Open Path Optical Sensing of Particulate Matter

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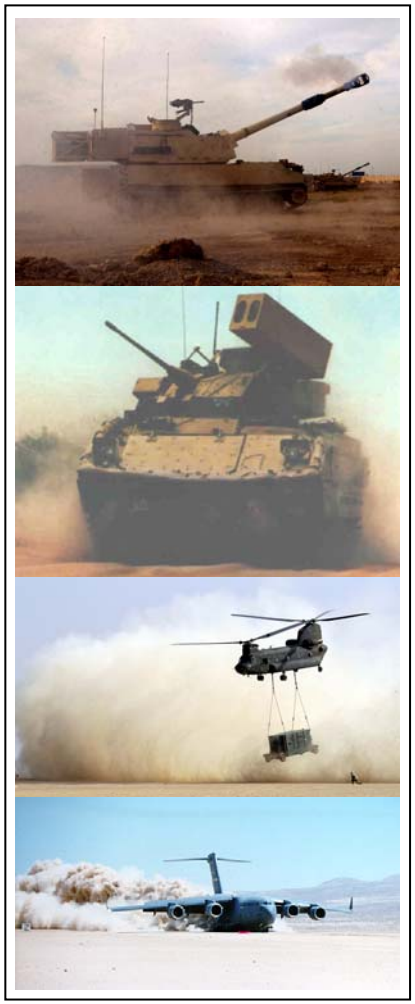
Background

- ERDC-CERL
- Environmental Quality Technology User Requirements
- Fugitive dust (PM) monitoring technology
- No standards, no emission factor data
- Filter method/ in-plume
- Collaboration: ARCADIS, U of Illinois
- Strategic Environmental Research and Development Program (SERDP)

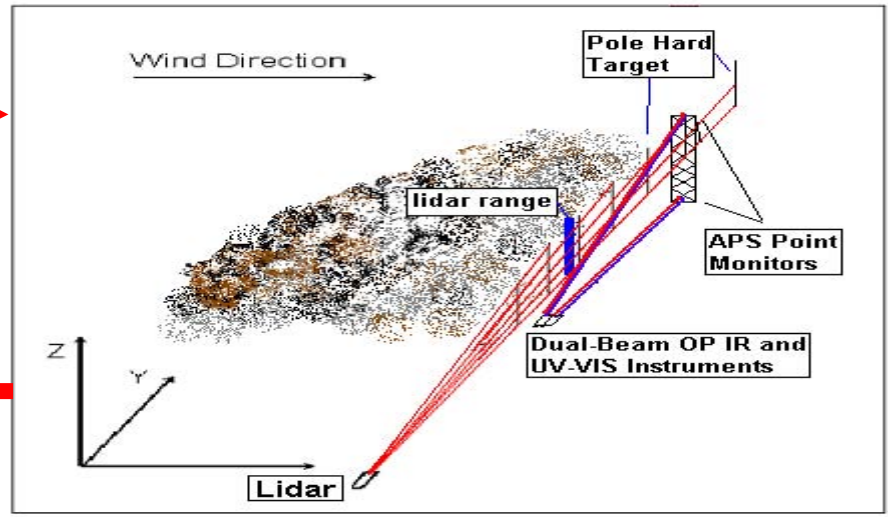
Concept Development

- ARCADIS
- Oct 2002, Dec 2003-Jan 2004, Sep 2004
- OP-FTIR spectrometers, Visible spectrometers, and APS
- Dust , Fog oil, Graphite
- Yuma Proving Ground
- Artillery back blast, Tracked vehicle movement, Rotary & Fixed wing aircraft landing and take-off

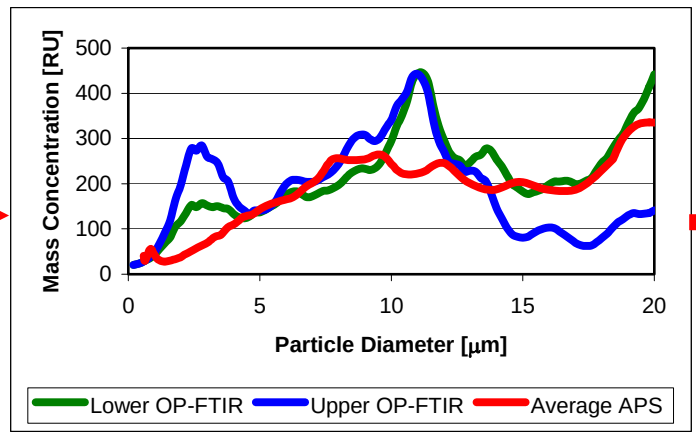
Field campaigns to measure military unique dust sources



Sample plumes with ORS instrumentation and *in situ* aerodynamic particle sizer (APS)

