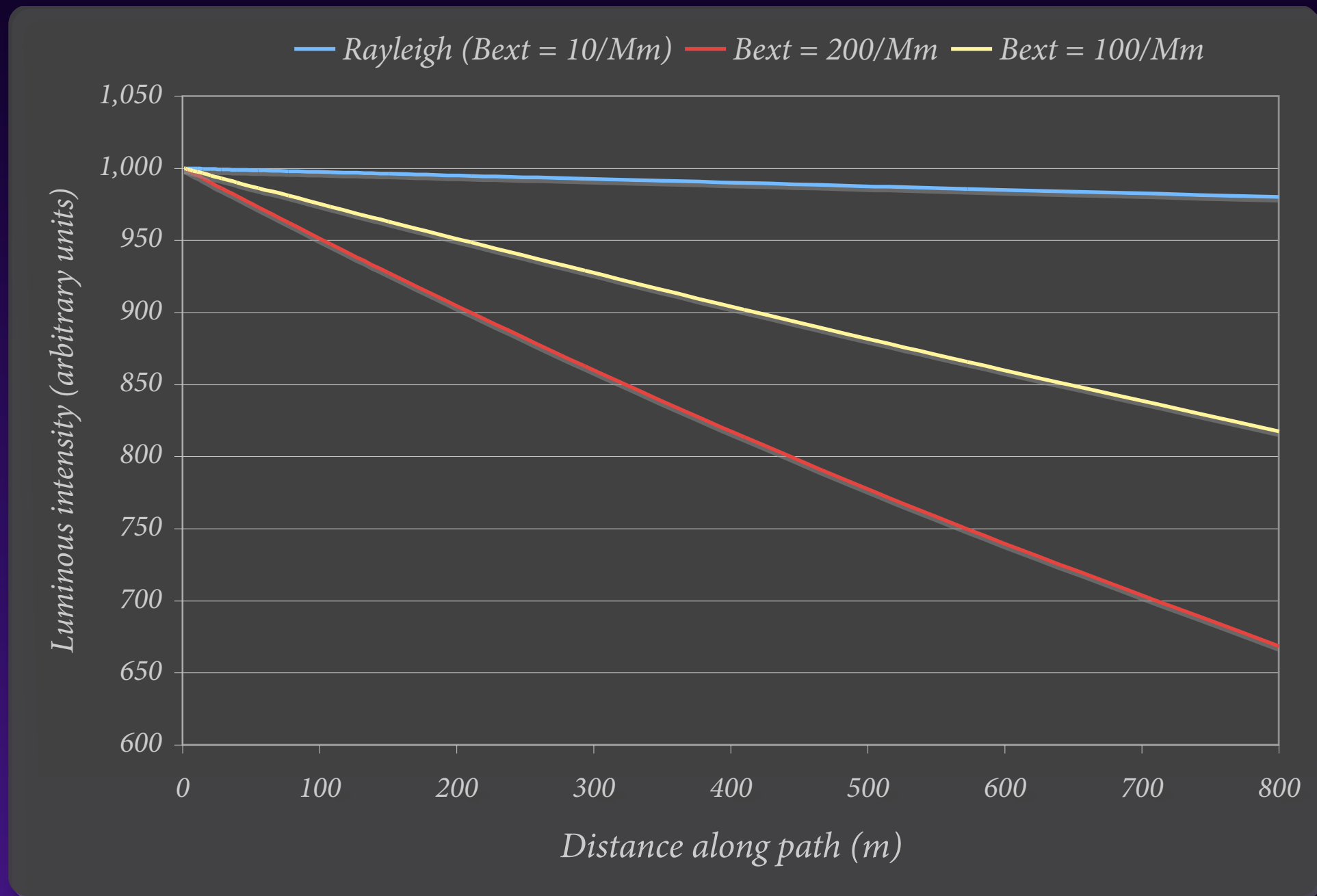
Defining a Few Terms

- Scattering and Absorption
- Atmospheric Extinction
- Extinction Efficiency
- Deliquescence

Scattering and Absorption



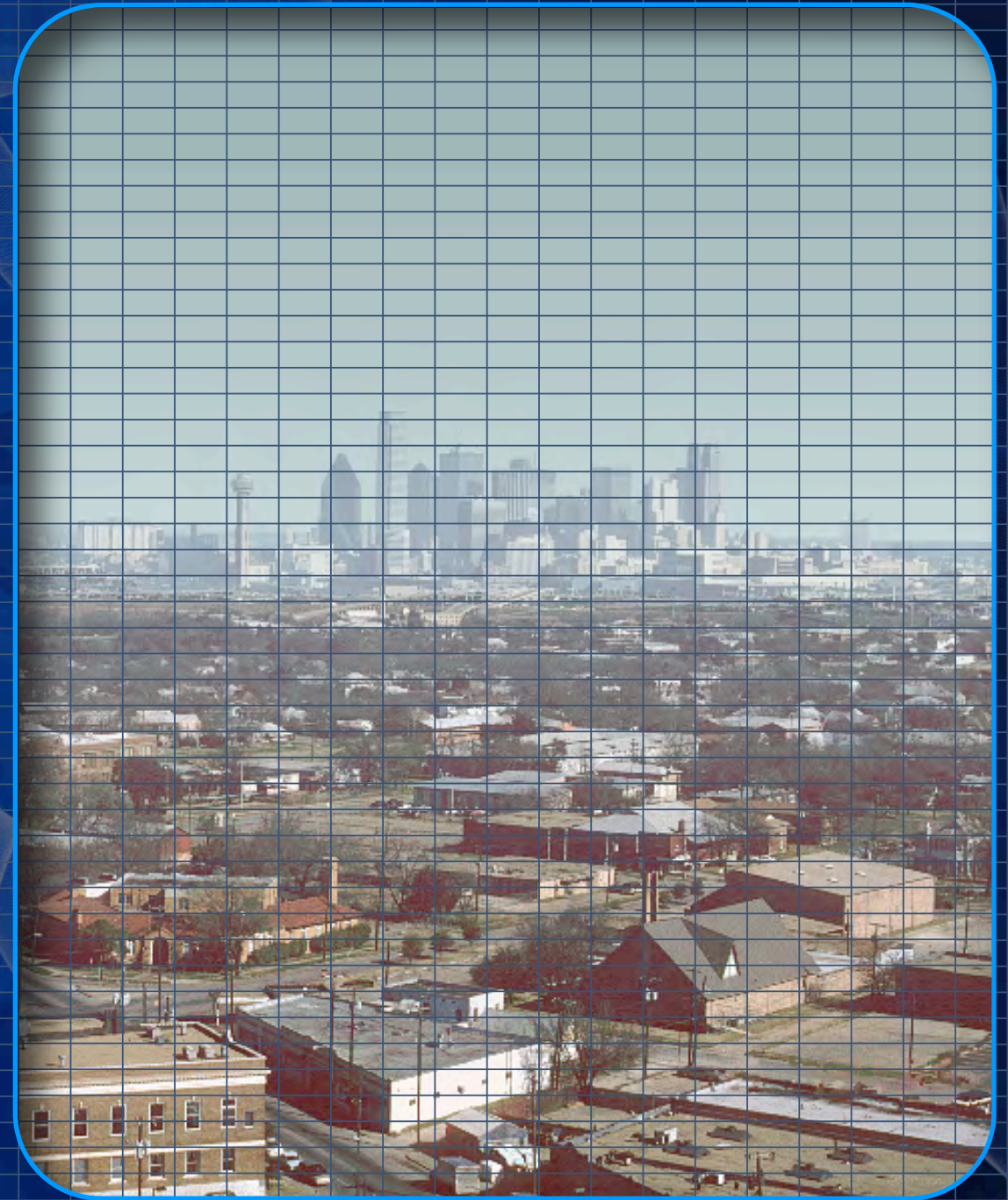
Atmospheric Extinction



ATMOSPHERIC EXTINCTION

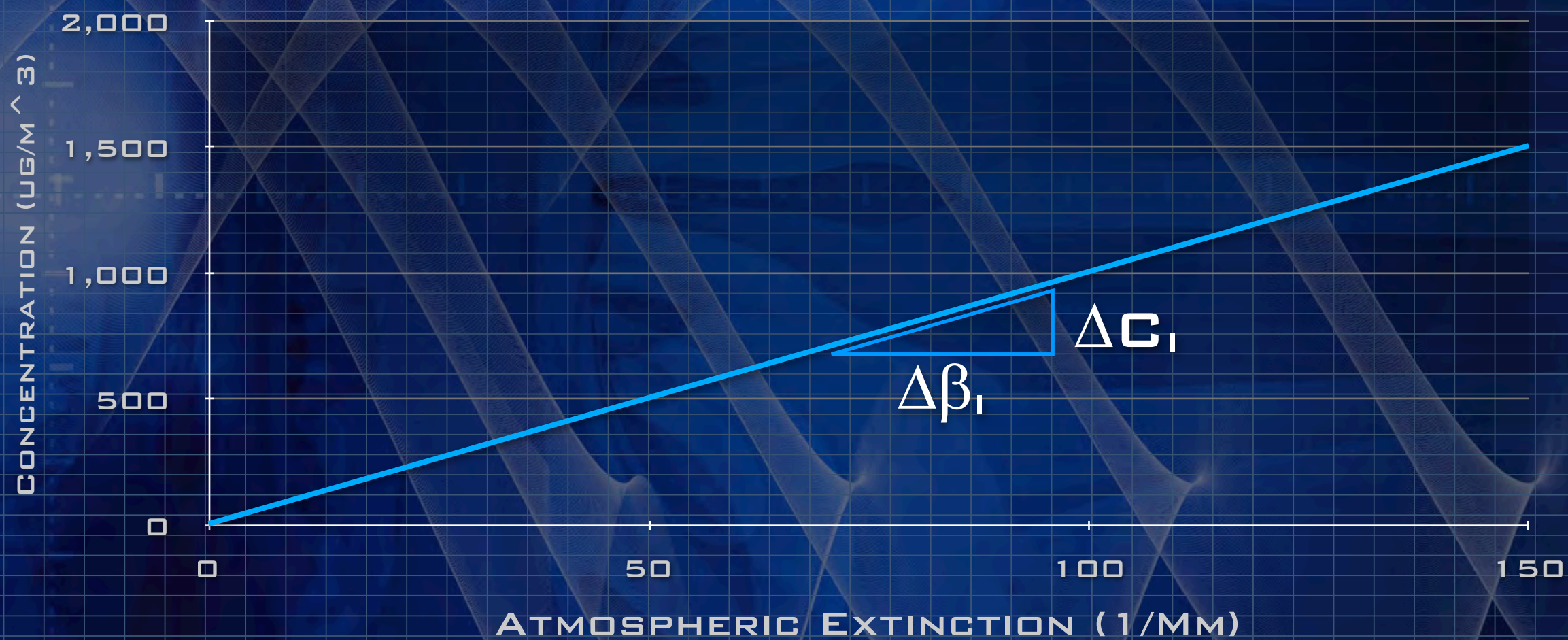


RAYLEIGH (10 MM^{-1})



