Evaluation of Fugitive Dust Deposition Rates Using Lidar

Dennis R. Fitz and David V. Pankratz

University of California, Riverside

Russell Philbrick and Homer Li

Pennsylvania State University

Emission Inventories-Applying New Technologies

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INTRODUCTION

- PM has been Shown to have Major Health Consequences
- Optical properties Affect Visibility and Radiative Balance
- Geologic PM is a Significant Contributor to Air Quality Standard Exceedances
- PM Inventories Overestimate Measured Geologic PM by 50% or More
- Discrepancy May be due to Inaccurate Inventories or Rapid PM Deposition

- Disturbing Soil is a Significant Source of Geologic PM
- Particle Lifetime is Difficult to Estimate
  - Can’t use stokes settling velocity due to air currents
  - Can’t directly sample from a moving plume

OBJECTIVE

- Characterize the Deposition and Transport of Dust Generated by soil disturbing Activities
  - Unpaved Roads
  - Agricultural Tilling

APPROACH

- Use Two-Wavelength Lidar to Characterize PM Concentration and Size
- Generate Actual and Artificial Dust Plumes Under Controlled Conditions
- “Calibrate” Lidar using Particles of Known Size
- Model Results with Respect to Backscatter and Extinction
- Monitor Dust Plumes

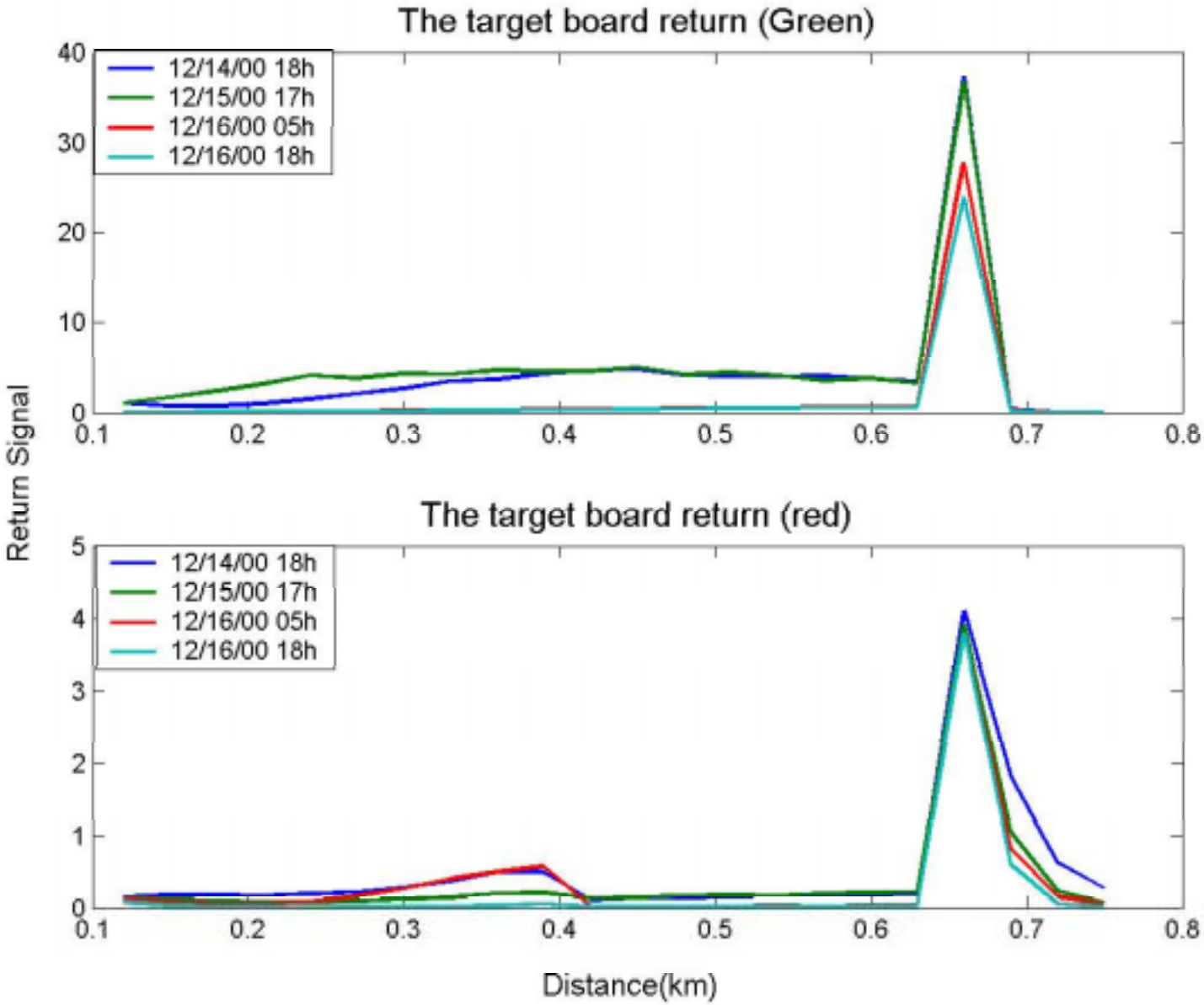
Lidar Basics

- Transmit a Laser Pulse Through the Atmosphere
- Measure Intensity of Light Returned due to Scattering by
  - Molecules (Rayleigh)
  - Particles
- Determine Backscatter and Extinction to Estimate Particulate Size and Concentration

SESI Micro-Pulse Lidar

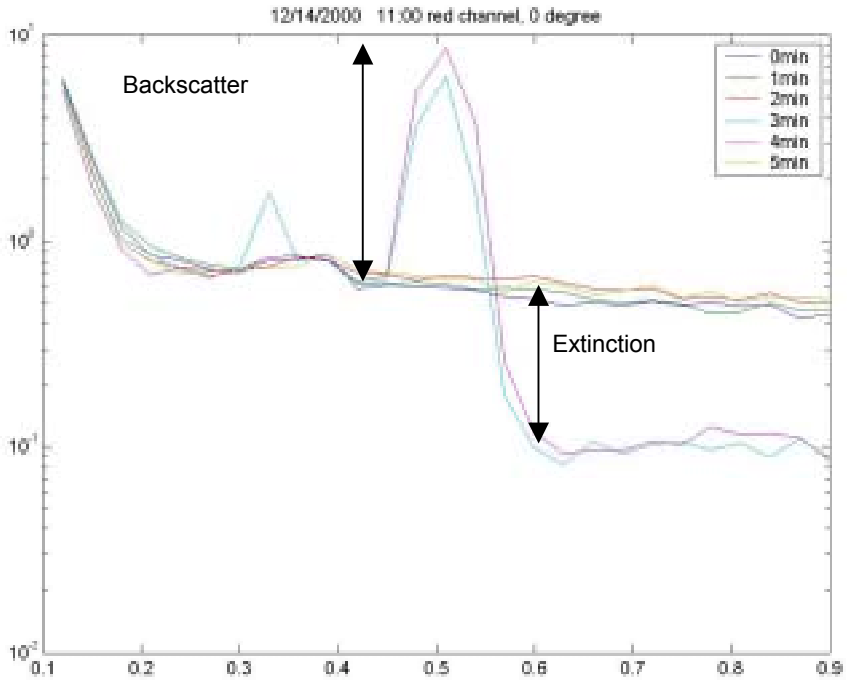
- Two Wavelengths
  - 523 nm
  - 1047 nm
- Eight Inch Schmidt-Cassegrain Telescope
- Horizontal Scanning
- Inclinometer
- Eye Safe

