Installation of the Model 5012 Multi-Angle Absorption Photometer (MAAP) for Real-time Black Carbon Monitoring

National Air Monitoring Conference
November 6, 2006
Las Vegas, NV

J. Ron Jernigan, P.E., BCEE
Kevin J. Goohs
Thermo Electron Corporation, Franklin, MA

Analyze • Detect • Measure • Control

Thermo
ELECTRON CORPORATION

Outline

- Background
- Measurement Principle
- Setup
- Operation
- Maintenance
- Applications

Background

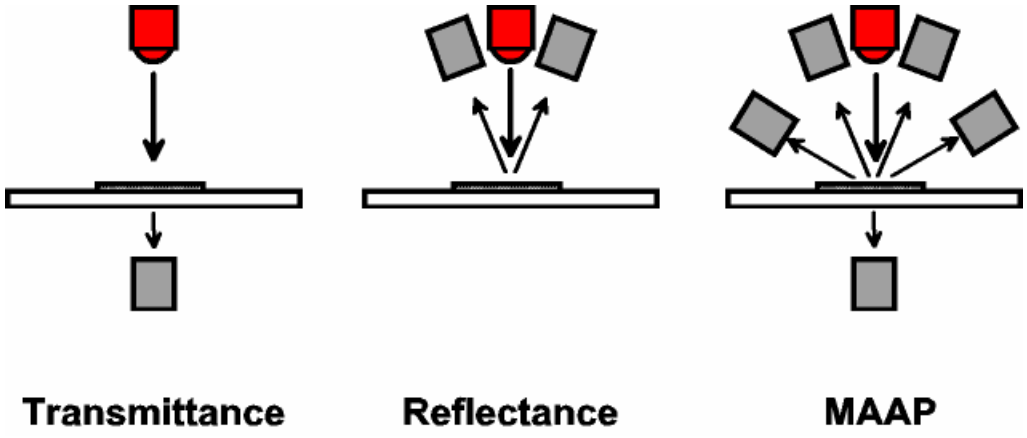
- "Elemental" Carbon
  - *Major component of PM2.5*
  - *Typically 25-50% of PM2.5 (as much as 70%)*
  - *Anthropogenic origin*
    - mobile sources
    - products of incomplete combustion

Background

- "Black" Carbon
  - *Surrogate for "elemental carbon" – not a chemical measure*
  - *Measured continuously via*
    - Optical (aerosol light absorption),
    - Thermal, and
    - Photoacoustic methods

Measurement Principle

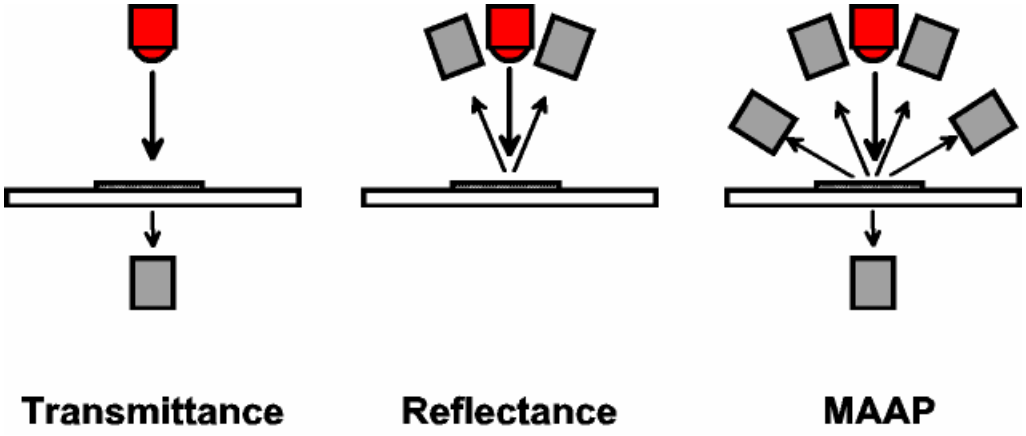
- Filter-based Aerosol Absorption Measurement Methods
  - *Sampling of particles on a fibrous filter matrix.*
  - *Measurement of the modified optical properties by the collected aerosol layer.*



$$\sigma_{0\ (TRANS)} = \frac{A}{V}\ln\left(\frac{T_0}{T}\right) \qquad \sigma_{0\ (REF)} = \frac{A}{2V}\ln\left(\frac{R_0}{R}\right) \qquad \sigma_{0\ (MAAP)} = \left(1 - SSA_L\right) LOD\ \frac{A}{V}$$

where,
σ_o = mass absorption efficiency, A = filter surface area, V = sampled volume, T = transmitted light, R = reflected light, SSA_L = single scattering albedo of filter aerosol layer, and LOD = layer optical depth