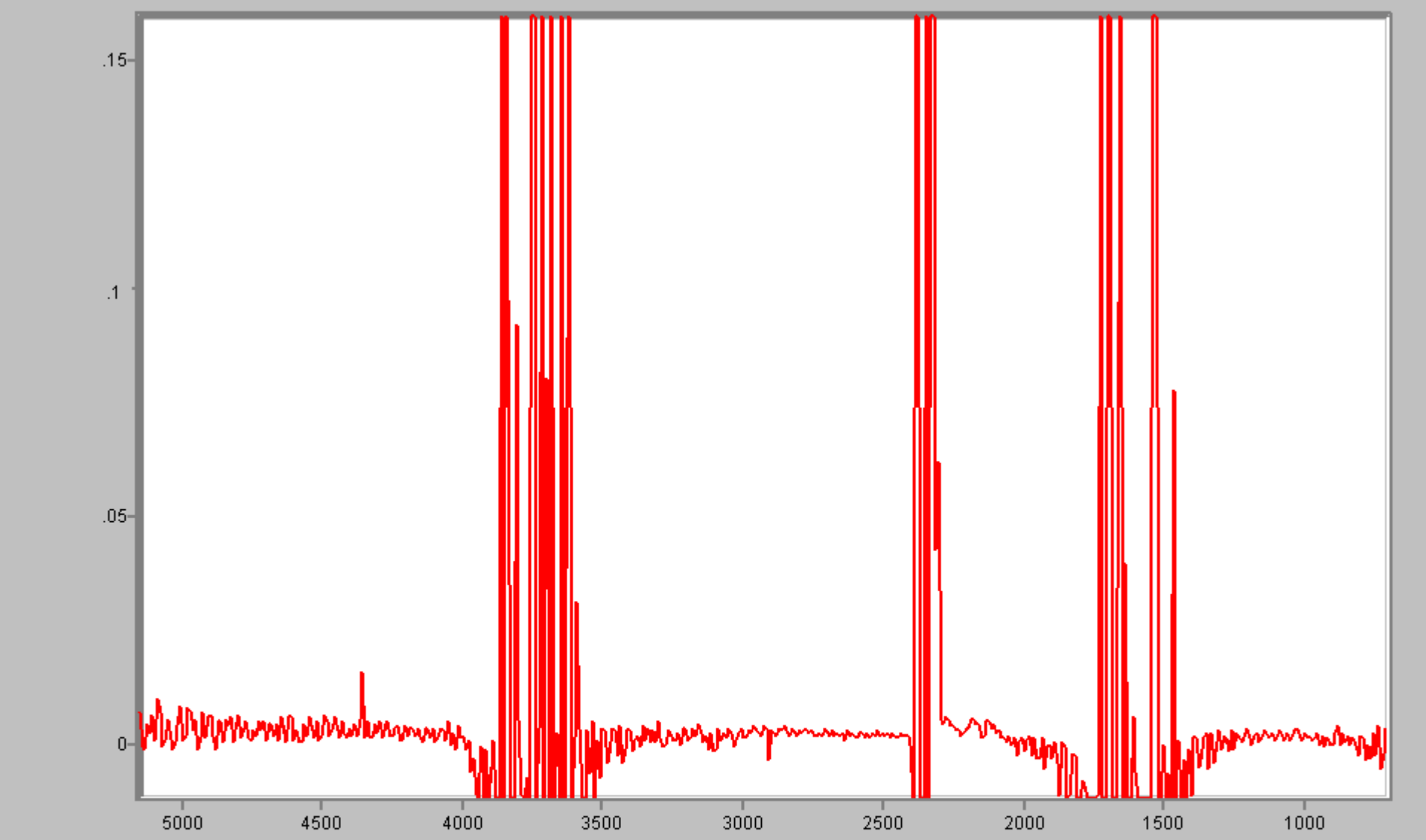


Quantify mass flux and emission factors



Rapid time-resolved (seconds) PM type identification and size-distribution determination

Movie of Dust Plume Measured with OP-FTIR (mean particle size of several microns)



Absorbance / Wavenumber (cm-1)