Target Board Example

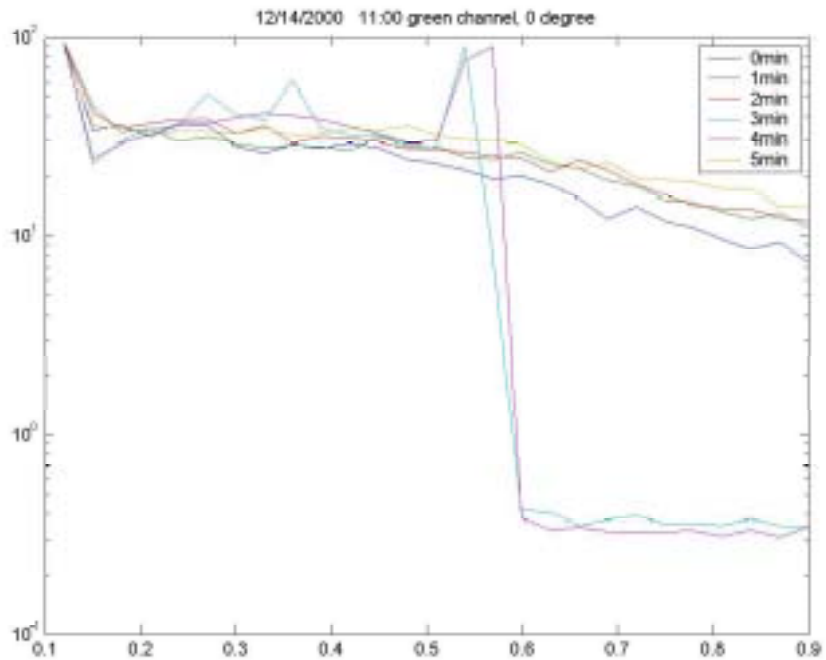


Lidar Example #1, Soil Dust

NIR



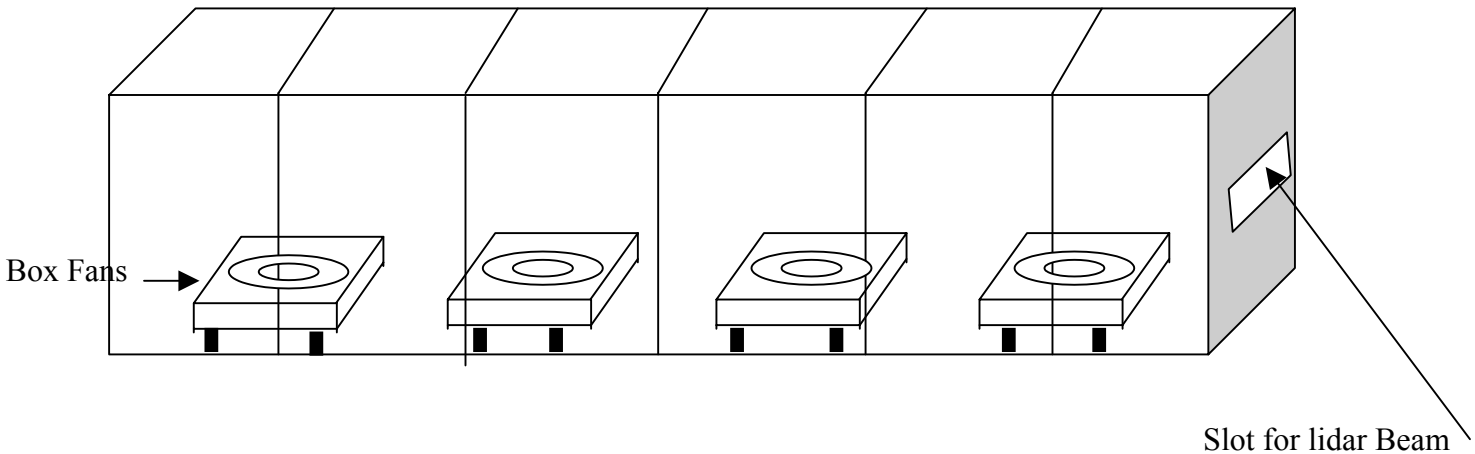
Visible



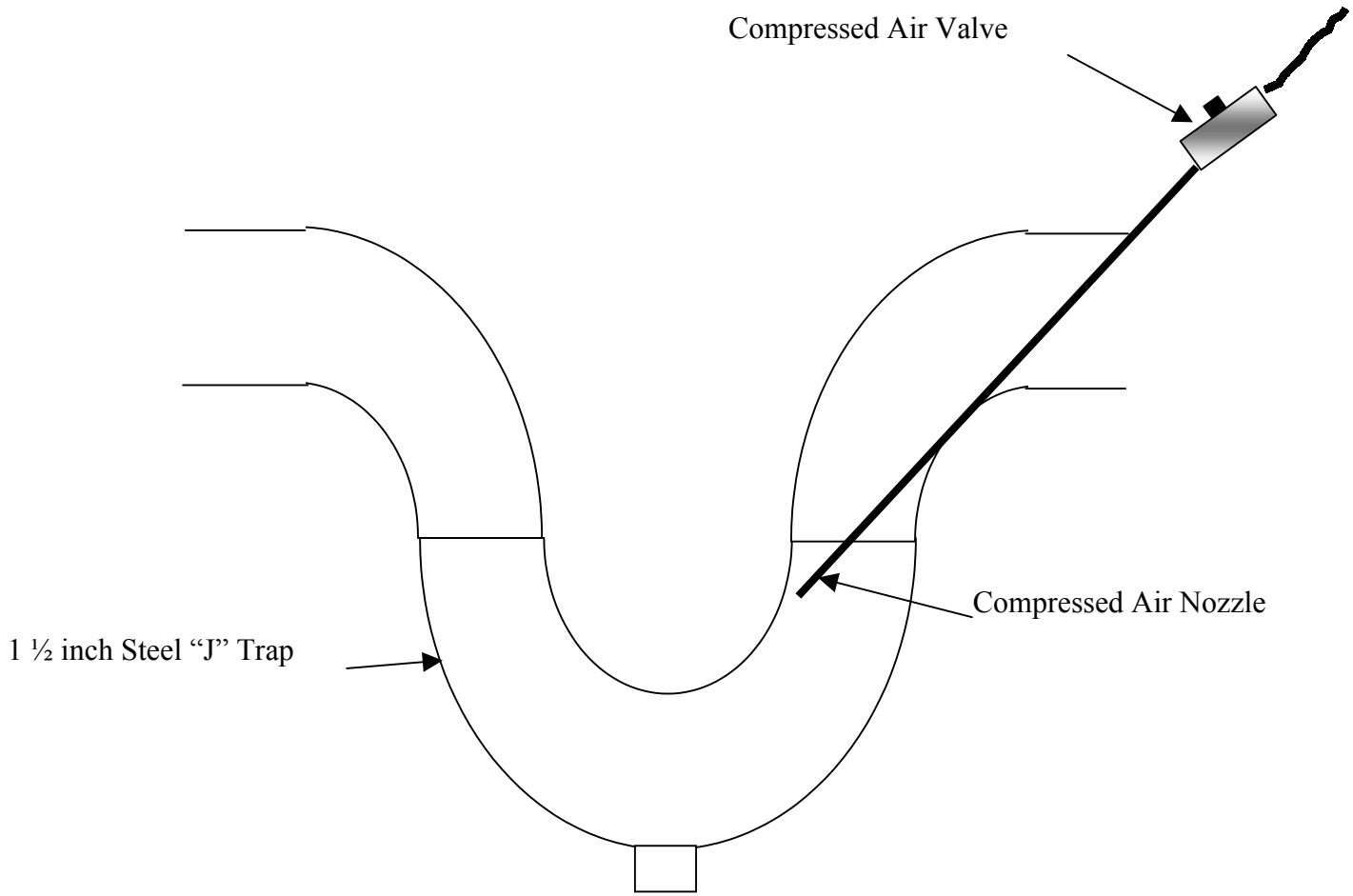
Test Chamber

- Box (4 feet x 4 feet x 24 feet long) Aligned with Lidar Beam
- Doors on Ends, Closed for Particle Mixing and Open for Lidar Measurements
- Particles Entrained by Blowing on with Compressed Air
- Four 18 inch Mixing Fans
- Four TSI DustTrak Optical Sensors to Measure PM_{10} Concentration and Uniformity
- Climet Spectro 0.3 to Optical Particle Counter to Measure Particle Size Distribution
- Tests Conducted in Early Morning for Still air and to Align Lidar Beam