Measurement Principle



Based on the 2002 Reno Aerosol Optical Study using kerosene soot and sulfate particle mixtures:

-**Filter transmittance method**

-required correction of filter loading and aerosol scattering

-**Filter reflectance method**

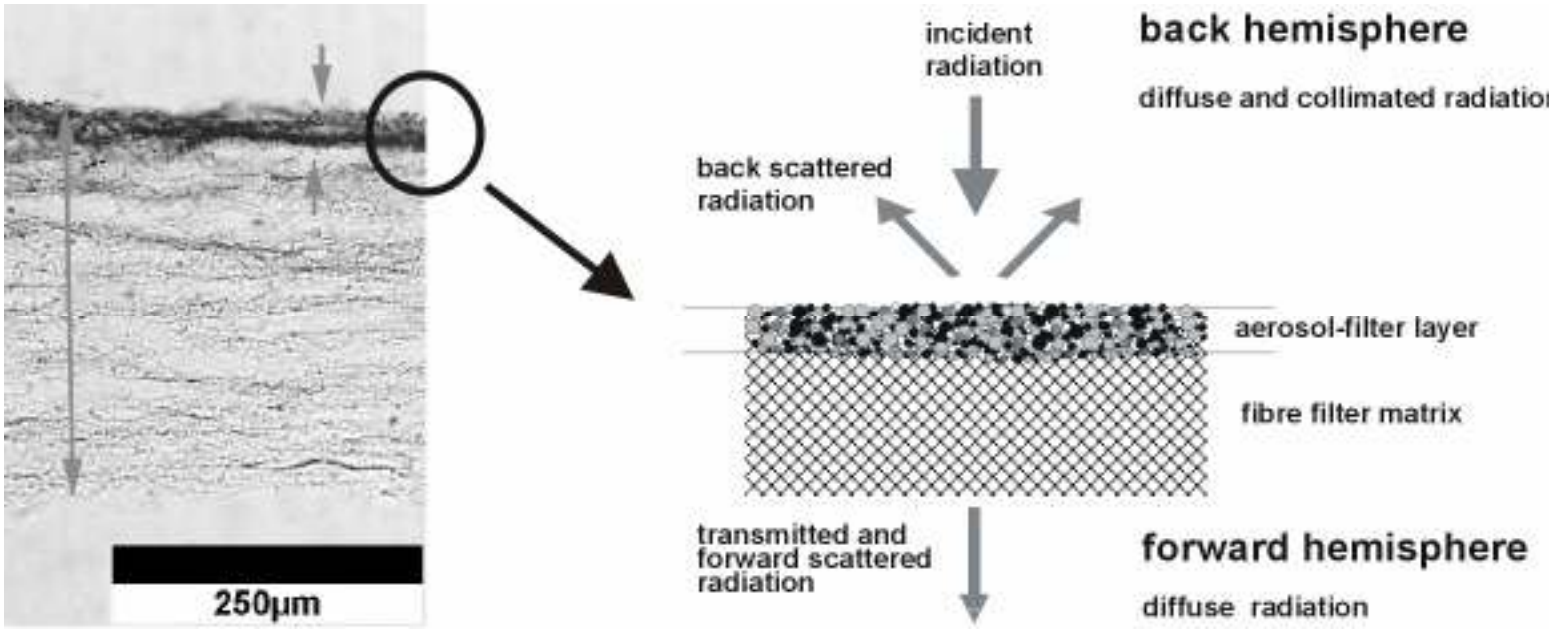
-required correction of filter loading

-**Multi-Angle Absorption Photometry**

-required no correction of filter loading or aerosol scattering effects

Measurement Principle