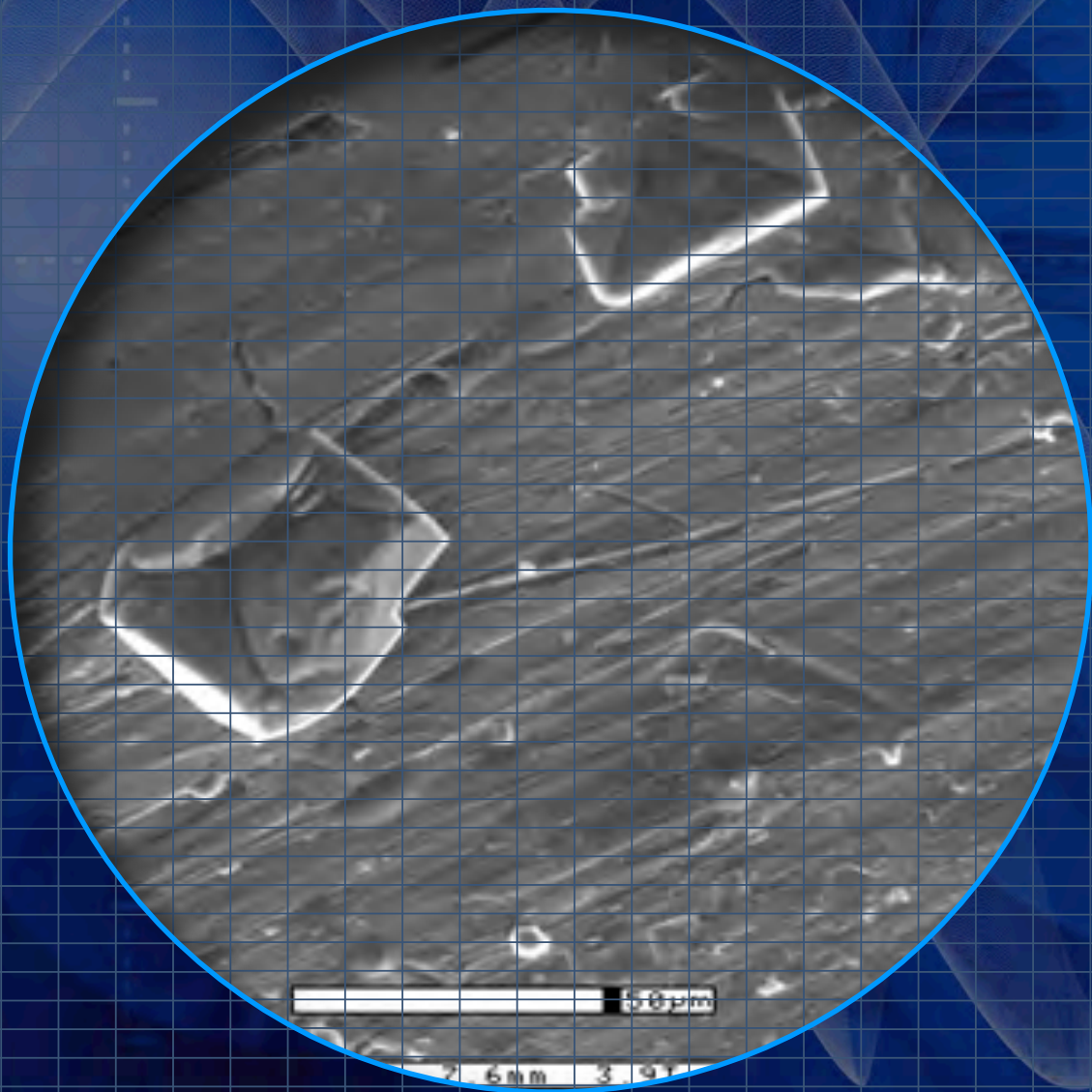
200 MM^{-1}

EXTINCTION EFFICIENCY

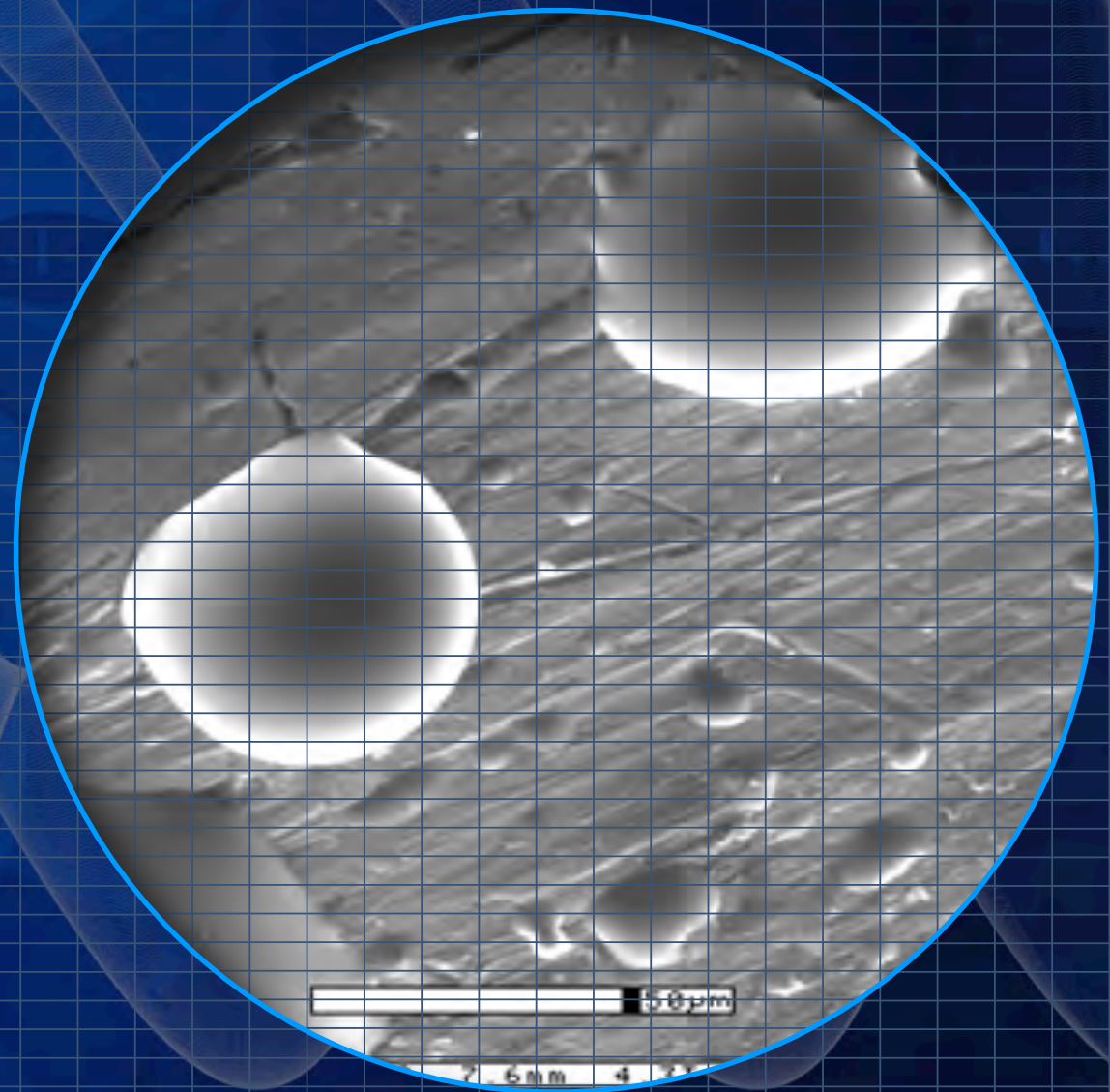


DELIQUESCENCE

RH=67.5%



RH=75%



SEM PHOTOS COURTESY DR. SARAH BROOKS, TAMU ATMOSPHERIC SCIENCES

EXPERIMENTAL DESIGN

EXPERIMENTAL SETTING

- ▶ **COMMERCIAL CATTLE
FEEDYARD**
- ▶ **CAPACITY: 50,000+**
- ▶ **GEOMETRY: RECTANGULAR,
~900M X ~1,200M**
- ▶ **FINISHING DIET: CORN
(FLAKED ON-SITE) +
ROUGHAGE, SUPPLEMENTS**
- ▶ **PREVAILING WIND: SSW**

MONITORING DEVICES AND LAYOUT



► TRANSMISSOMETER



► TEOM-PM₁₀

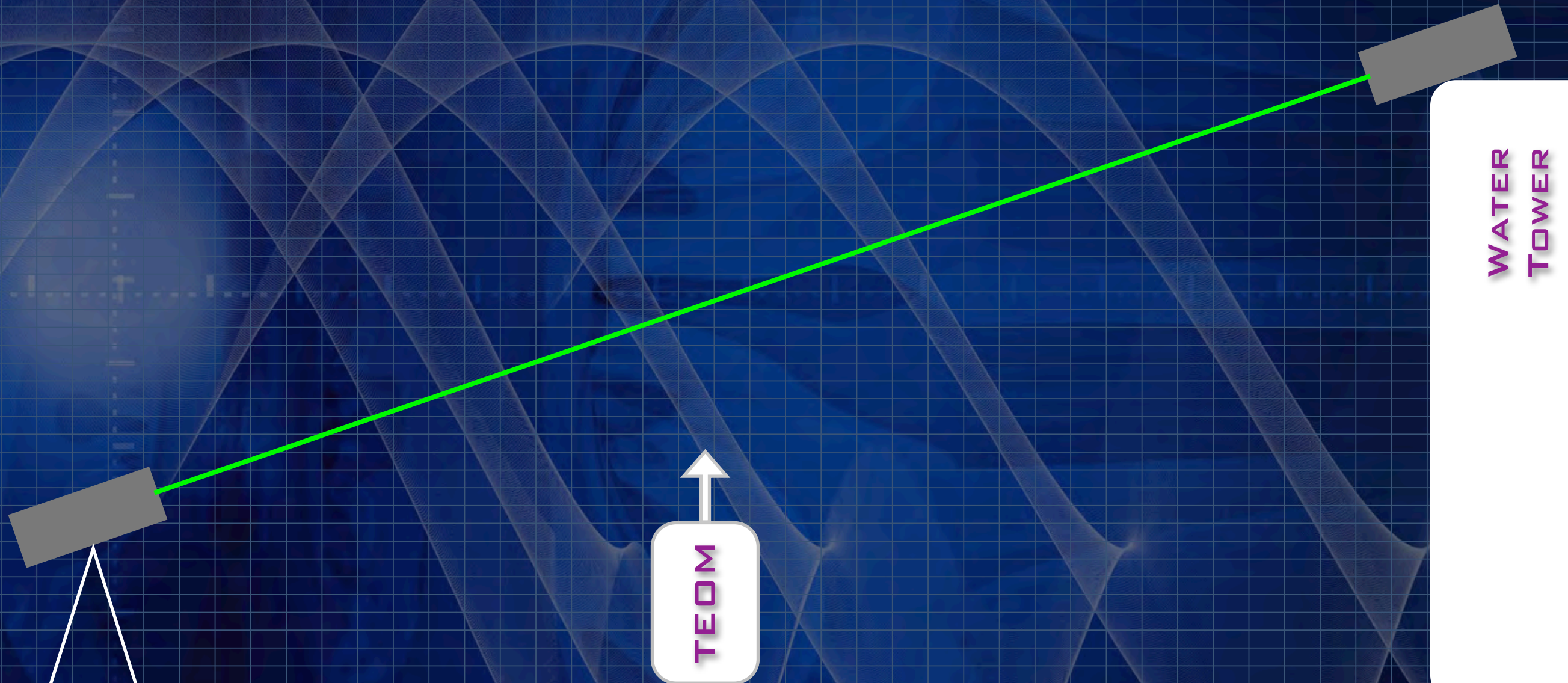


► TEOM-TSP



THE BASIC IDEA

(not to scale)