Test Chamber Schematic



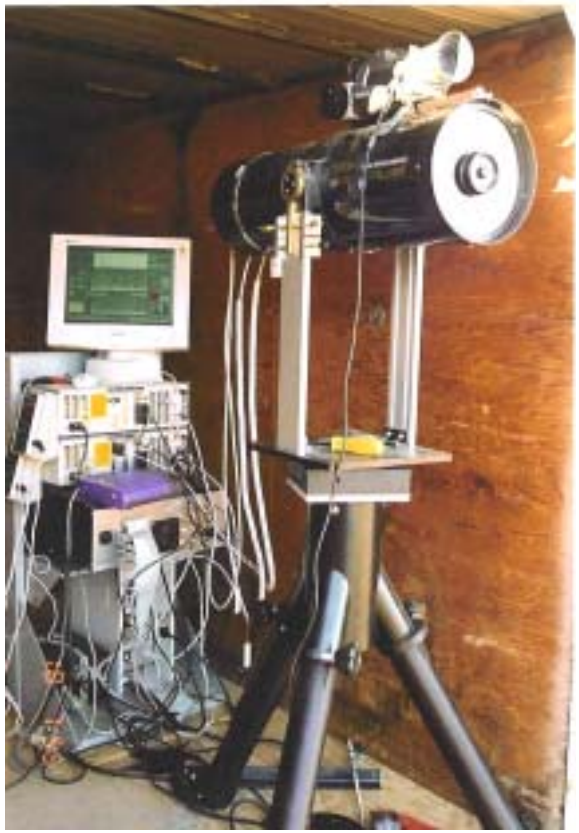
Test Chamber Dust Generator



Material Tested in Chamber

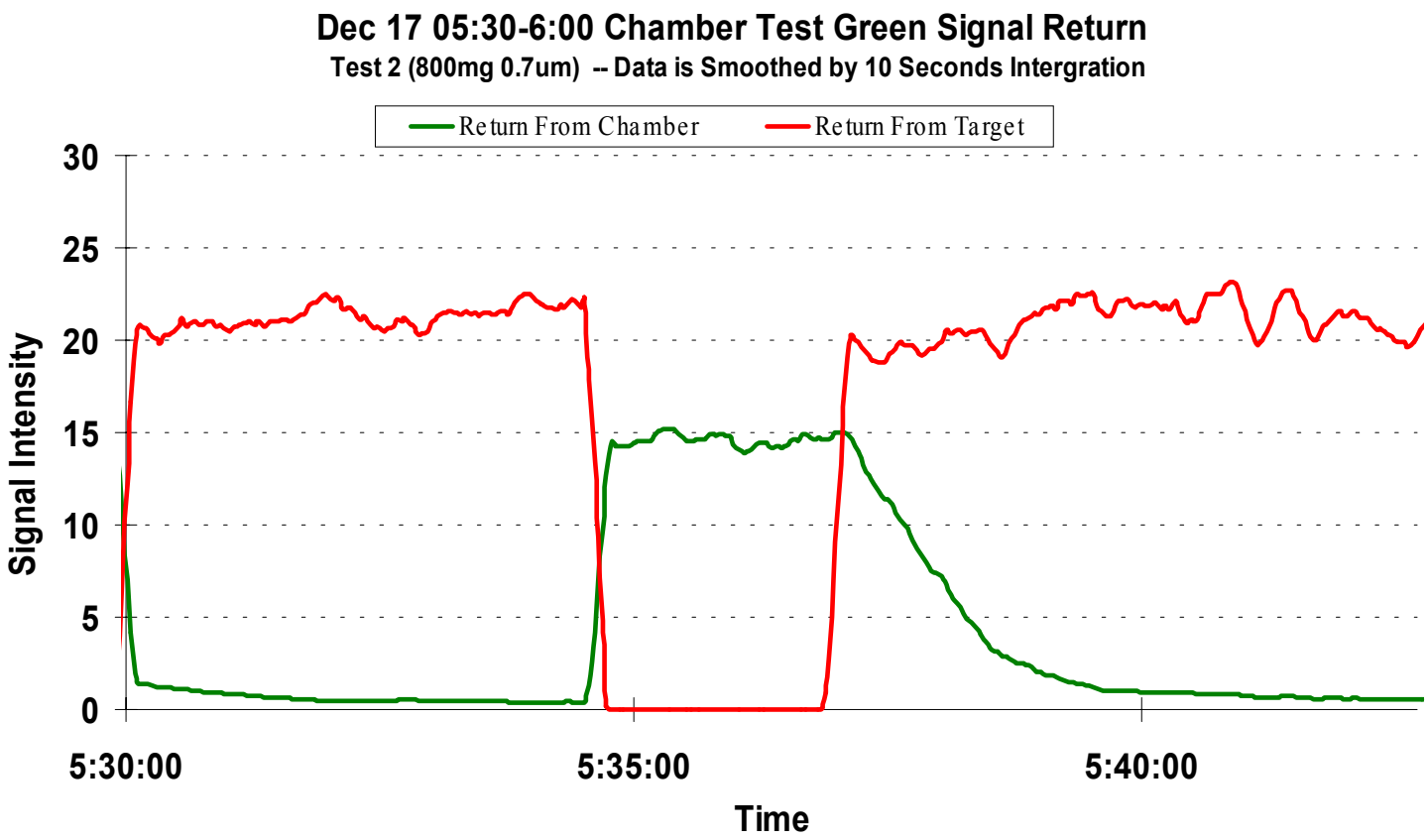
- Soils
  - Riverside
  - Kearney
  - Westside
  - Shafter
- Arizona Road Dust
- Carbonate Pigments (mmd)
  - 0.7 um
  - 2.0 um
  - 4.0 um
  - 8.0 um
  - 10 um
  - 15 um
  - 100 um
  - 200 um