Interaction of Aerosol, Filter Matrix, and Incident Radiation



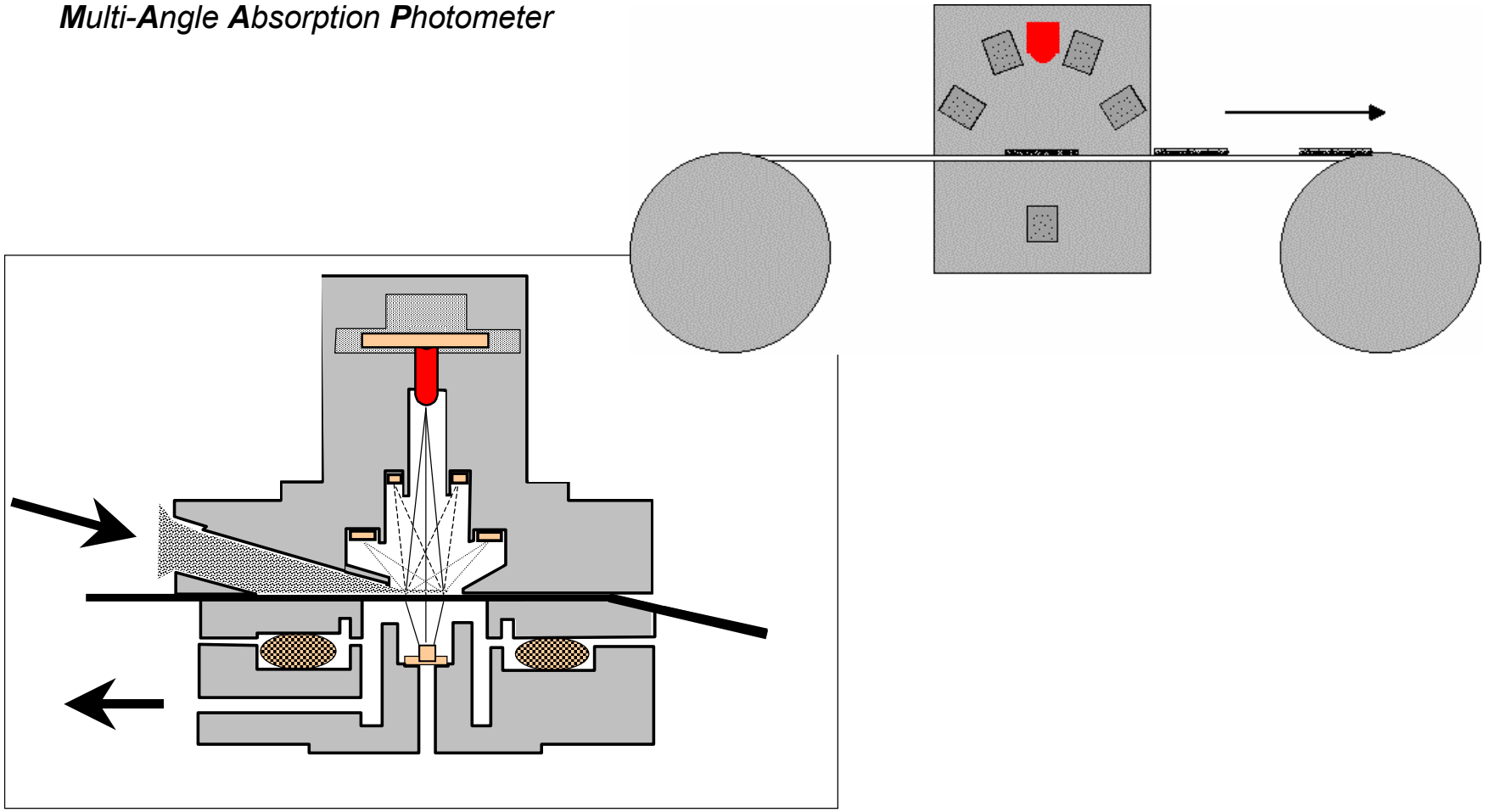
Filter Matrix Effects (both positive and negative bias possible)

\+ Multiple scattering of light by filter fibres and light-scattering aerosol particles tends to overestimate the absorption coefficient.

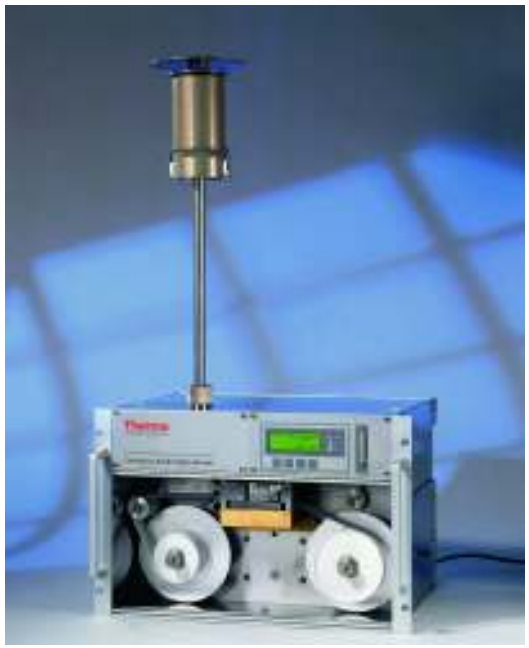
\- ”Shadowing” of collected particles inside the fibre matrix tends to underestimate the absorption coefficient .