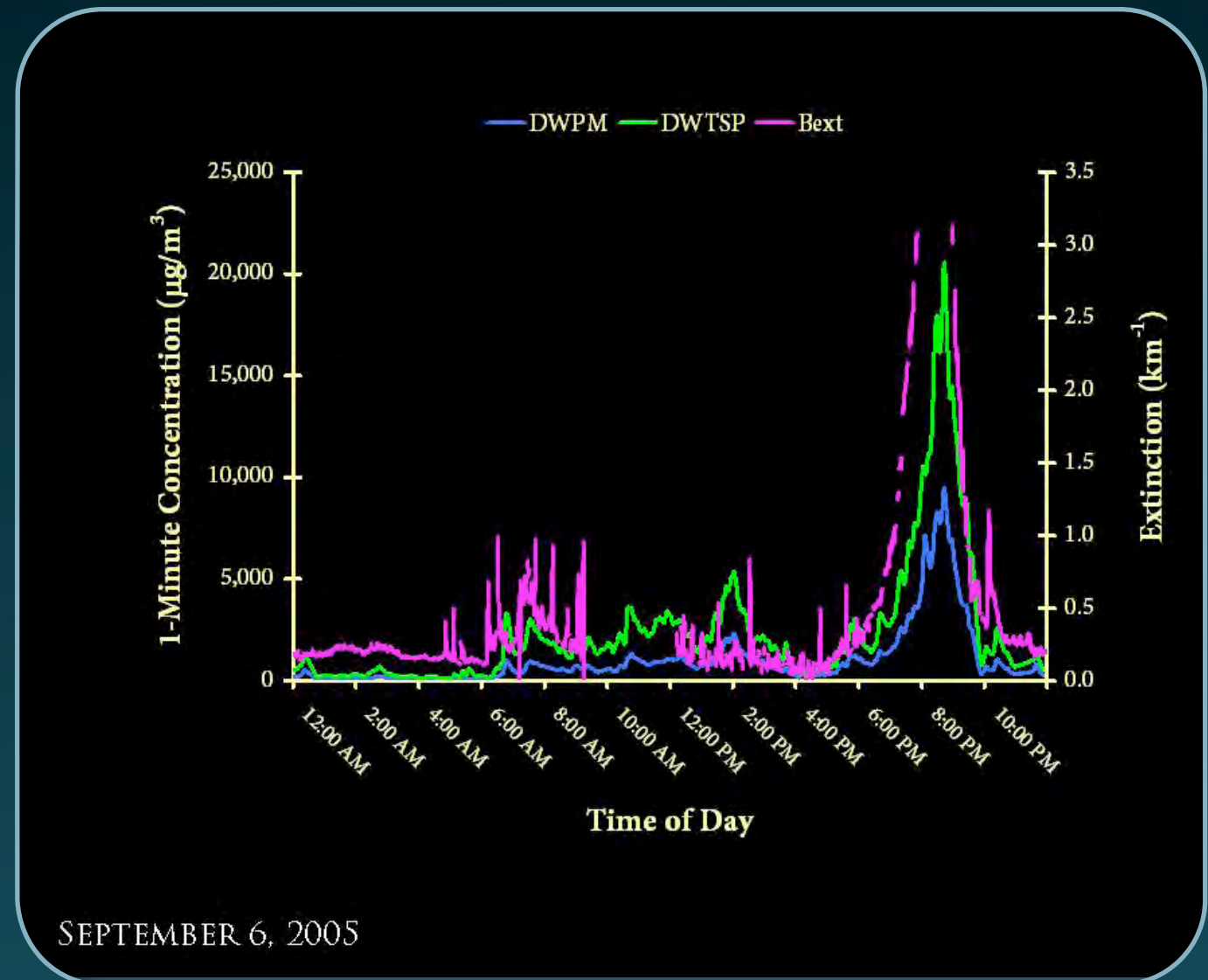


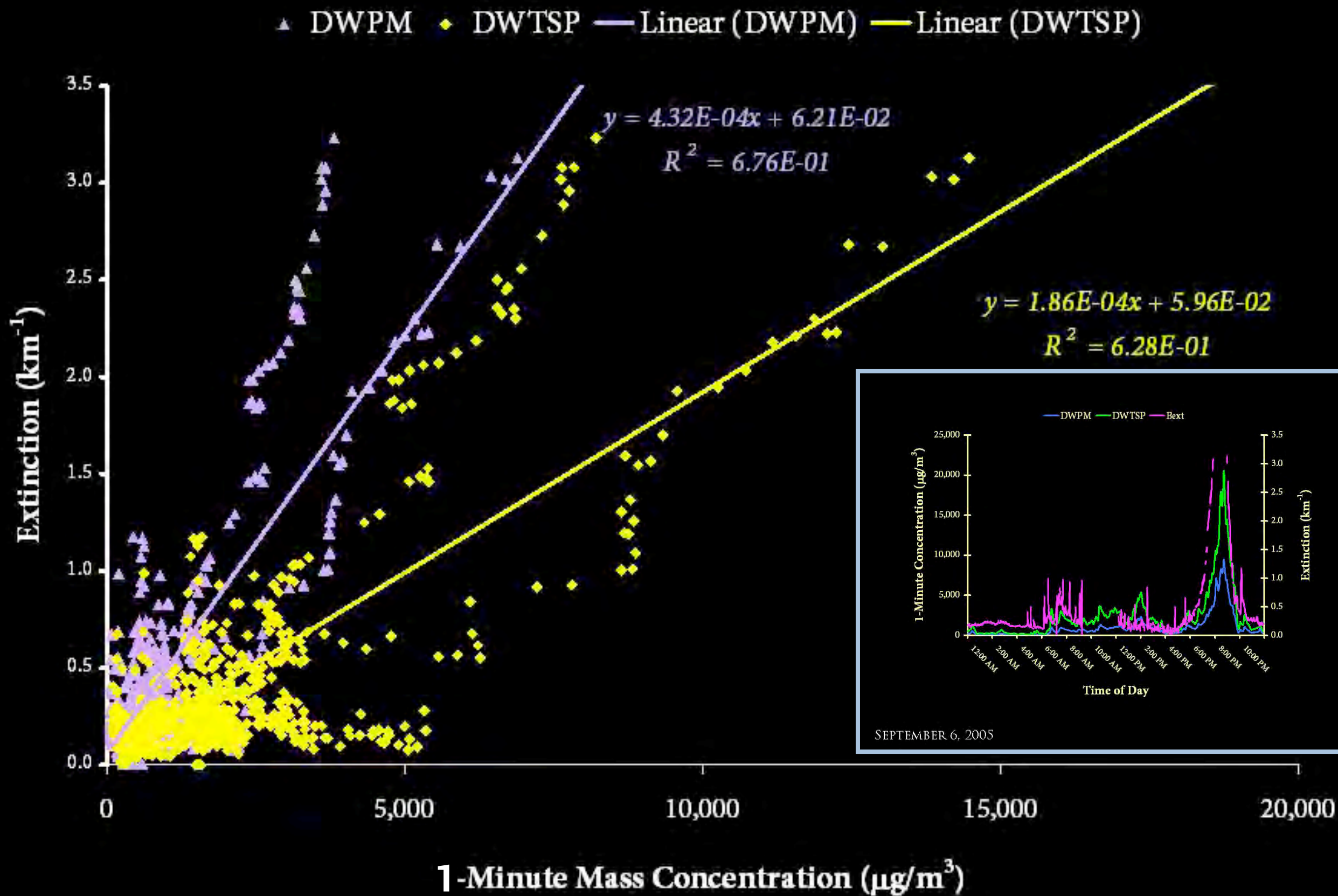
Weaknesses of the Approach

- TEOM is point measurement; LPV is a path-averaged measurement
- TEOM inlet is not precisely in centerline of LPV beam cone
- LPV beam cone is inclined to ground surface
- Time-series LPV and TEOM data are autocorrelated

MONTHLY 24-HR EXTREMA

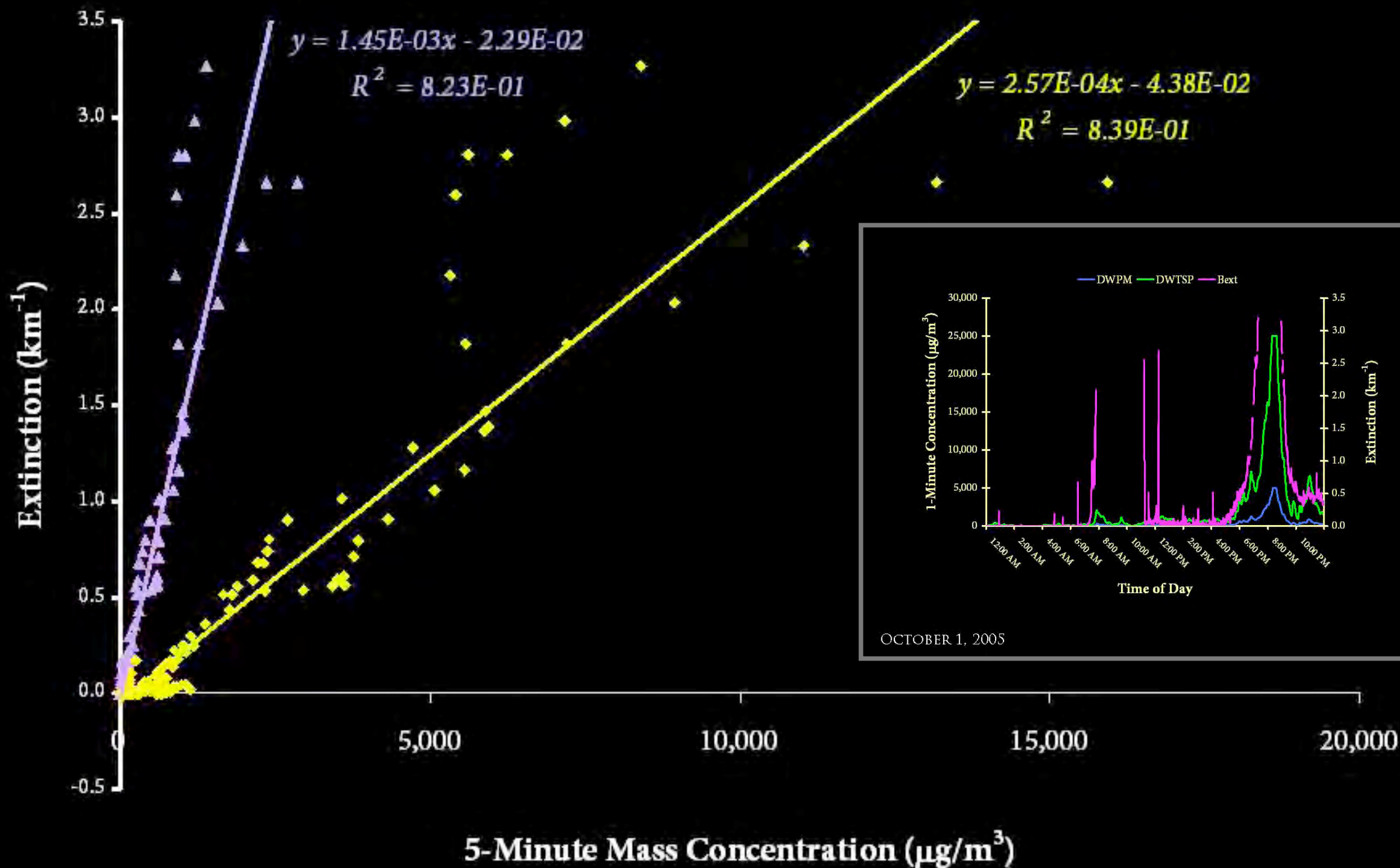
- ▶ TIME-RESOLVED DATA (1-MIN AVG.)
- ▶ EVENING PEAKS IN LPV AND TEOM DATA ARE NICELY CORRELATED
- ▶ LPV PICKS UP VEHICLE TRAFFIC
- ▶ PM_{10}/TSP RATIO CAN BE INFERRED