File # 1 = 2MFUTILS#30 @29

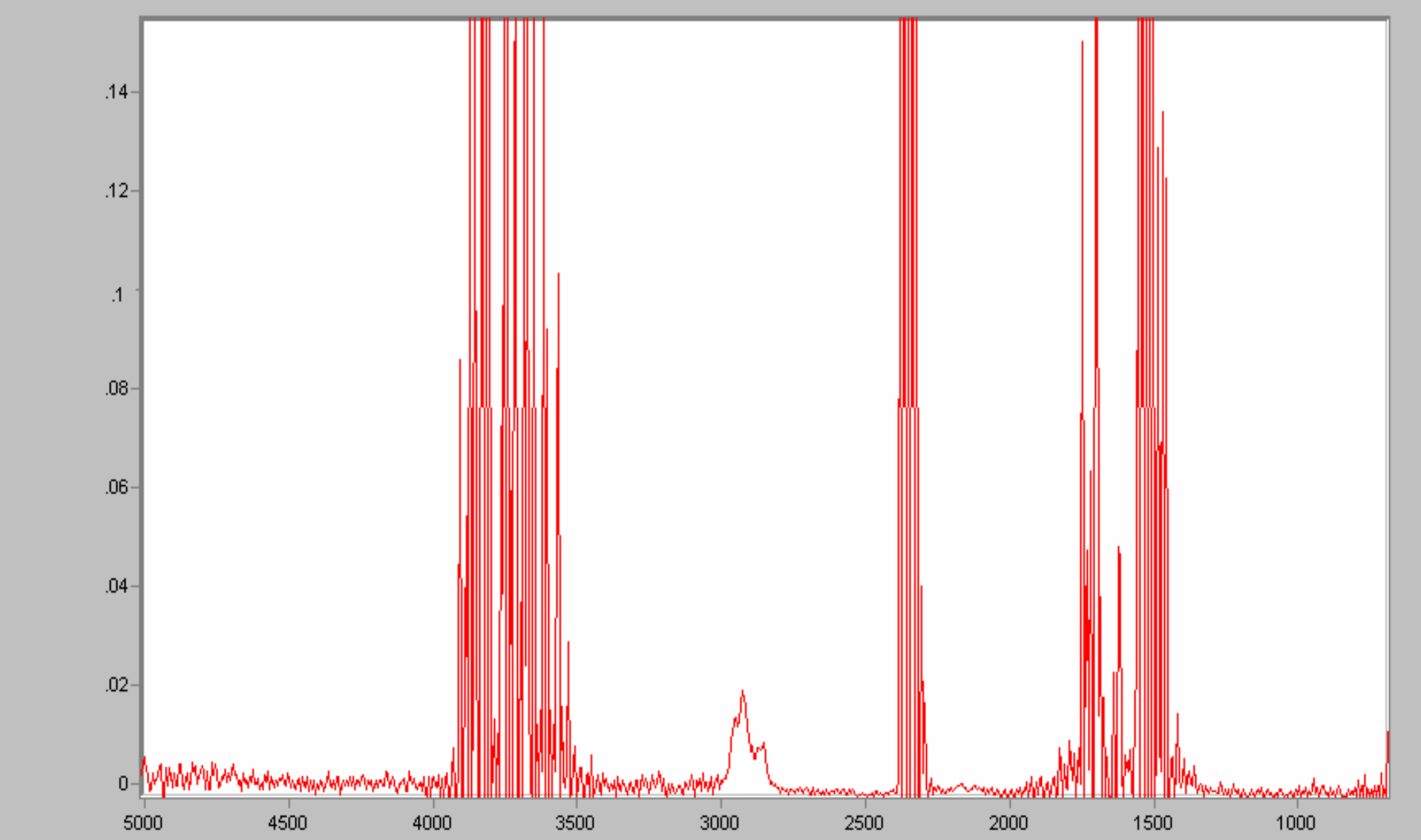
4:18:08 PM

Paged Y-Zoom CURSOR

12/17/2003 4:04 PM Res=None

Press to skip

Movie of Fogoil Plume Measured with OP-FTIR (sub-micron mean particle size)



Absorbance / Wavenumber (cm-1)

File # 1 : FOGOIL_MULTI#234 @233

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1/14/2004 4:26 PM Res=None

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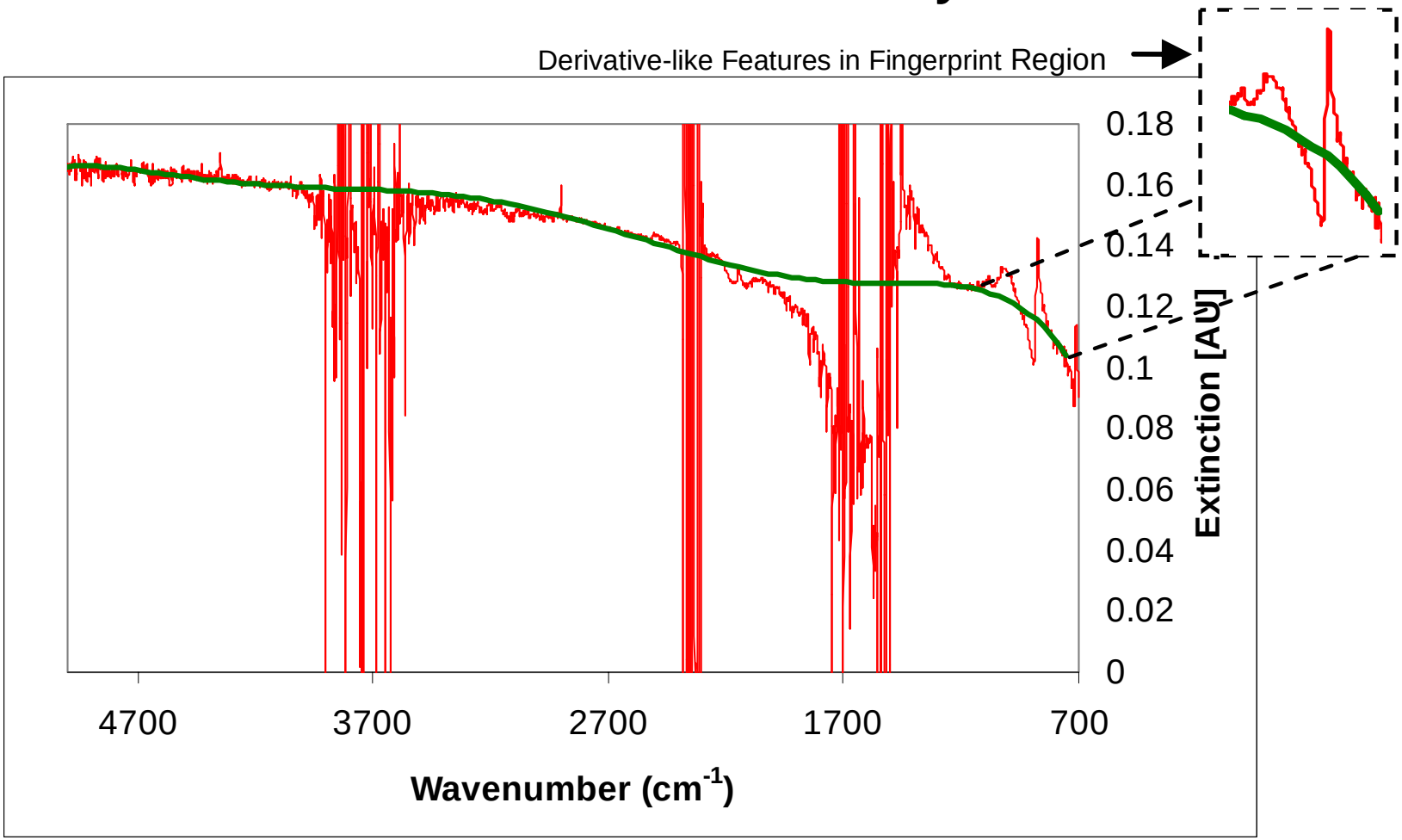
Dust Plume Features Measured by a Monostatic OP-FTIR System