Measurement Principle

Model 5012 MAAP *Continuous Black Carbon Monitor:*
***M**ulti-**A**ngle **A**bsorption **P**hotometer*



Setup



- Standard 19” rack mounted (top rack)
- 110/220 VAC
- 8 – 20 L/min volumetric flow control
- Single point sensor and flow calibrations
- Compatible with USEPA 10-micron inlets and $PM_{2.5}$ sharp-cut cyclones.
- Indoor or outdoor shelter options
- Report in $\mu g/m^3$ or ng/m^3
- > 1-year tape supply
- Auto-filter advance (loading, cycle time, and hour of day)

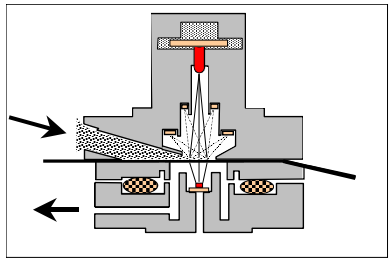
Setup

- Front and rear door access
- -20 to 60 deg C

Operation

- Dual Serial Port Communications @9600 baud rate
- Front and rear scalable analog output (mA or VDC)
- Continuous Operation w/minimal maintenance
- Calibrate with FRM Calibration kits (NIST traceable flow transfer standard, thermometer, and barometer).
- 1 – 30 minute internally stored averages
- Internally logged calibration changes
- Internally logged instrument status

Annual Maintenance



- Sensor and flow calibration
- Cleaning of photo-detectors
- Vacuum pump maintenance
- O-ring replacements
- Filter tape replacement

Quarterly Maintenance

- System Audit
  - *flow rate, temps, pressure, optical check*
- PM_{10} inlet and cyclone cleaning (w/optional inlets)
- Check filter tape supply

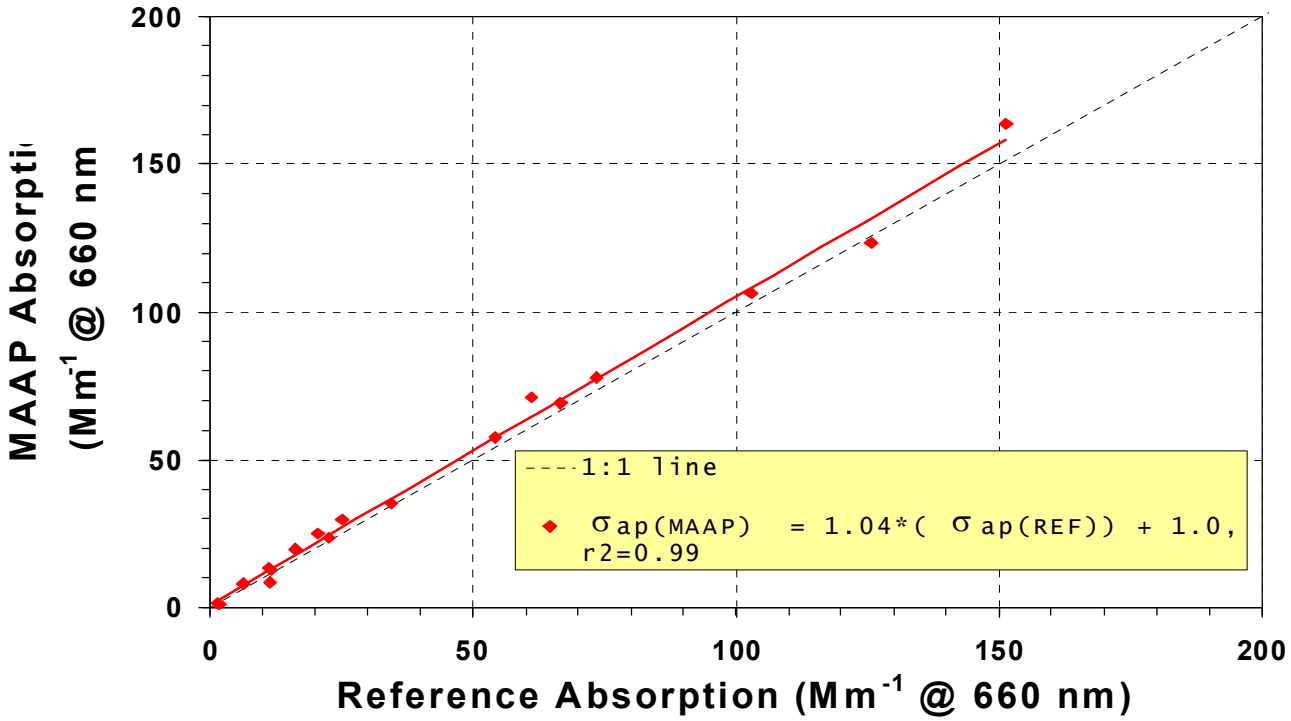
Monthly Maintenance

- Flow checks (control chart)
- Temp and Barometric check (control chart)
- Cyclone cleaning (w/optional inlet)
- Check filter tape supply