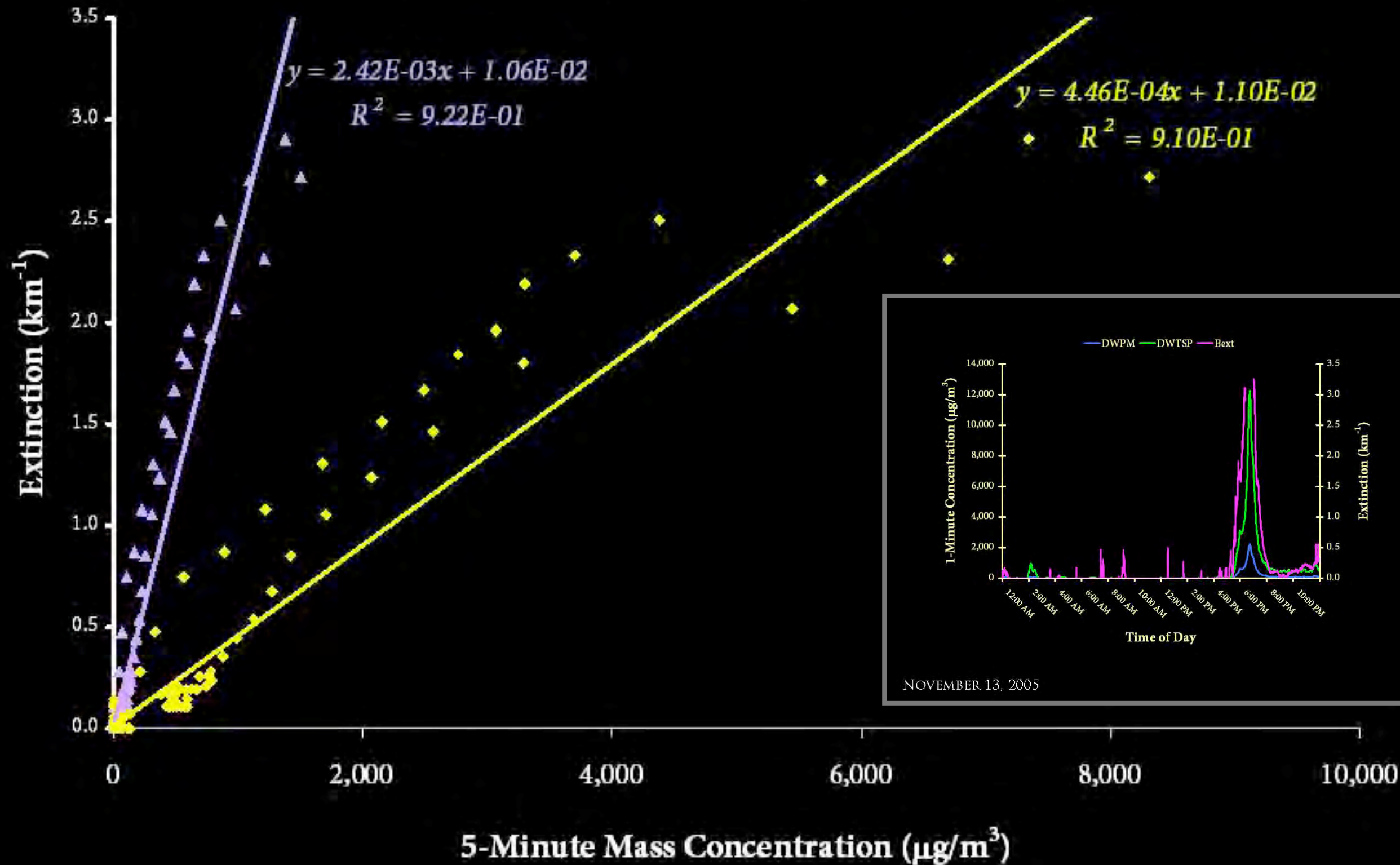
SEPTEMBER 6, 2005

▲ DWPM ◆ DWTSP — Linear (DWPM) — Linear (DWTSP)

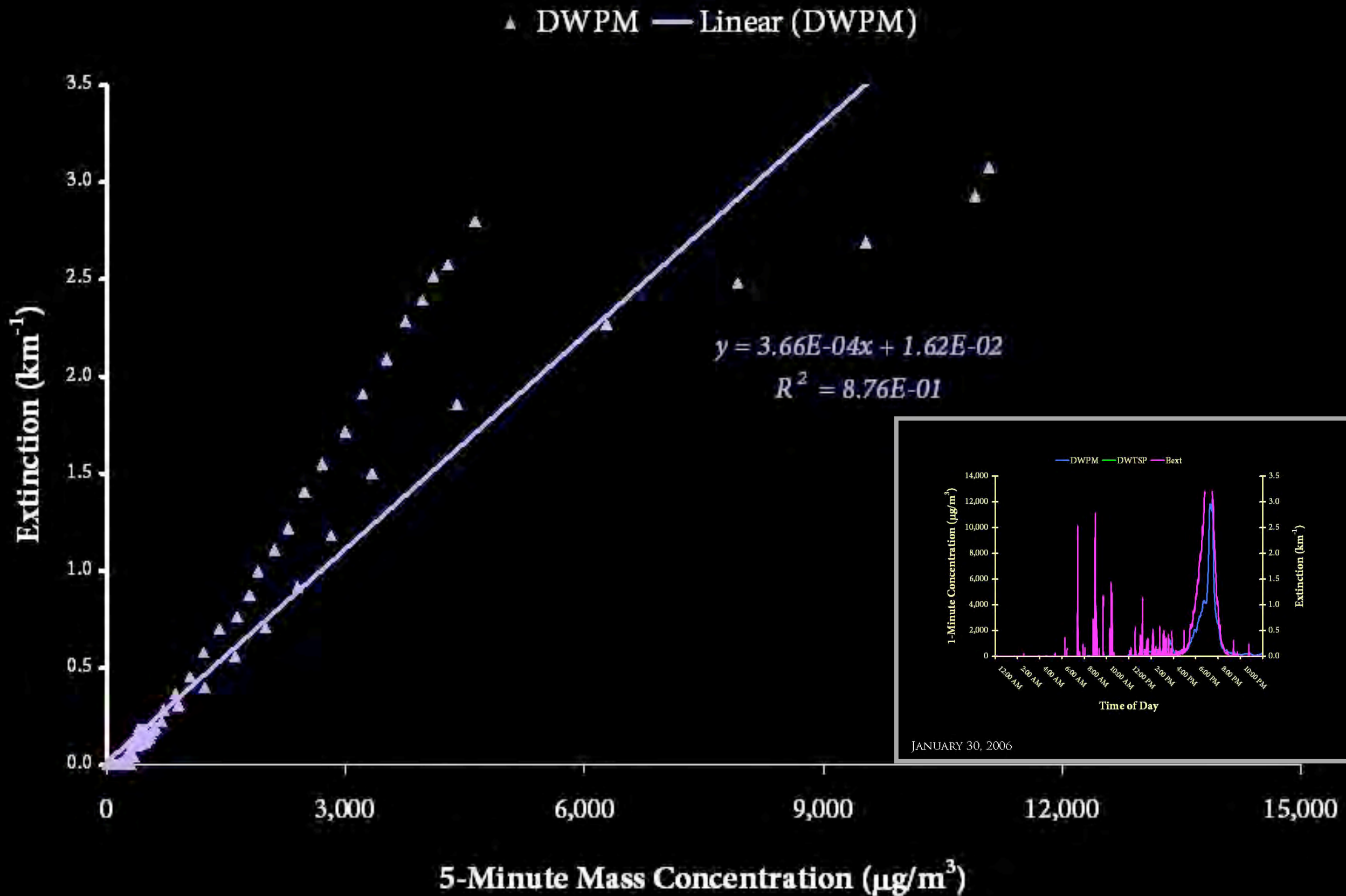


OCTOBER 1, 2005

▲ DWPM ◆ DWTSP — Linear (DWPM) — Linear (DWTSP)