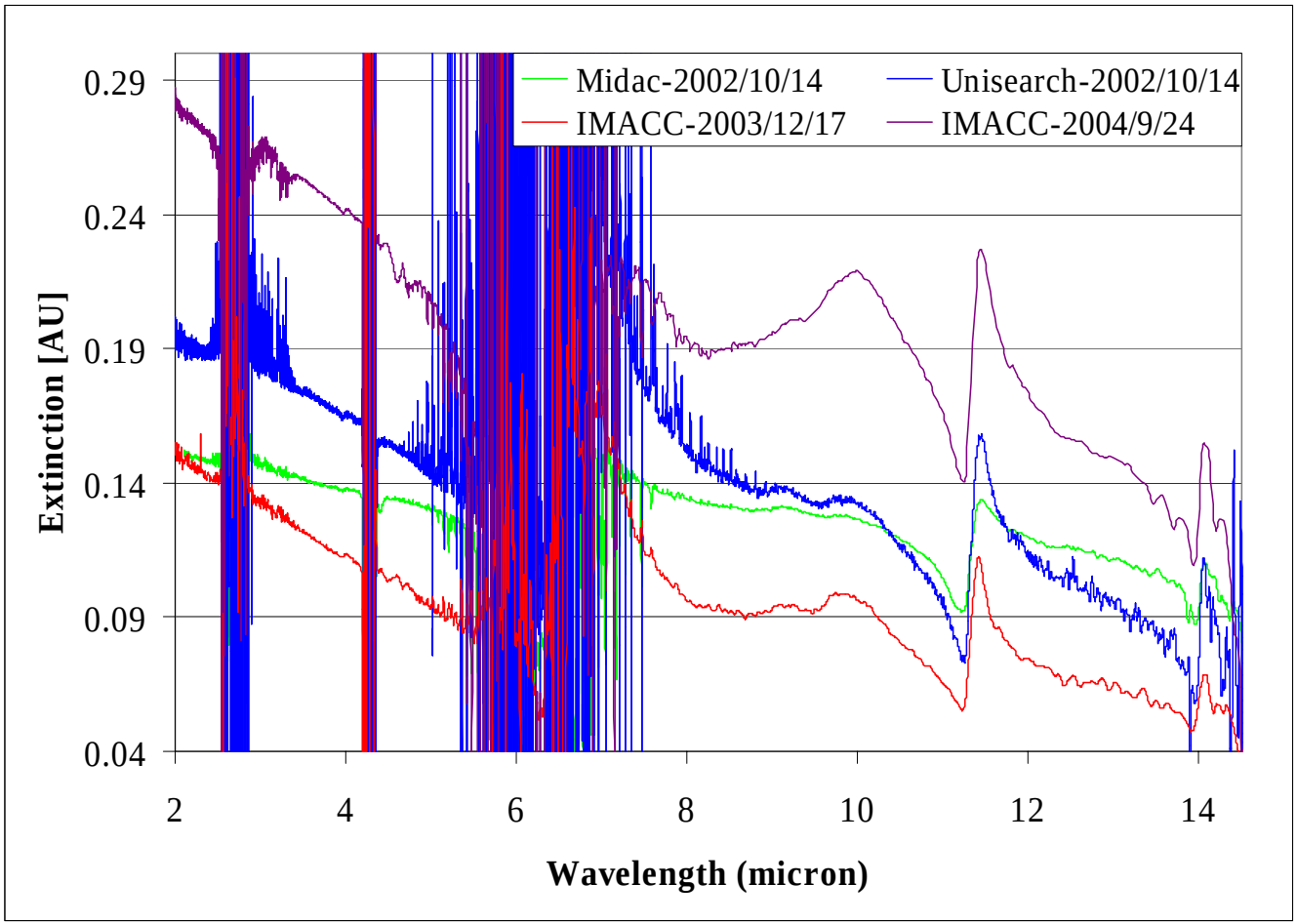


[Explanation of figure on next slide]

Dust Plume Features Measured by a Monostatic OP-FTIR System

- Typical dust plume absorbance spectra from active OP-FTIR (70 m optical pathlength)
- Specific derivative-like features (example near 900 cm^{-1} are unique for dust
- Smoothed baseline (in green) contains mass distribution information for the plume

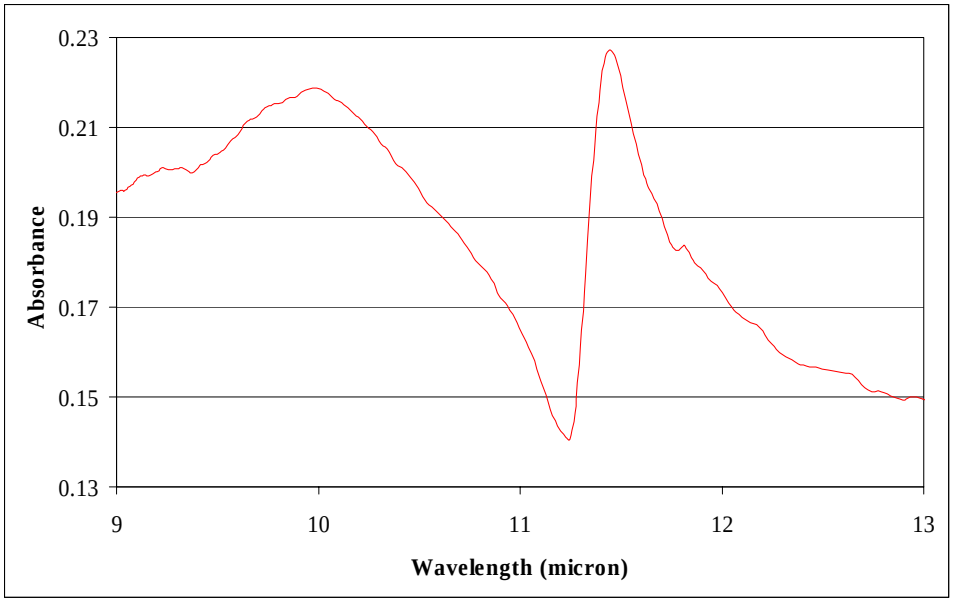
Comparison of Dust Plume Measurements by OP-FTIR