Applications

Bench Studies

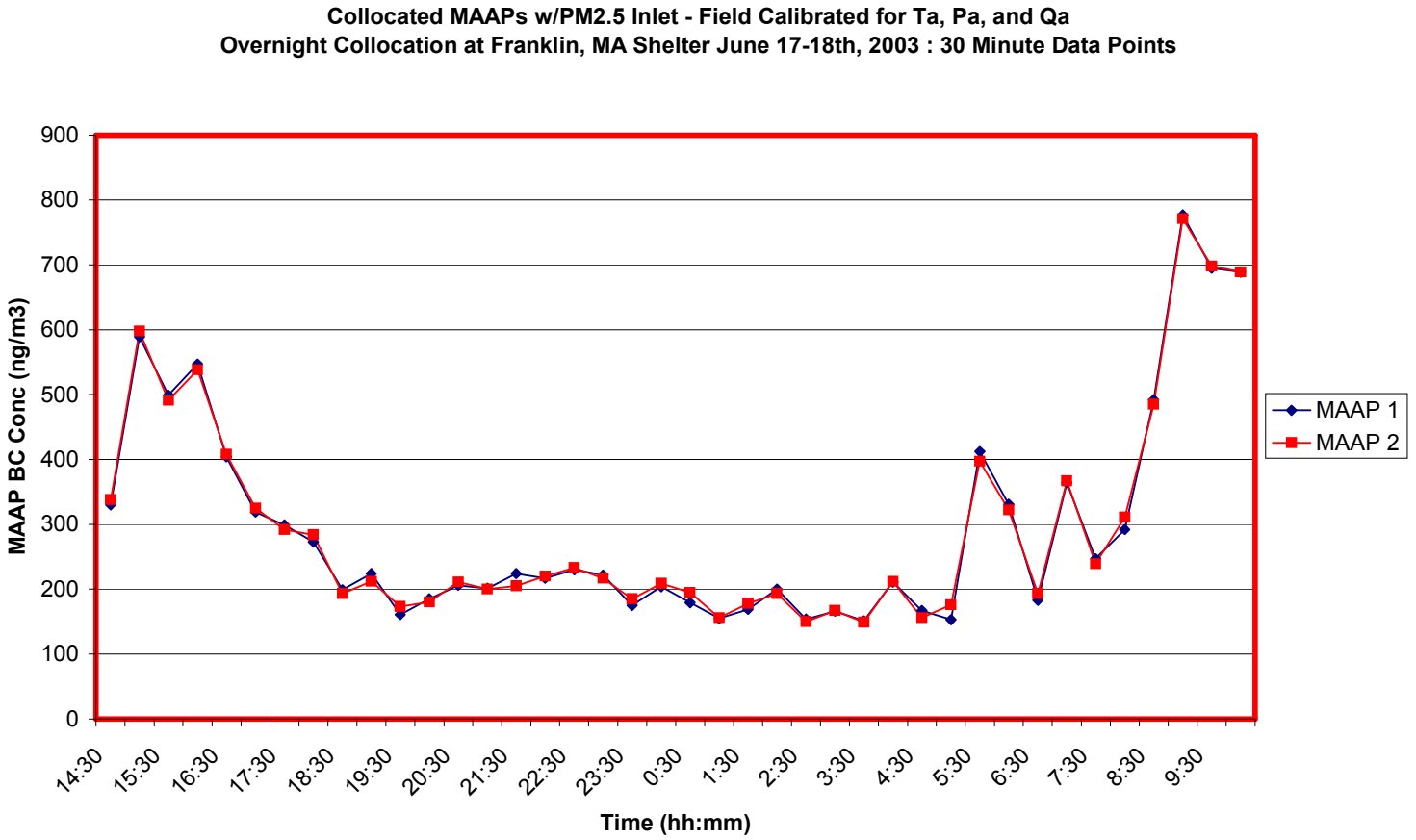
Reno Aerosol Optics Study June 2002 – accurate measure of of aerosol absorption