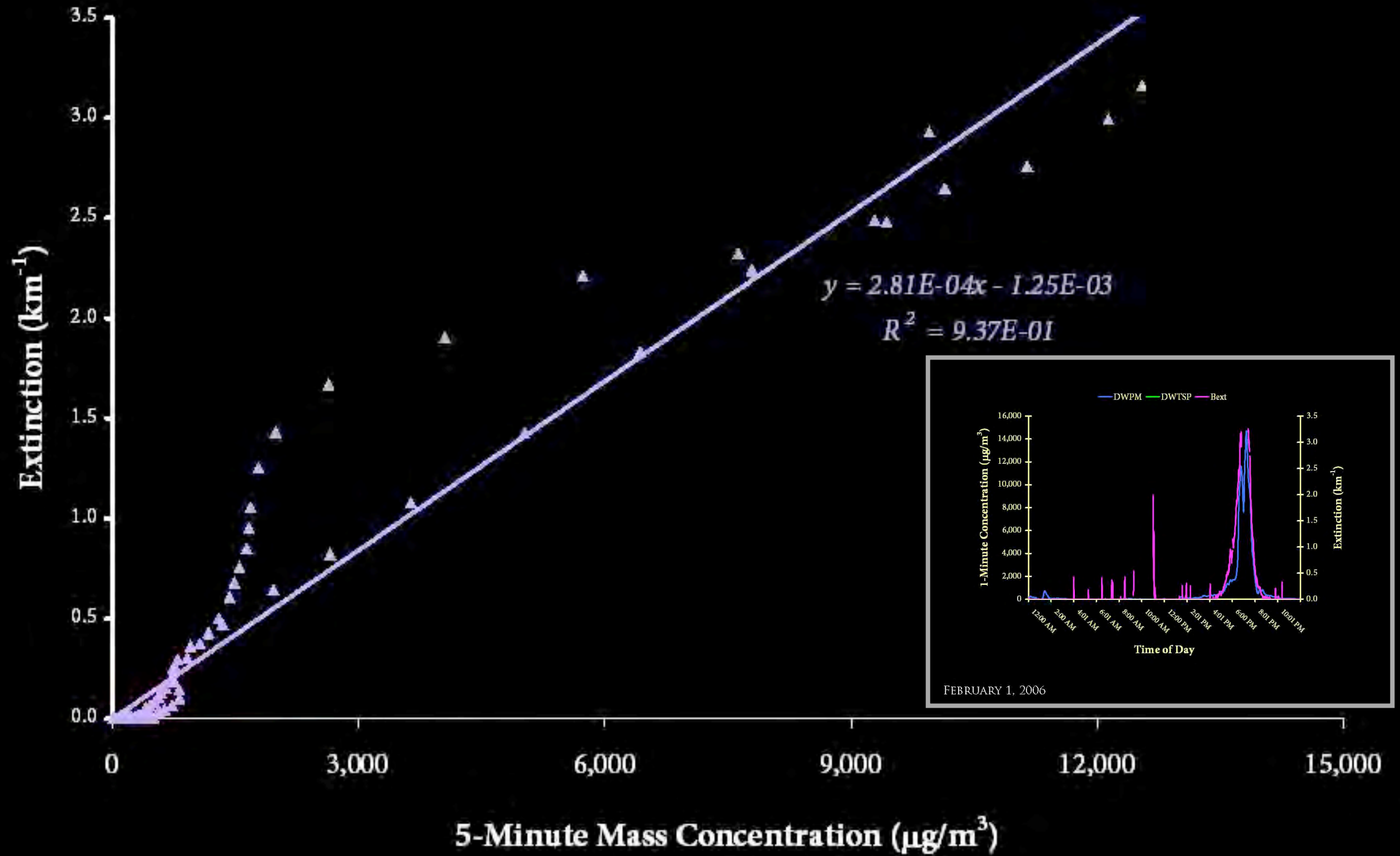


NOVEMBER 13, 2005



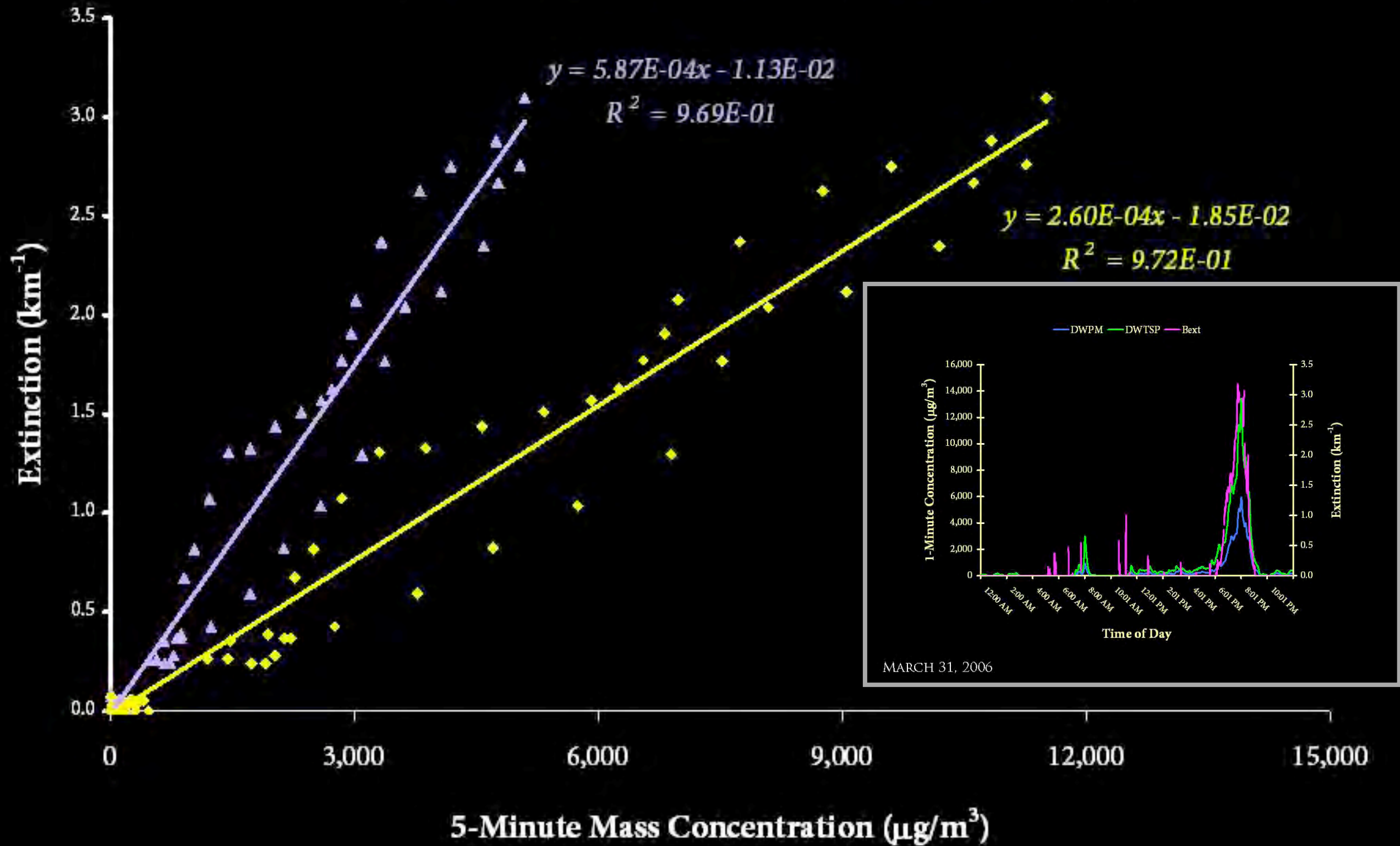
JANUARY 30, 2006

▲ DWPM — Linear (DWPM)



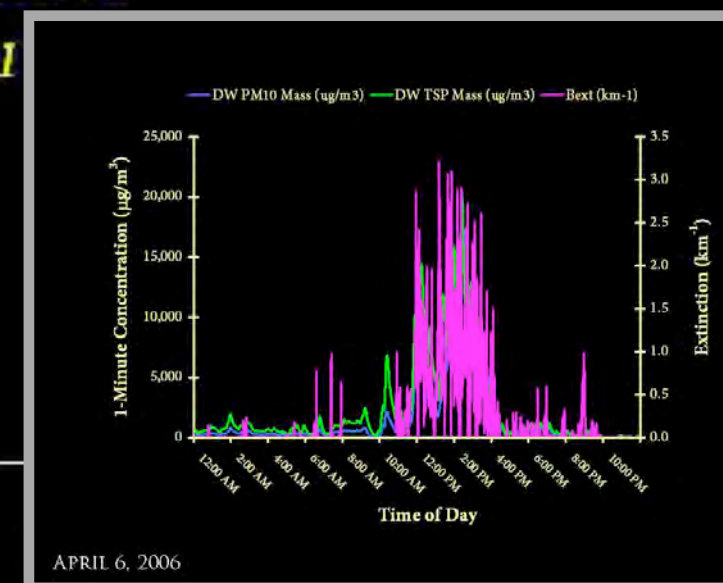
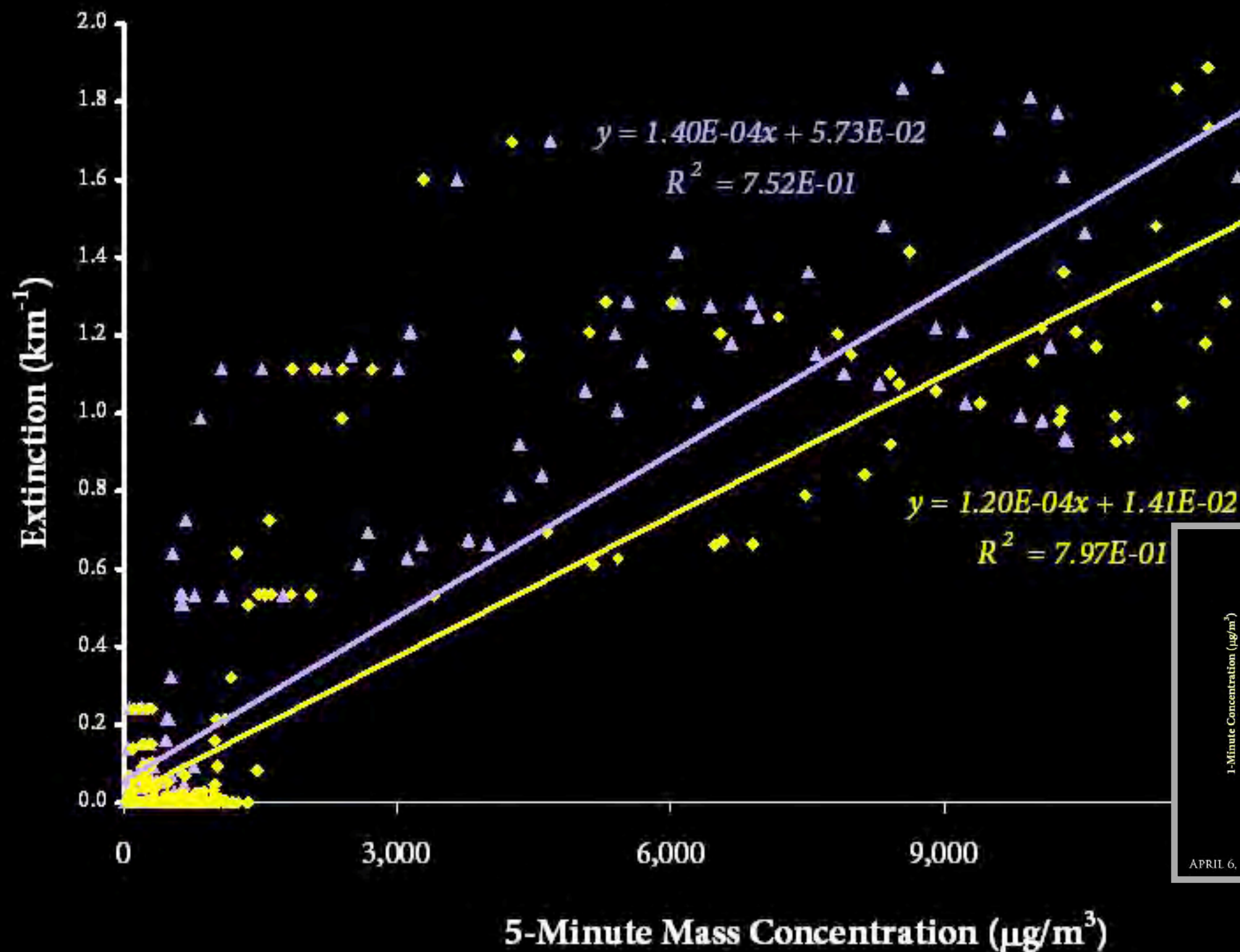
FEBRUARY 1, 2006

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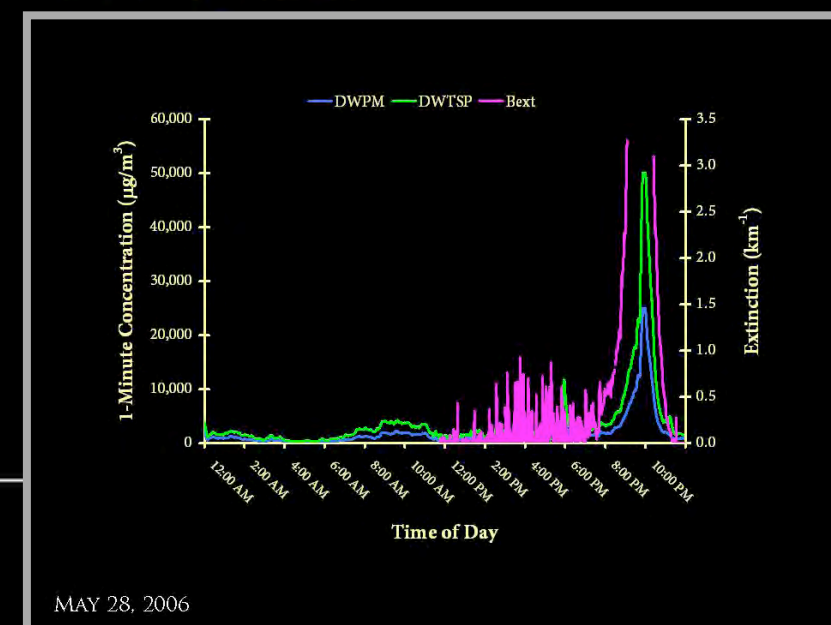
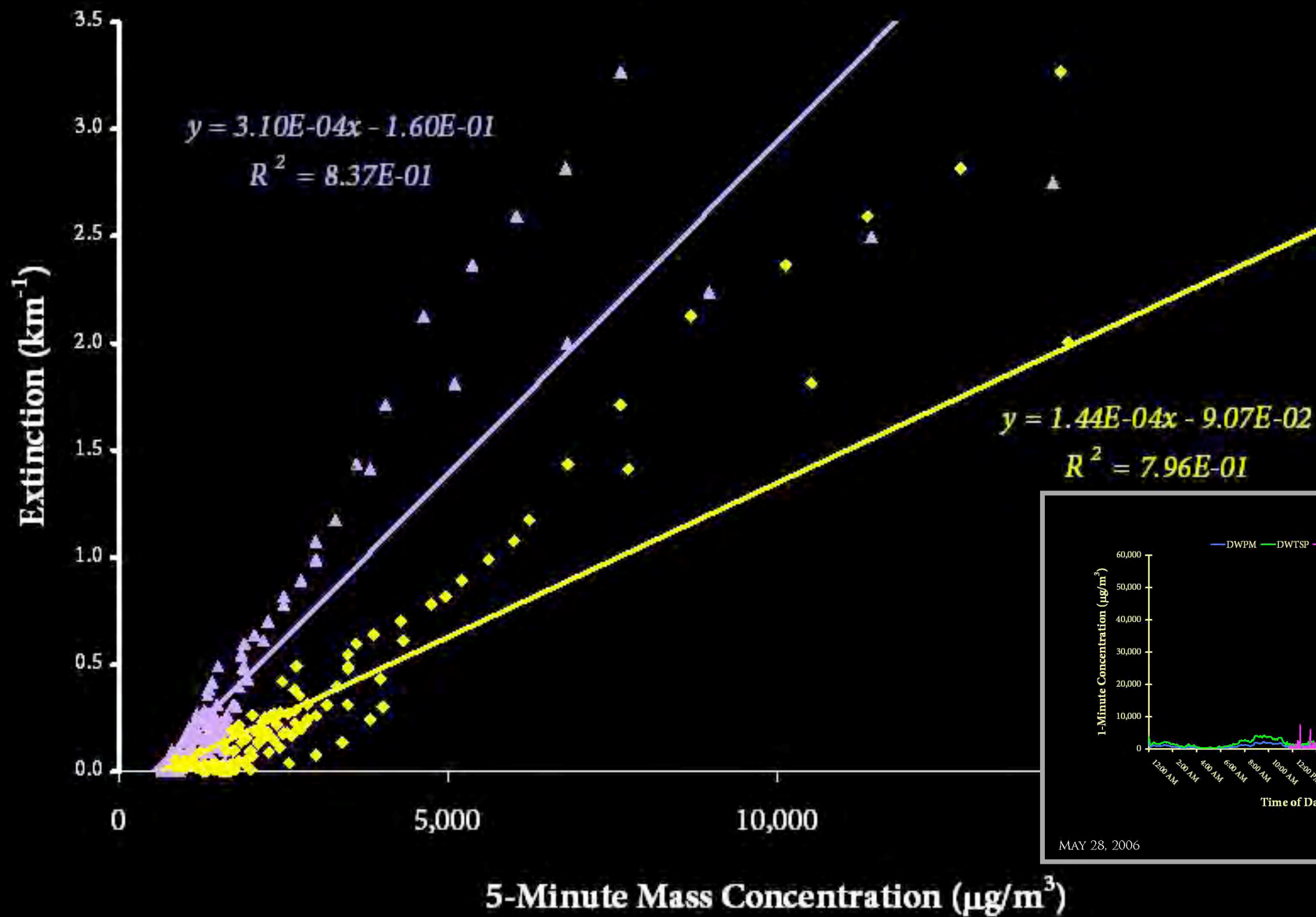
MARCH 31, 2006