Explanation of figure on next slide

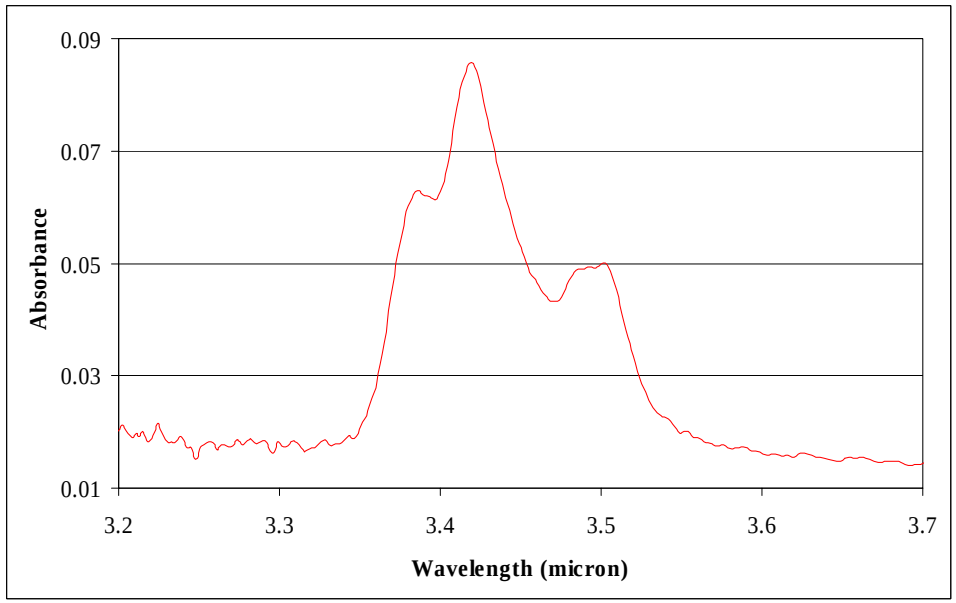
Comparison of Dust Plume Measurements by OP-FTIR

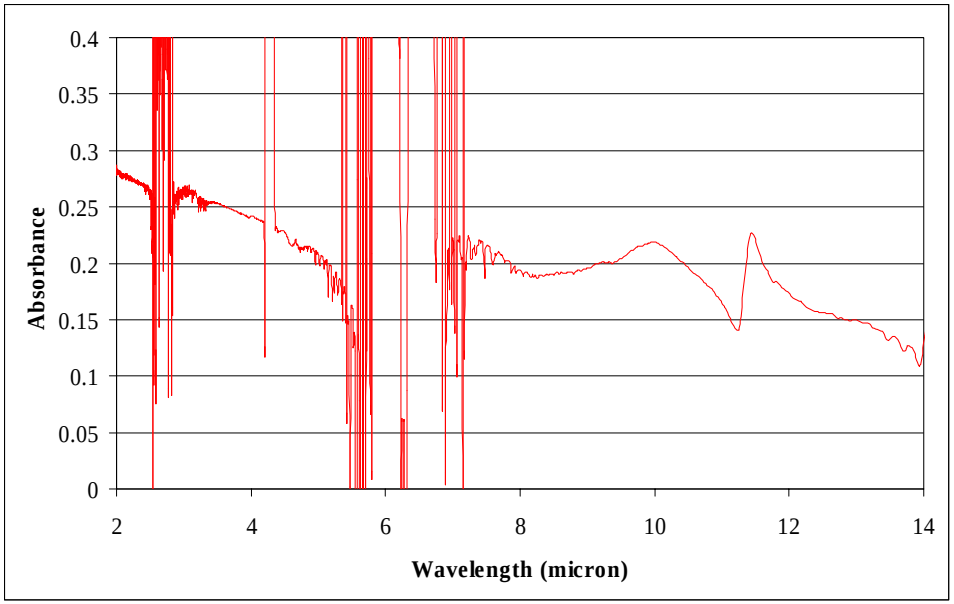
- Comparison of dust plume extinction spectra from different instruments and experiments reveals similarities
- Unisearch & Midac OP-FTIR exhibit identical extinction features because they are from the same dust sample
- 2003 and 2004 samples (both from IMACC OP-FTIR) contain smaller particles, evident from the sloping of the baselines towards the smaller wavelength region
- Strong absorption feature around 11 micron is present in all four samples



Spectral Feature for Dust Particles

Spectral Feature for Fogoil Particles

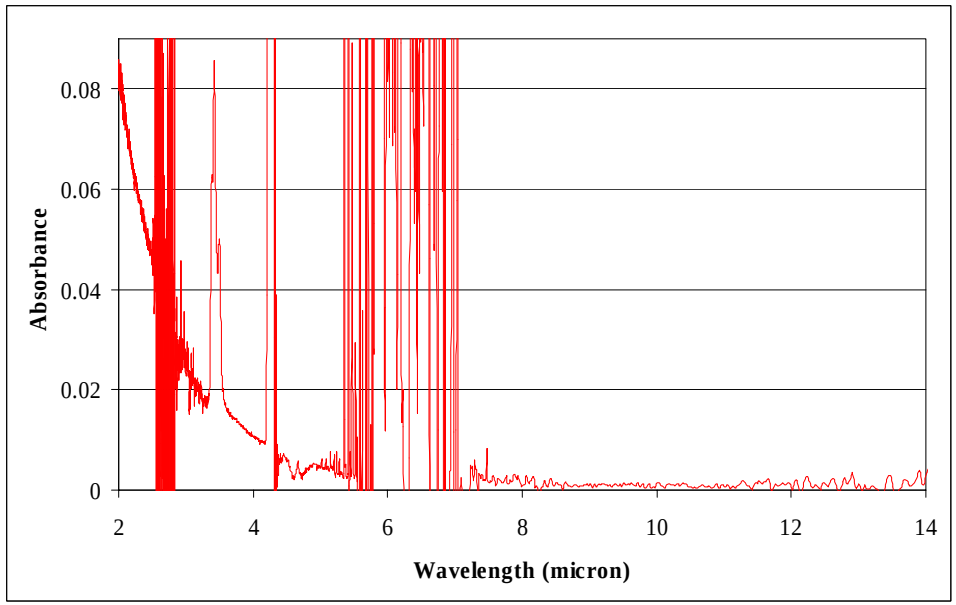




Baseline Shift for Dust PM Plumes (2004 experiments)