Applications

Ambient Precision Studies

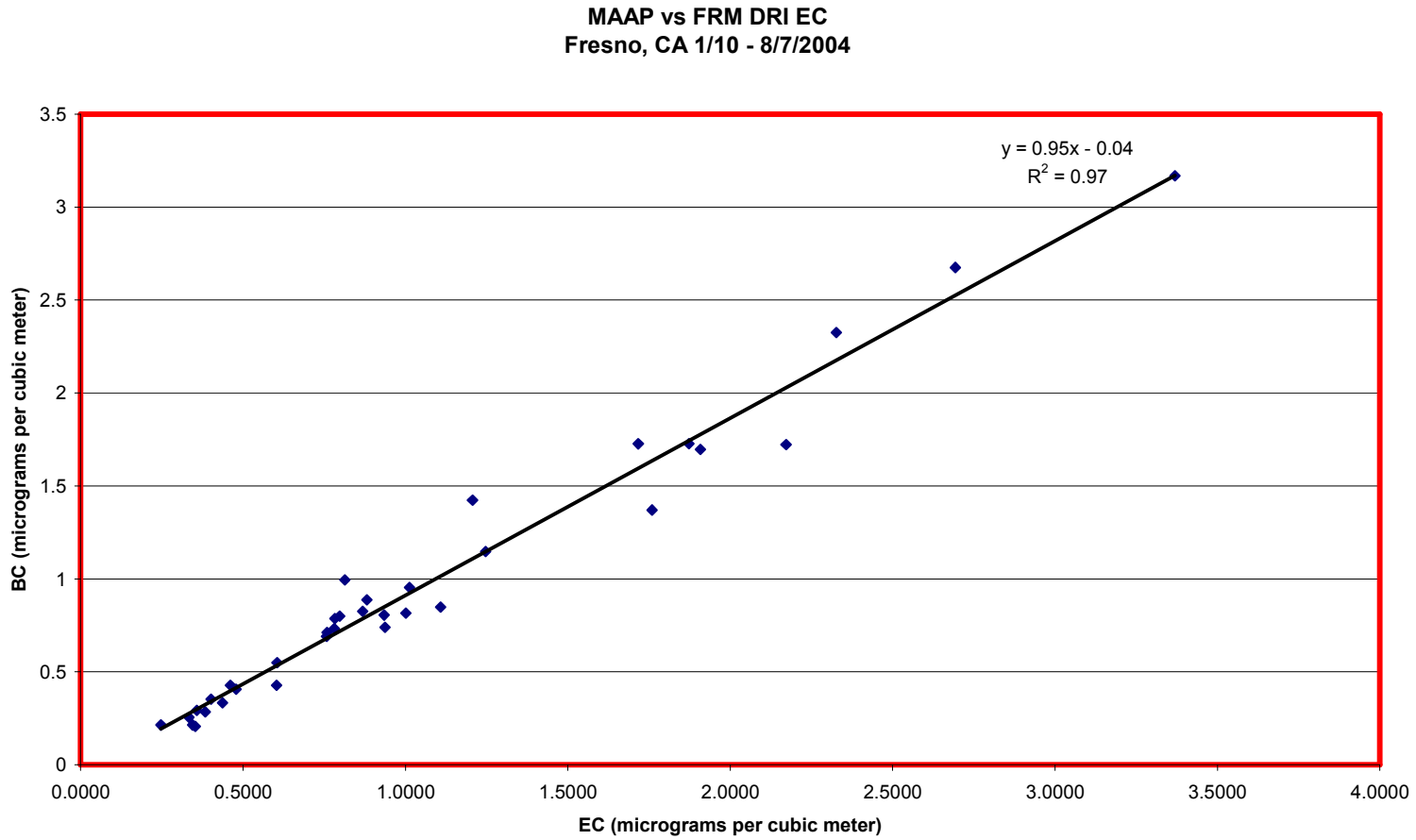
Franklin, MA Collocated Precision Evaluation June 2003



Applications

Ambient Accuracy Studies

Fresno, CA Supersite EC Data Comparison ***y = 0.95x – 0.04; R^2 = 0.97***



Applications - 3 studies cited

Reno Aerosol Optics Study - Desert Research Institute, June 2002

Sheridan et al., Aerosol Sci. Technol, 2004

Test aerosols: *kerosene flame soot, graphite particles, amm. sulphate*
Reference methods: *long-path extinction cell, integrating nephelometer*

Optical properties of biomass burning - MPI Chemistry Mainz, February 2003

Schnaiter et al., Aerosol Sci. Technol., submitted

Test aerosols: *combustion aerosol from corn stem burning*

Reference methods: *long-path extinction spectrometer, integrating nephelometer*

AIDA SOOT 03 Study - Research Centre Karlsruhe, November 2003

Schnaiter, Schmid, Petzold, Kaminski, Weingartner, Saathoff et al.