▲ DWPM ◆ DWTSP — Linear (DWPM) — Linear (DWTSP)

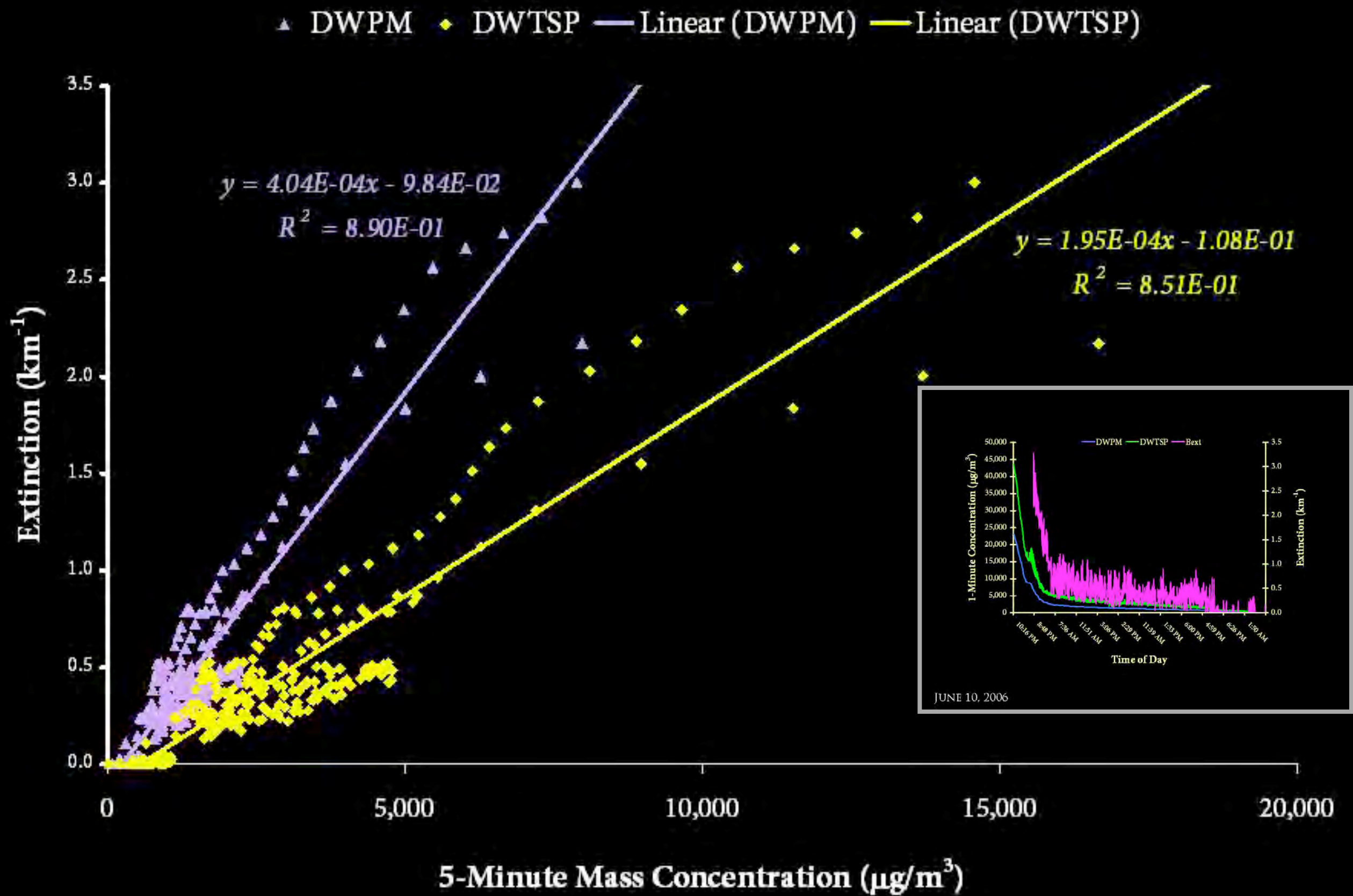


APRIL 6, 2006

▲ DWPM ◆ DWTSP — Linear (DWPM) — Linear (DWTSP)

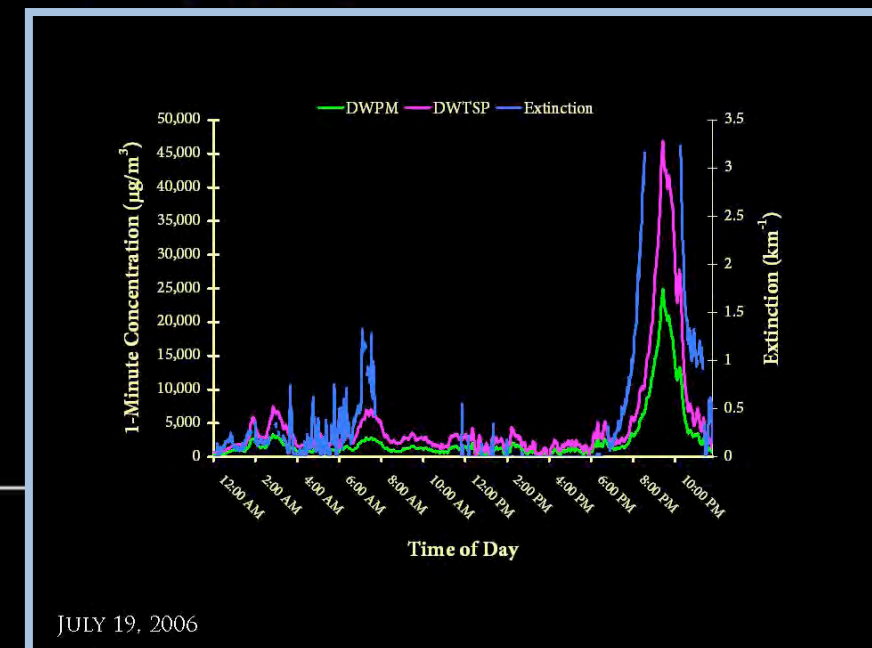
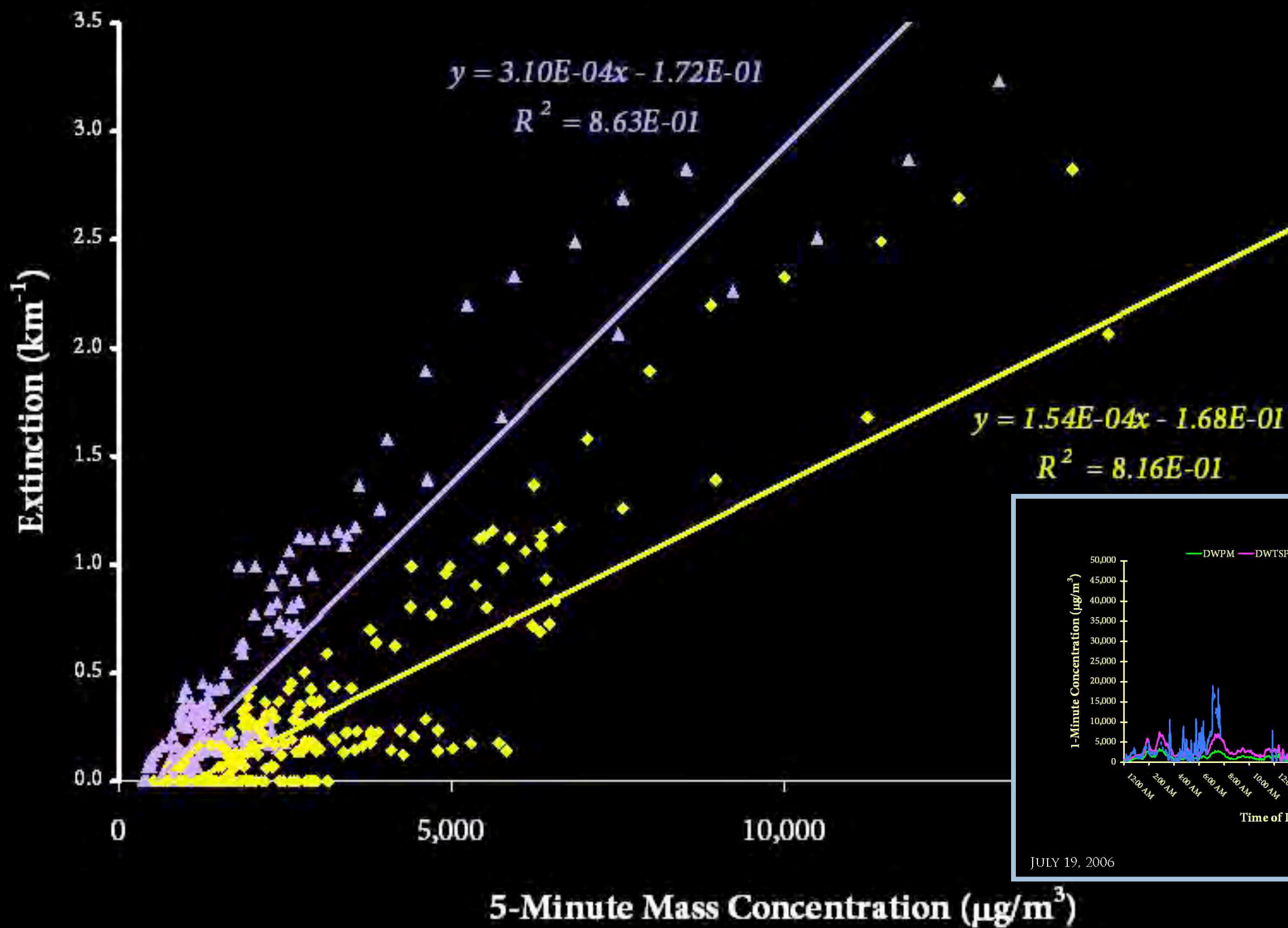