Baseline Shift for Fogoil PM Plumes

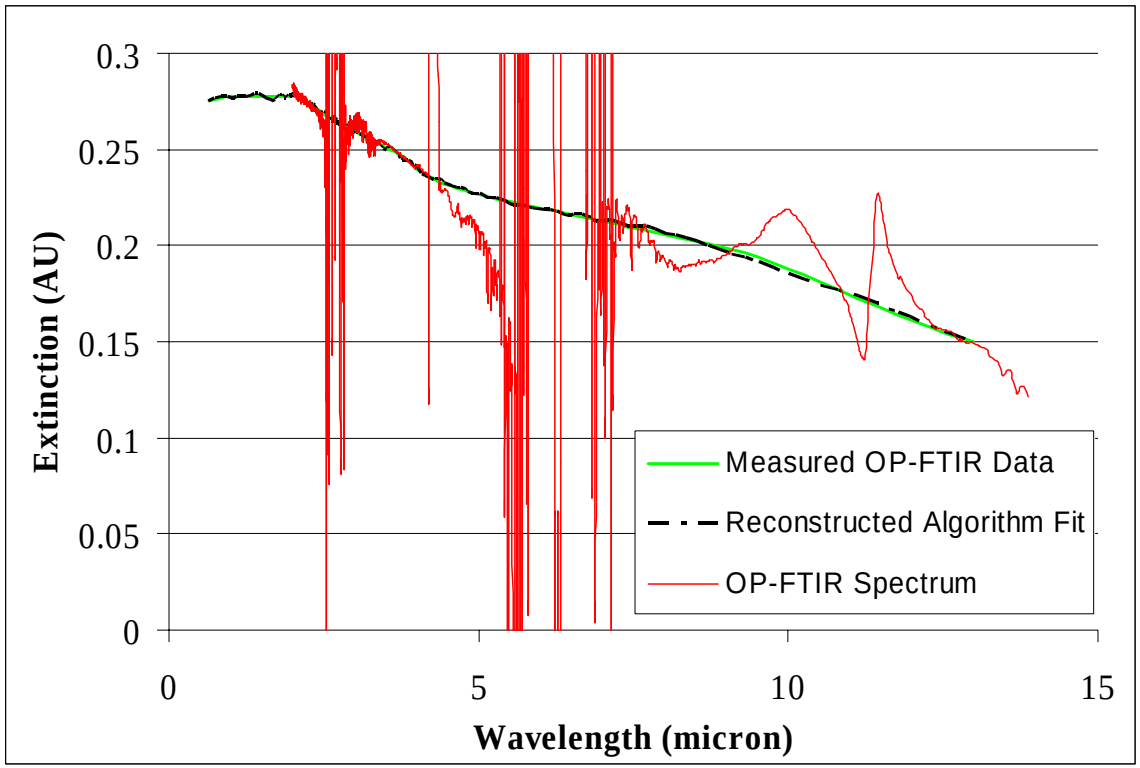
(2004 experiments)



Inverse Mie Theory
Mass Distribution Retrieval

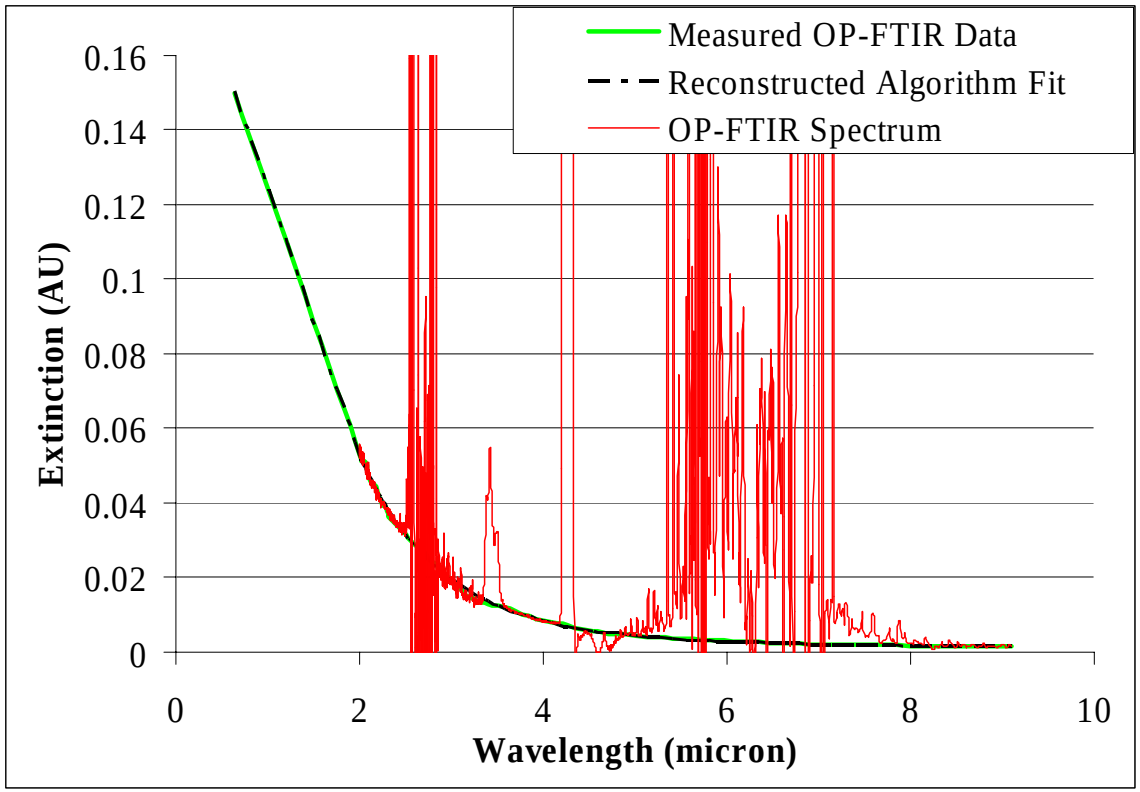
- Inverse Mie Theory algorithm was used to retrieve mass distribution for PM plumes
- Following figures show example dust and fogoil plumes observed by both the OP-FTIR and the APS, and uses values averaged over the duration of the selected plumes
- Baseline points were selected from the OP-FTIR spectra, avoiding atmospheric carbon dioxide and water absorption regions and the specific absorption features of the PM plume materials
- LIDAR extinction values measured for a plume maximum were used as extinction input point at 650 nm and the baseline of extinction spectra from OP-FTIR were interpolated to get slope between 650 nm and 2 micron
- Where no absorption features are present, the elevation of the baseline is due to the scattering of the light by plume particles