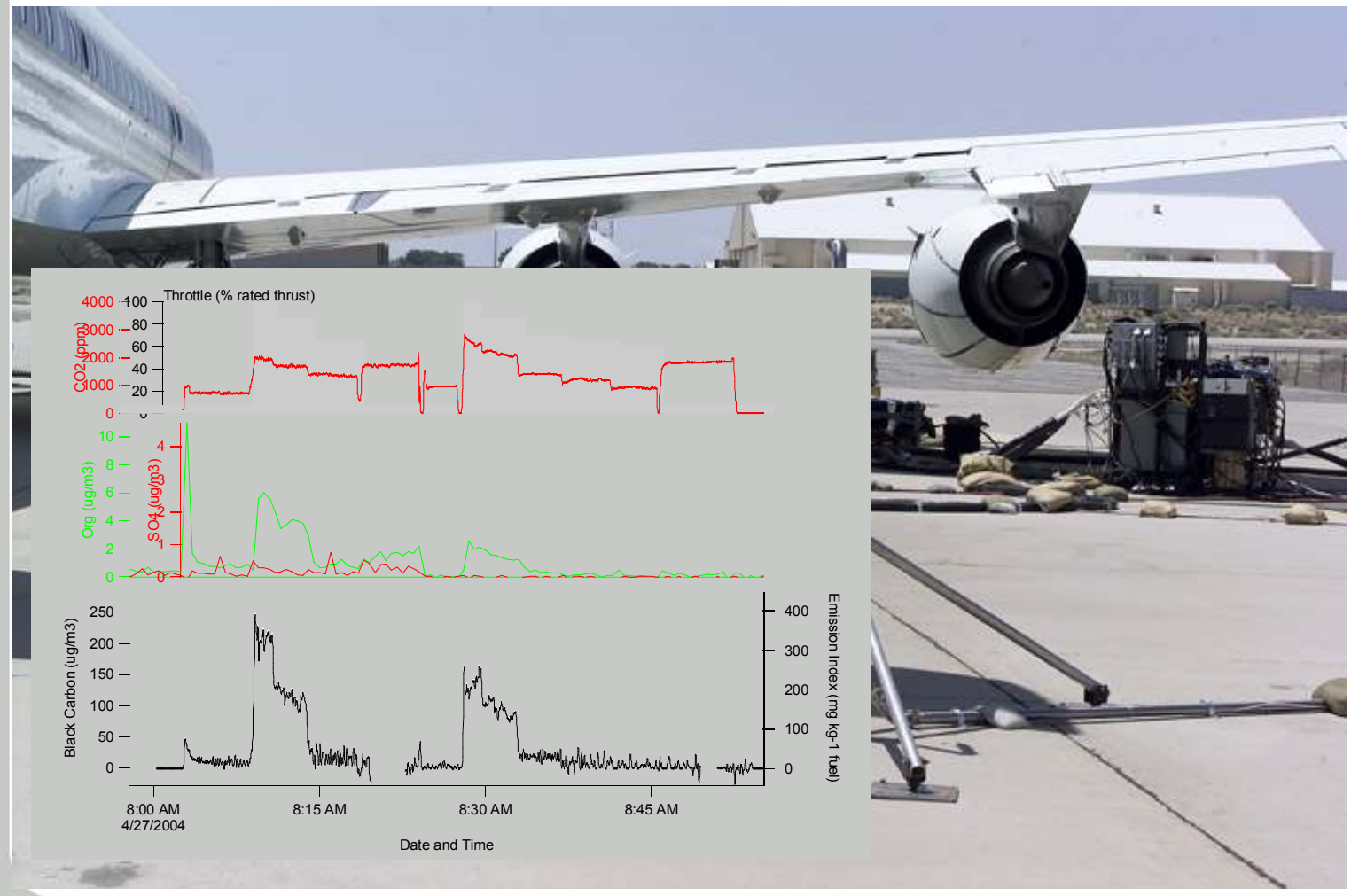
Test aerosols: *Diesel particles, PALAS spark discharge generator particles*
Reference methods: *long-path extinction spectrometer, integrating nephelometer*