MAY 28, 2006



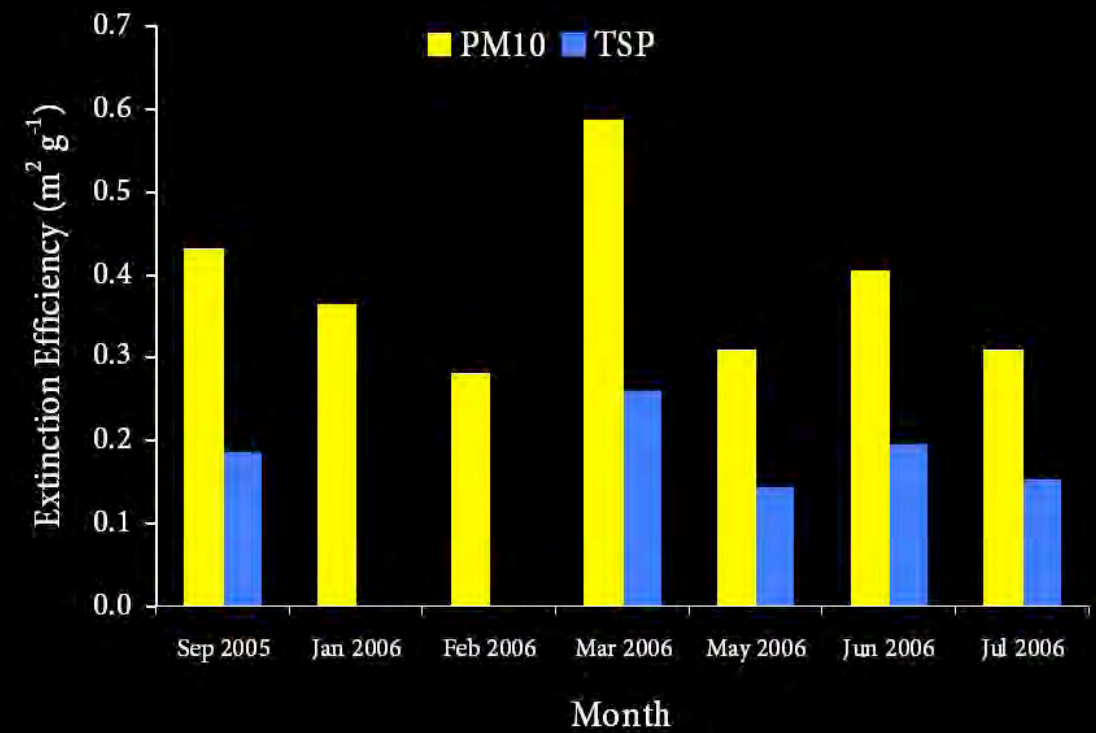
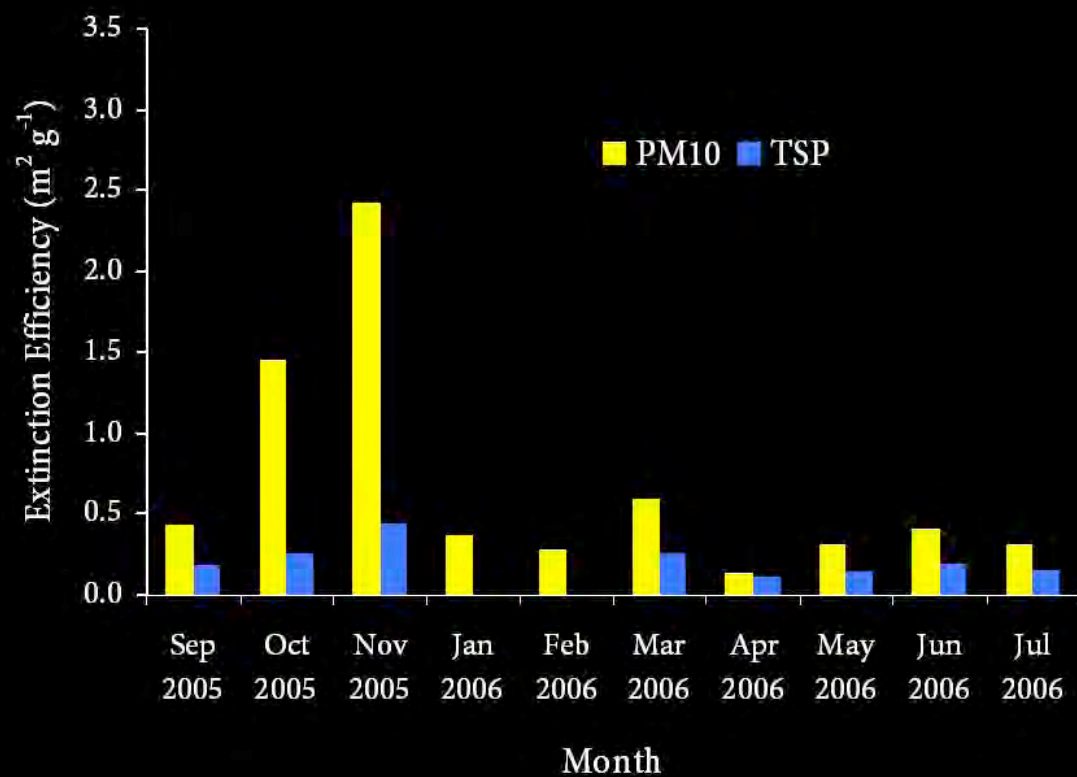
JUNE 10, 2006

▲ DWPM ◆ DWTSP — Linear (DWPM) — Linear (DWTSP)



JULY 19, 2006

EXTINCTION EFFICIENCIES

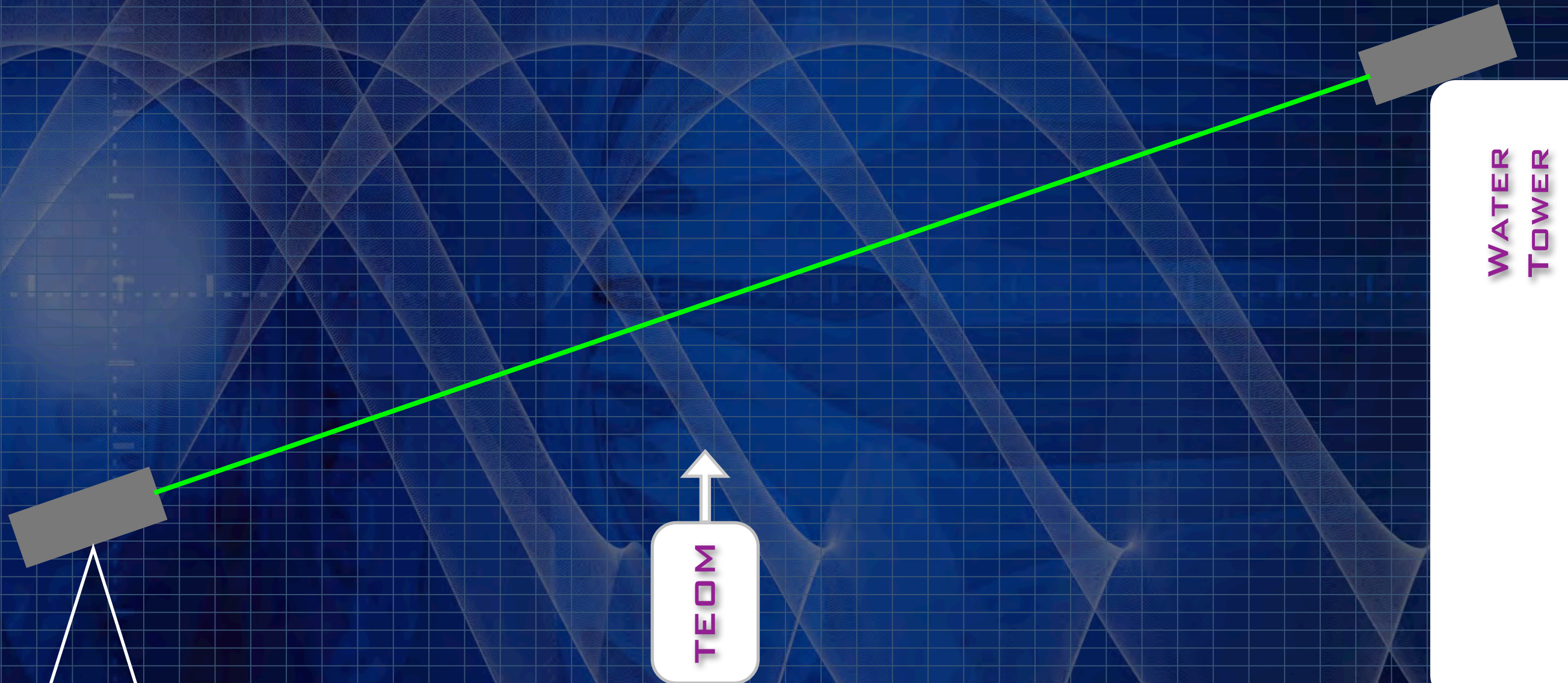


Issues in the Spotlight

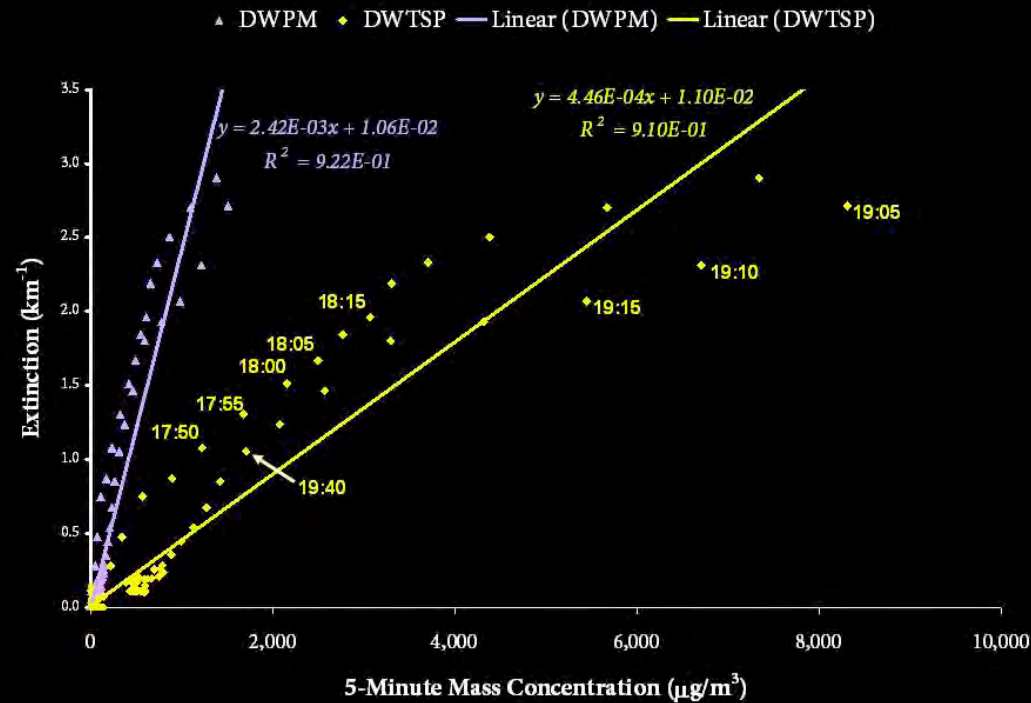
- Looping behavior in diurnal LPV-TEOM traces
- Plume development vs. LPV incline - is a time-lag phenomenon responsible for looping behavior?
- Predictive value of extinction efficiency model vs. data autocorrelation and statistical rigor