Inverse Mie Theory
Mass Distribution Retrieval



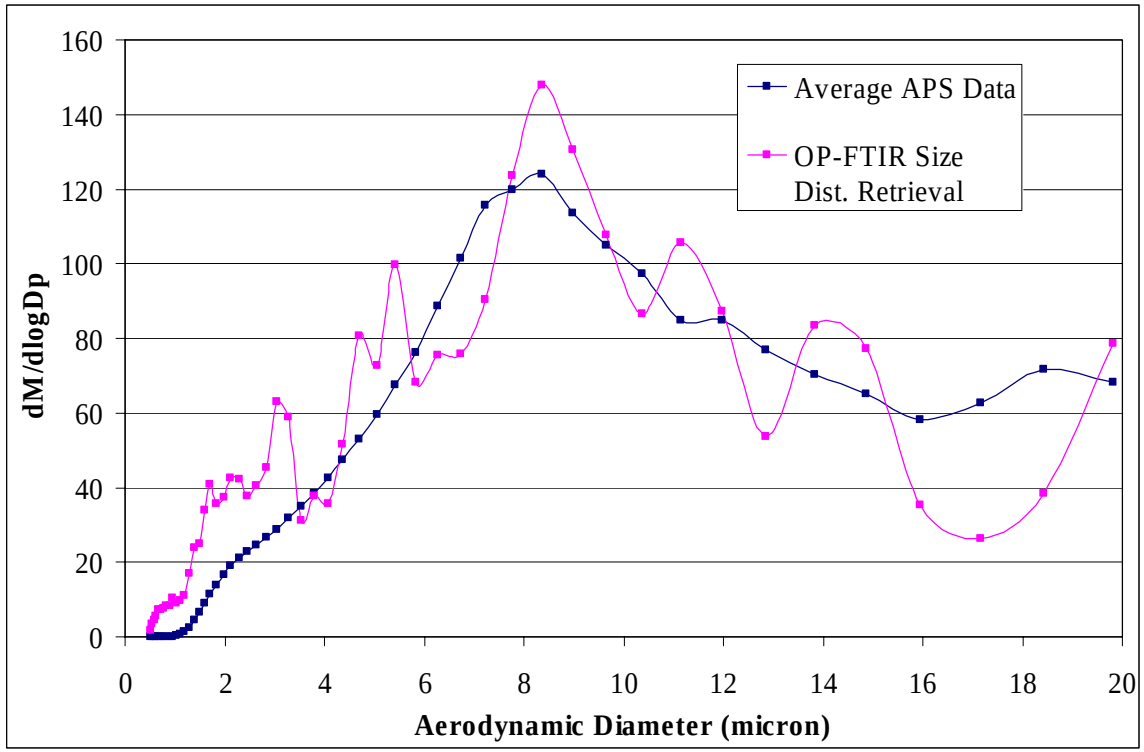
OP-FTIR Data and Algorithm
Input and Fit for Dust

Inverse Mie Theory
Mass Distribution Retrieval



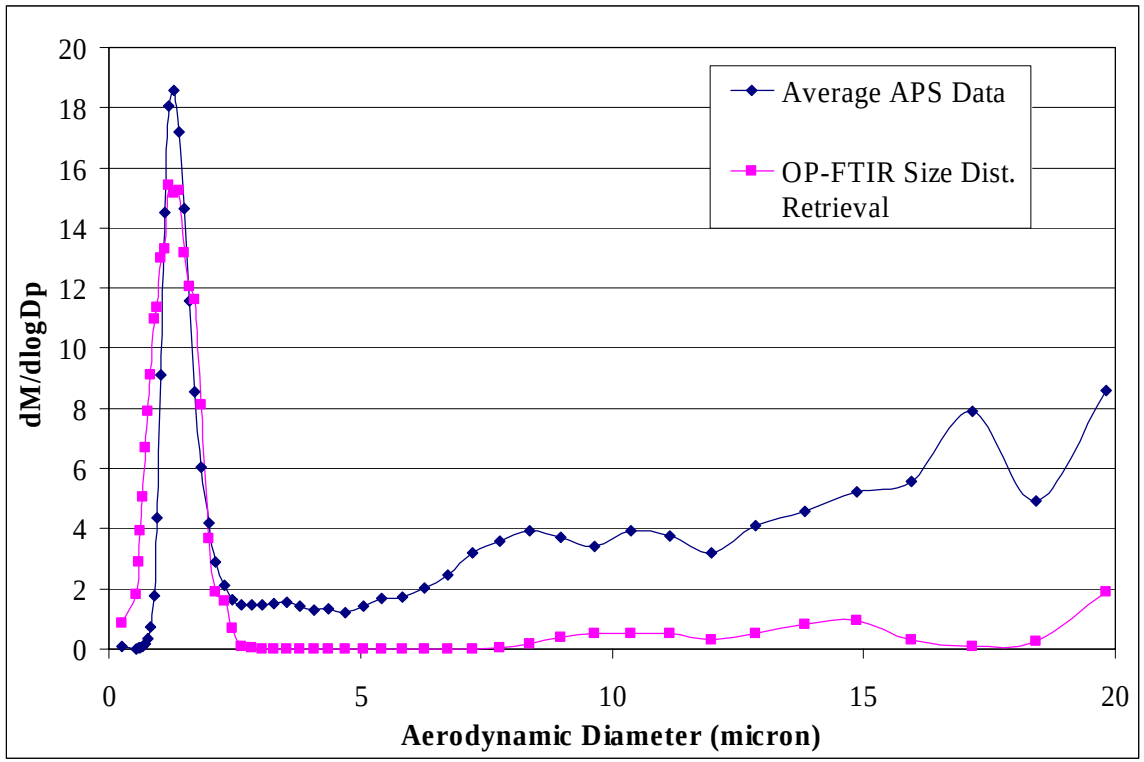
OP-FTIR Data and Algorithm
Input and Fit for Fogoil