Long-term measurements at Jungfraujoch High Altitude Research Station (11,745 feet amsl) Operational since March 2003

NASA Aircraft Particle Emissions Experiment

APEX April 2004 - in collaboration with Aerodyne Research Inc.,

1 Hz data resolution



Model 5012 MAAP Applications

TECHNICAL PAPER

ISSN 1047-3289 *J. Air & Waste Manage. Assoc.* 56:474–491

Comparison of Continuous and Filter-Based Carbon Measurements at the Fresno Supersite

Kihong Park, Judith C. Chow, John G. Watson, Dana L. Trimble, and Prakash Doraiswamy
Desert Research Institute, Reno, NV

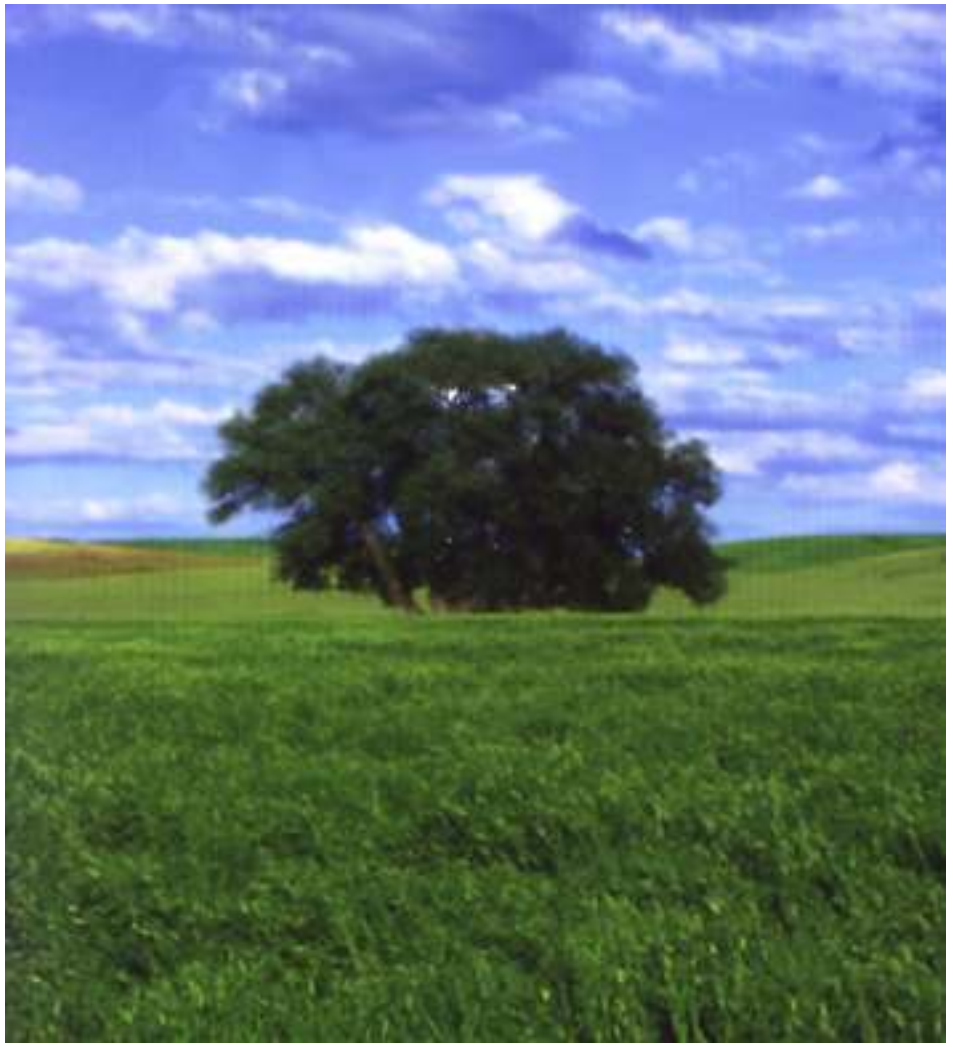
"*… The IMPROVE EC versus MAAP BC comparison almost meets the equivalence criteria in summer except for a lower slope (0.94 ±0.06).*"

The MAAP demonstrated an insignificant amount of seasonal variation during this study.

Model 5012 MAAP Applications

Ambient

- Air Toxic Monitoring
- AQ Index Reporting
- Fenceline Monitoring
- Air shed Characterization
- Visibility research
- Tropospheric Carbon Studies



Model 5012 MAAP Applications

For Questions or more Information

Contact:

Kevin Goohs
508-553-6808
kevin.goohs@thermo.com