THE BASIC IDEA

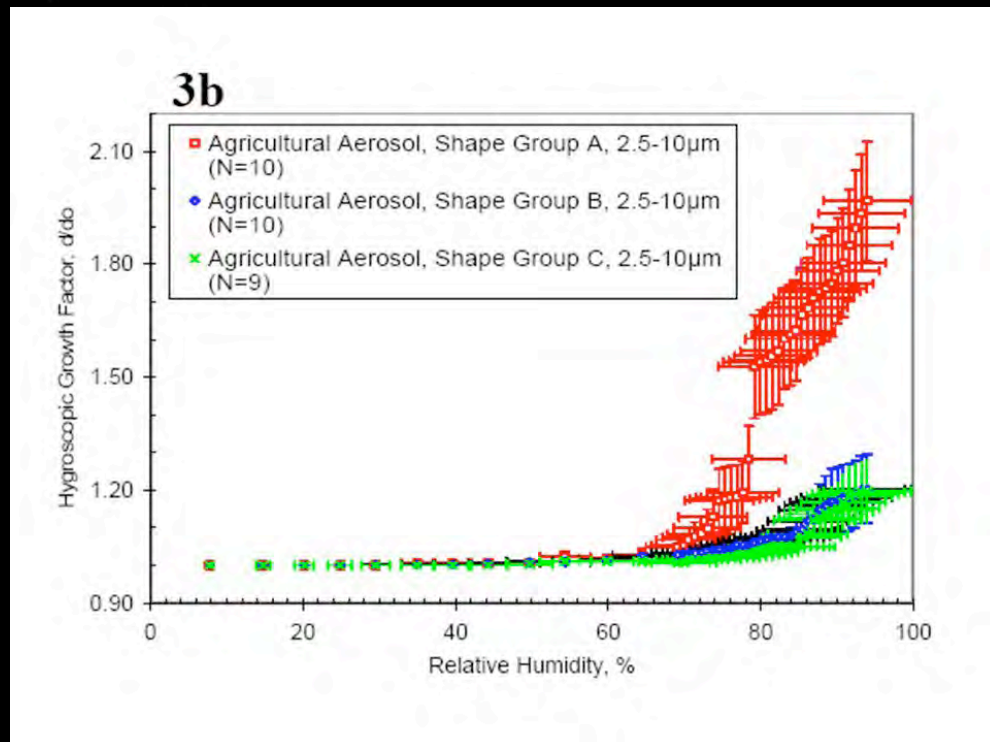
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Deliquescence and Hysteresis



NOVEMBER 13, 2005



Graph courtesy Dr. Sarah Brooks, TAMU

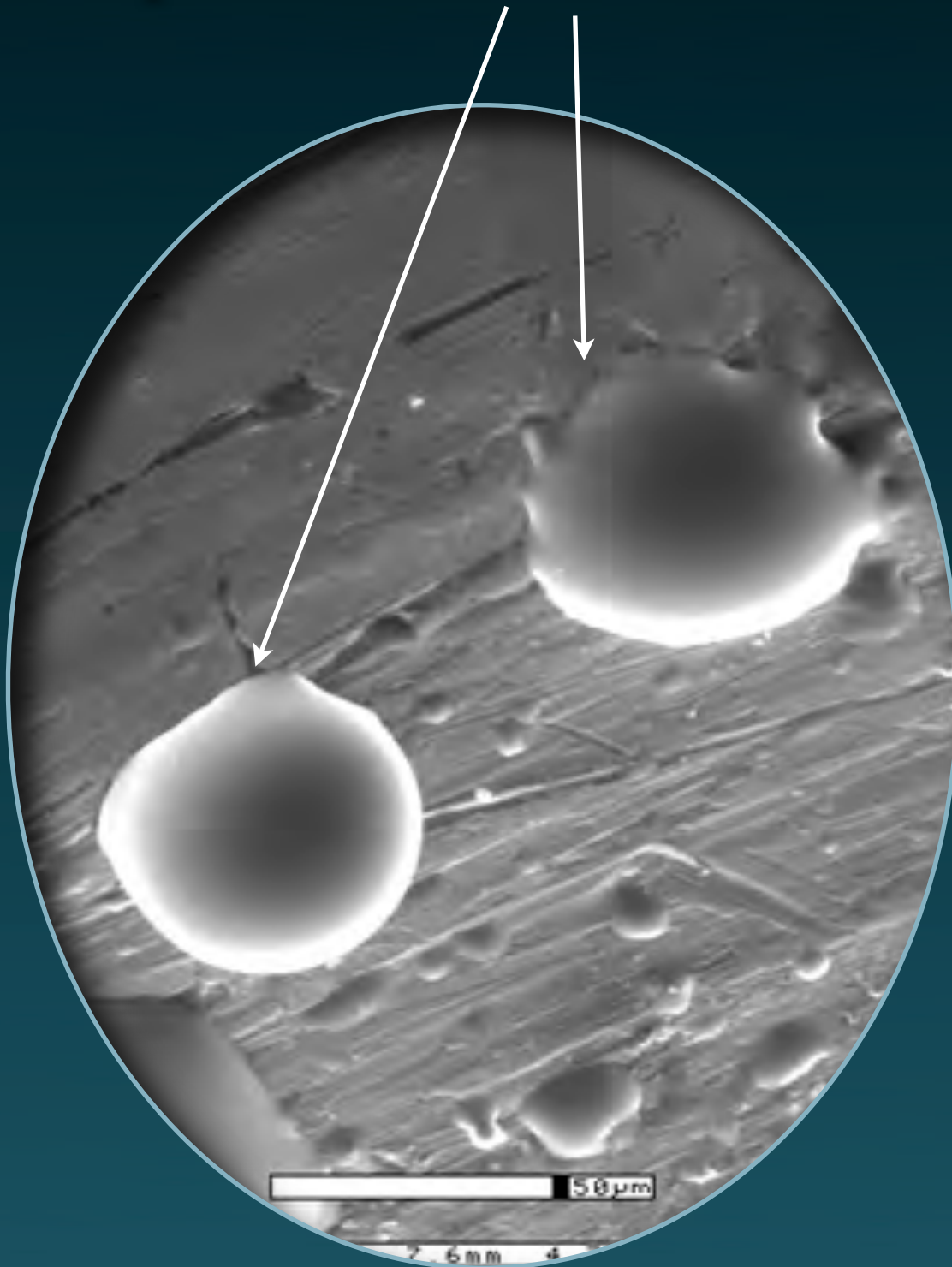
Looping behavior follows clear, diurnal pattern

Deliquescence threshold $\text{RH} \sim 75\%$

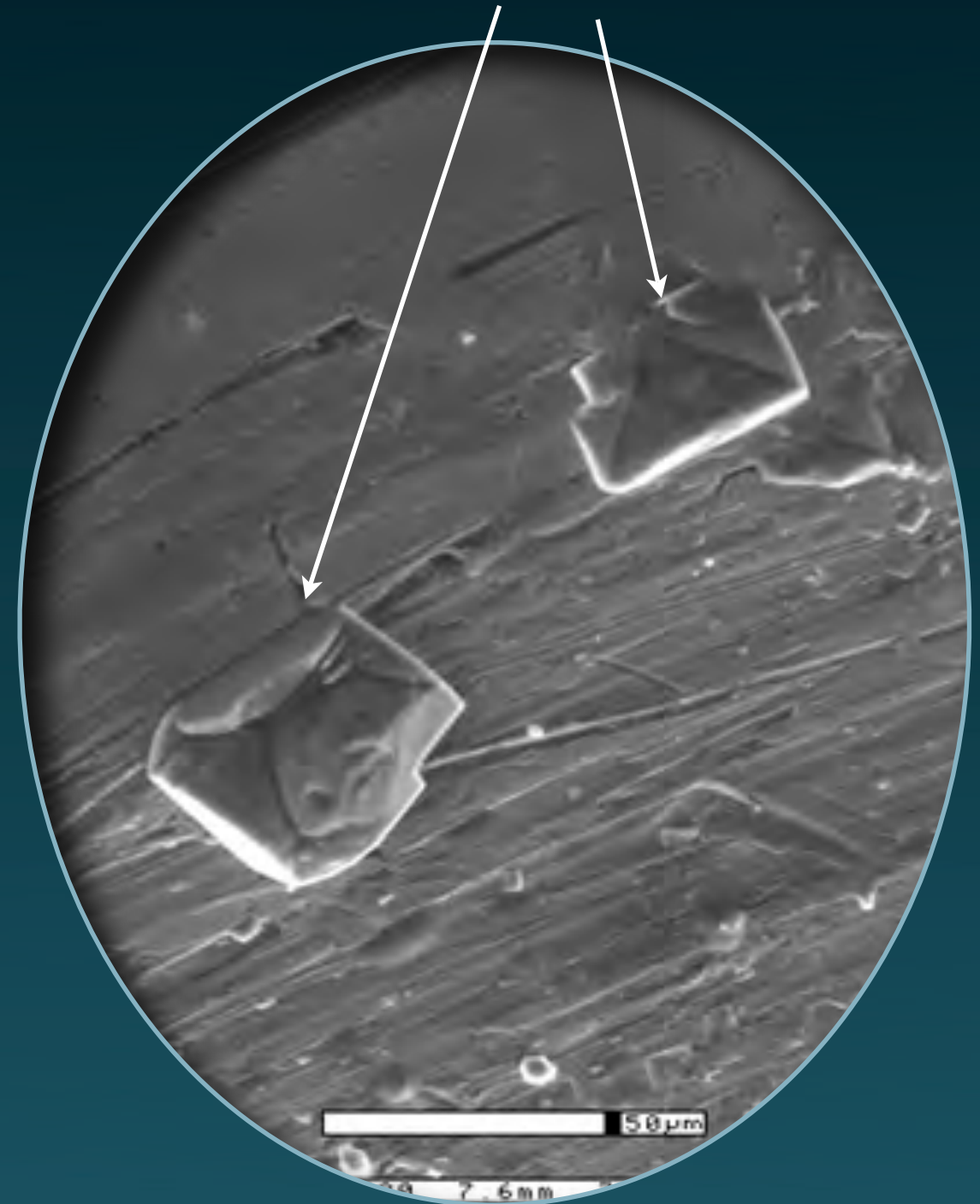
Efflorescence threshold $\text{RH} \sim 60\%$

Deliquescence dominated by narrow fraction of particle size, shape

What the inertial
preseparator “sees”



What the mass
transducer
measures



Particle-Size Distribution

- Linear model defies the nature of a well-graded aerosol
- Both hygroscopicity and dry extinction efficiency are strongly AED-dependent

$$\beta_{ext} = \beta_{Ray} + C_{PM} \int_{\delta=0}^{\delta=\delta_{max}} \frac{\partial \beta_{ext}}{\partial C(\delta)} p(\delta) d\delta$$

$$\beta_{ext} = \beta_{Ray} + C_{PM} \sum_{i=1}^n \frac{\partial \beta_{ext}}{\partial C_i} p(\delta_i)$$

Major Conclusions

- We are short of a truly predictive model for $C=f(\beta_{\text{ext}})$, but the current values for bulk extinction efficiency of feedlot PM are within ranges reported by Malm (1999) for “coarse mass;” success is likely if...
- Hygroscopicity affects both LPV and TEOM measurements, but in different ways
- “Bulk” extinction efficiency is related to aerosol PSD, RH and corral-surface conditions
- Would prefer to have a laser-based LPV to avoid having to incline the open path

The End

Storage Bin