Inverse Mie Theory
Mass Distribution Retrieval



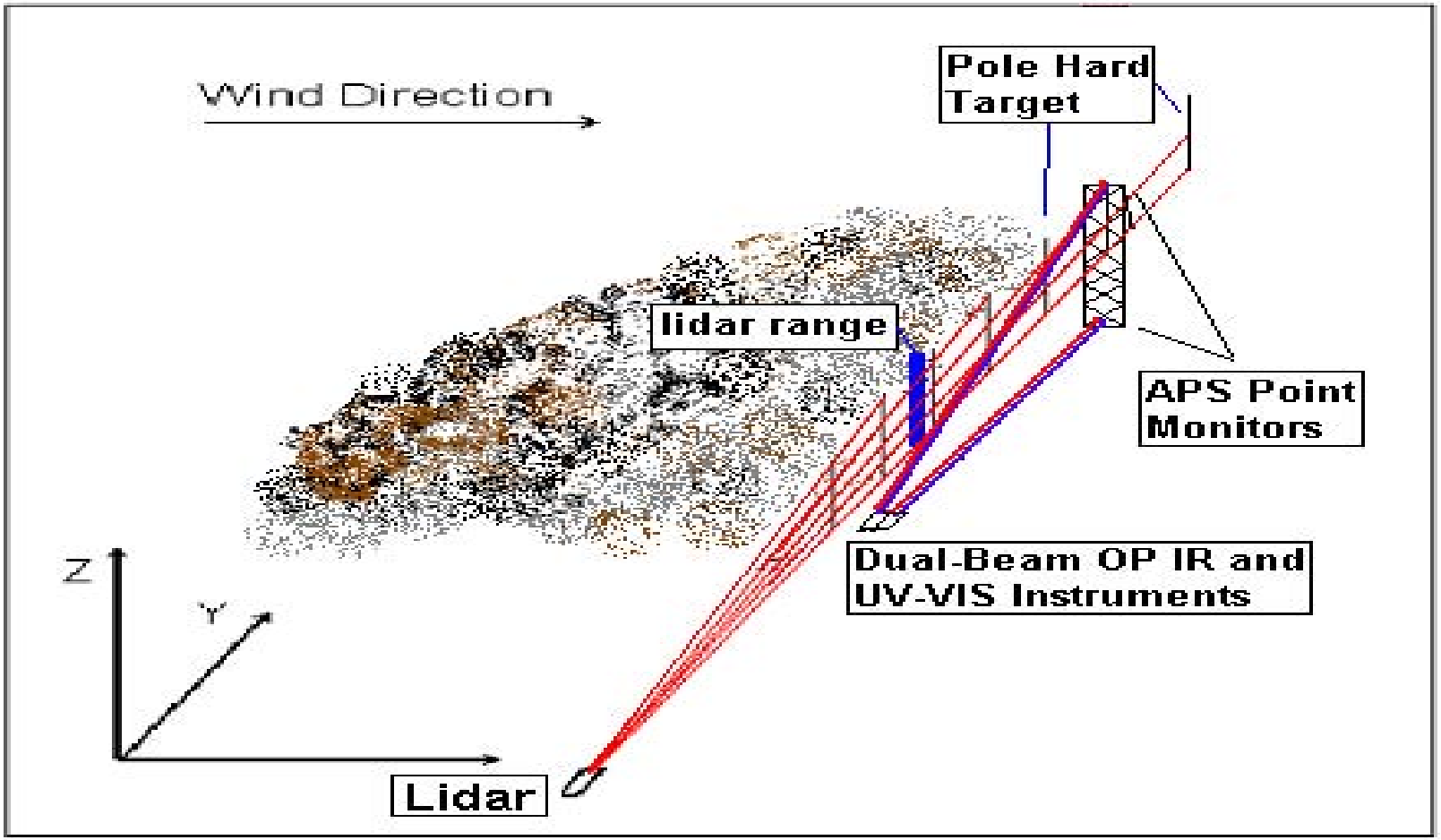
Size Distribution Retrieval
for Dust with APS Data

Inverse Mie Theory
Mass Distribution Retrieval



Size Distribution Retrieval
for Fogoil with APS Data

Measurement Approach for Ongoing SERDP Project



Explanation of figures in next couple of slides

Measurement Approach

- By situating hard targets over the measurement domain we obtain:
  - reliable inversion of the lidar equation
  - better penetration into the dust plume in the dense near-field conditions and significant extension of the lidar measurement distance

Measurement Approach

- OP-FTIR, OP-UV-VIS spectroscopy and real-time point dust monitors (APS) used concurrently with lidar and wind measurements, in a downwind vertical plane from the studied activity.
- This measurement configuration will provide important information for converting the lidar extinction distribution data into mass concentration distributions and thus in conjunction with the wind measurements, reliable mass fluxes