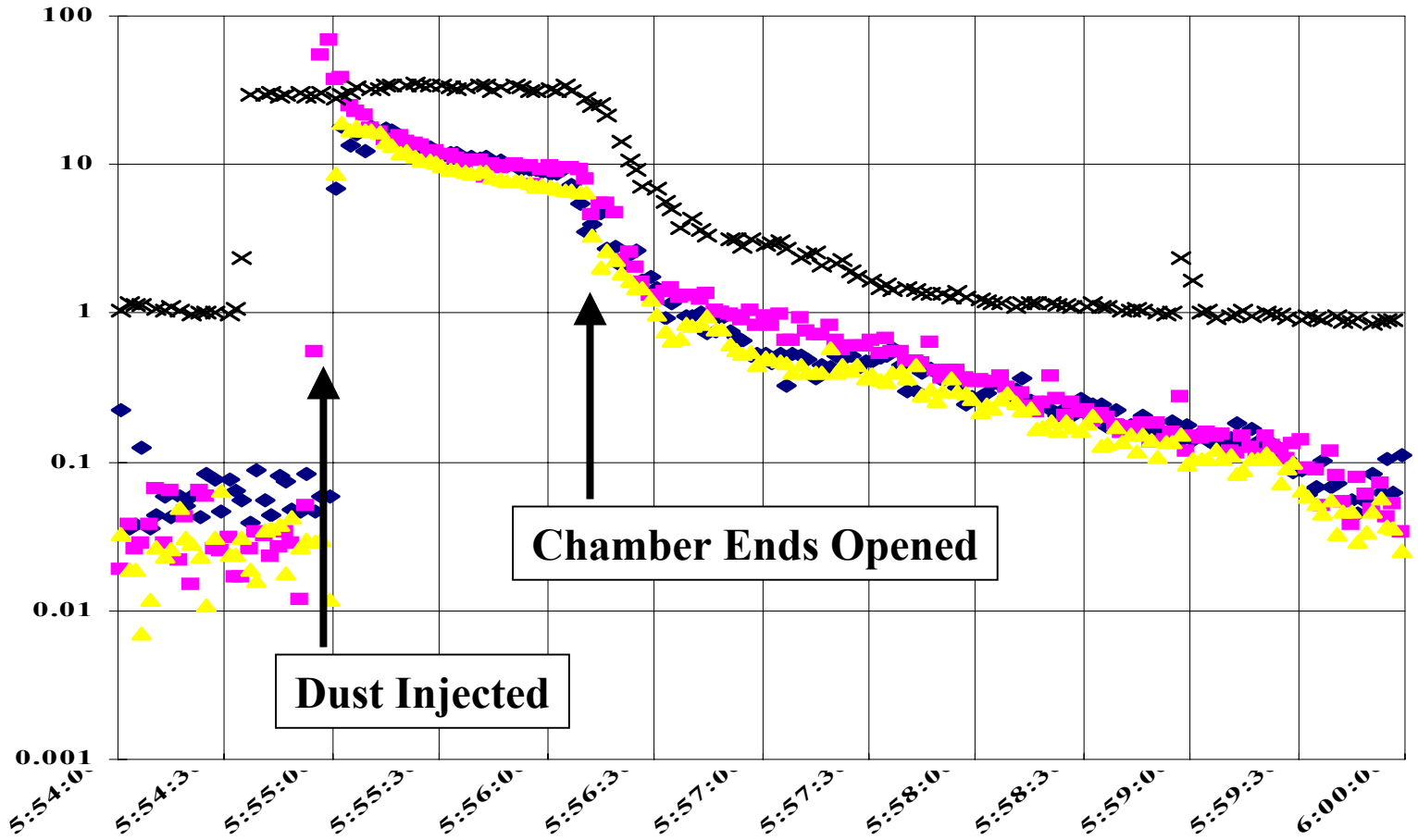
Field Dust Generator



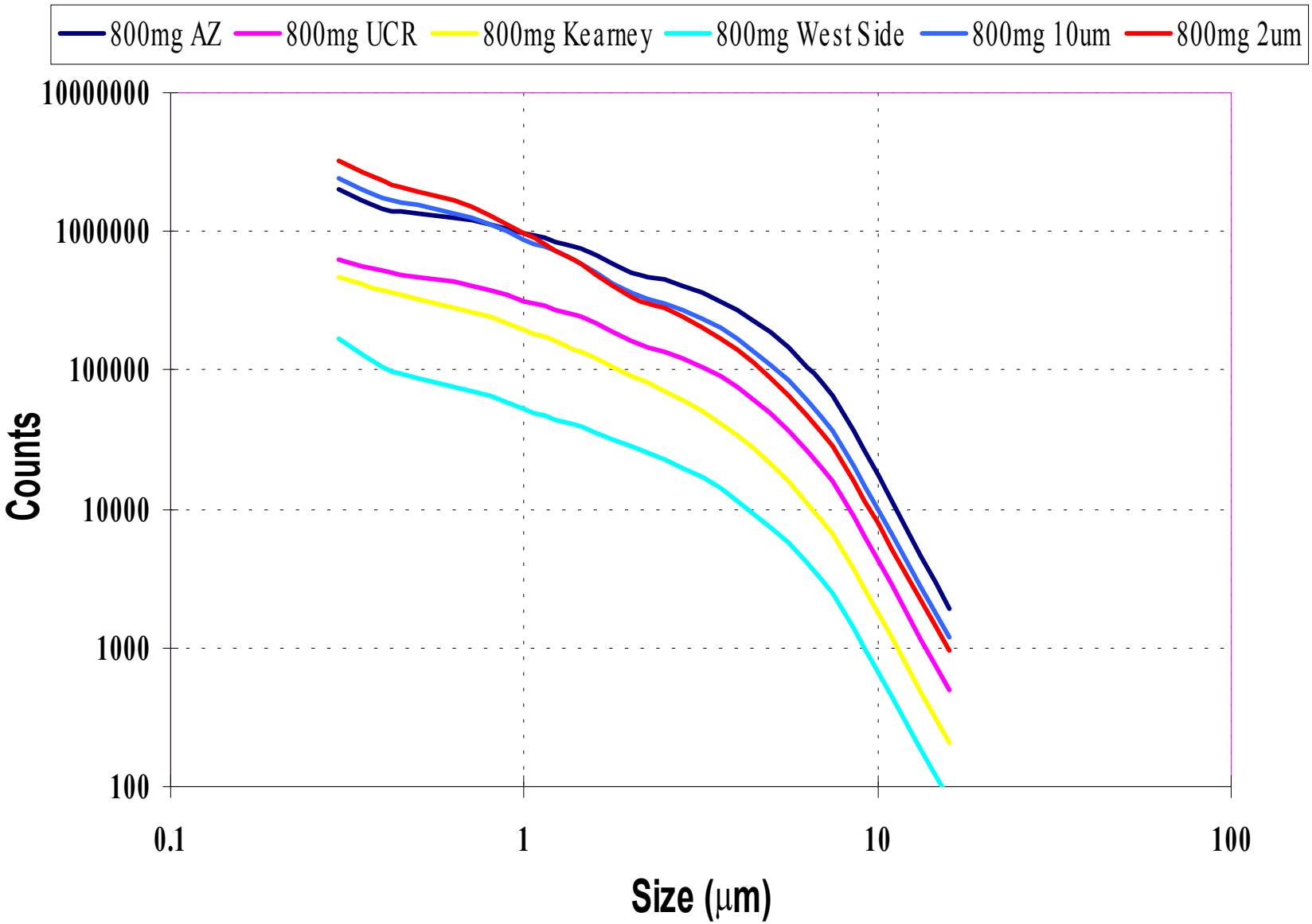
RESULTS

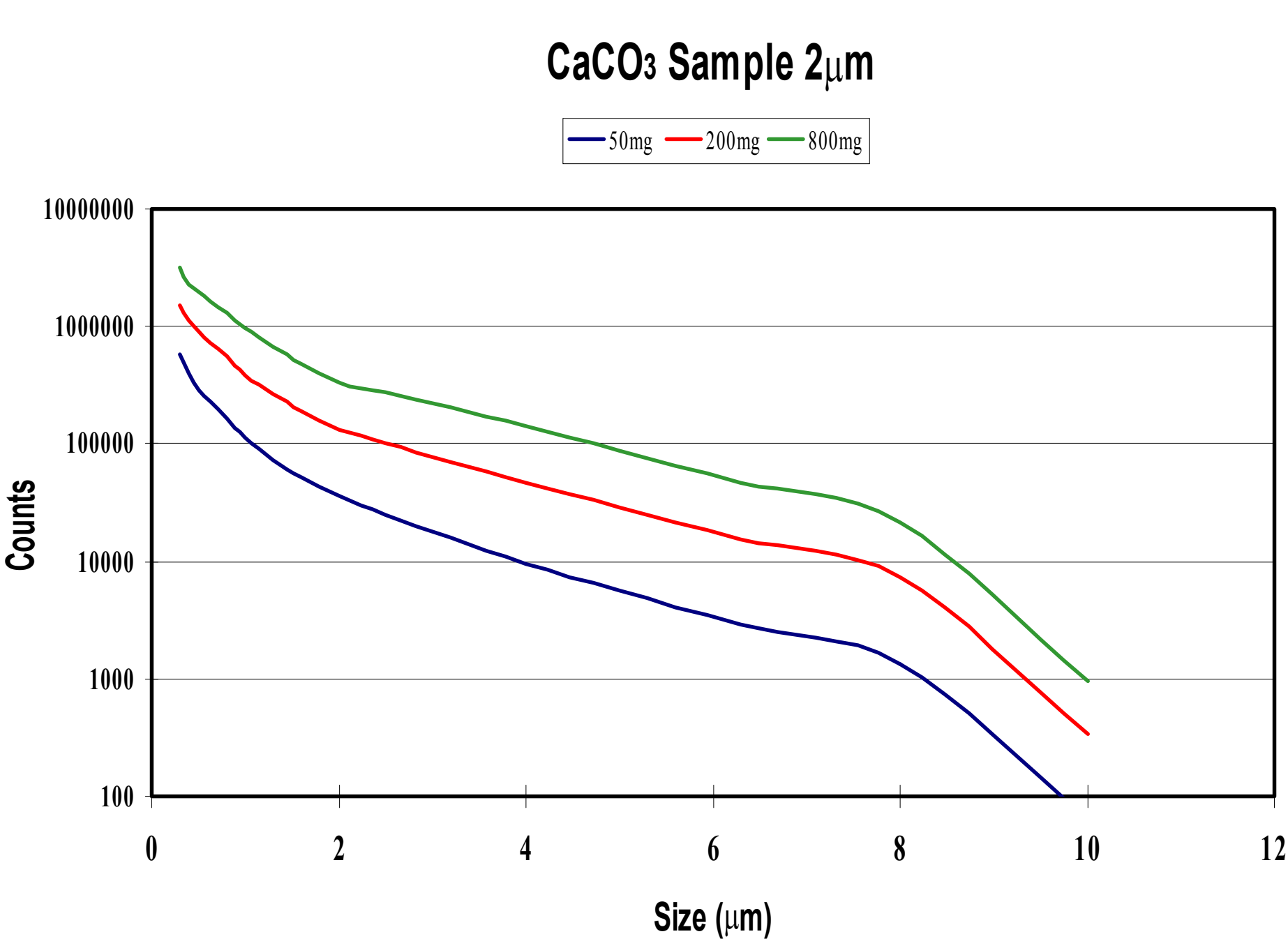
- Modeling (Previously Presented)
  - Backscatter and extinction both depend on particle size
  - Extinction depends strongly on concentration of larger particles
  - Backscatter does not depend strongly on concentration of larger particles
  - Modeling in qualitative agreement with field measurements
- Calibration Chamber
- Initial Field Measurements


Dec 17 05:30-6:00 Chamber Test Green Signal Return
Test 2 (800mg 0.7um) -- Data is Smoothed by 10 Seconds Intergration
Return From Chamber
Return From Target
Signal Intensity
30
25
20
15
10
5
0
5:30:00
5:35:00
5:40:00
Time

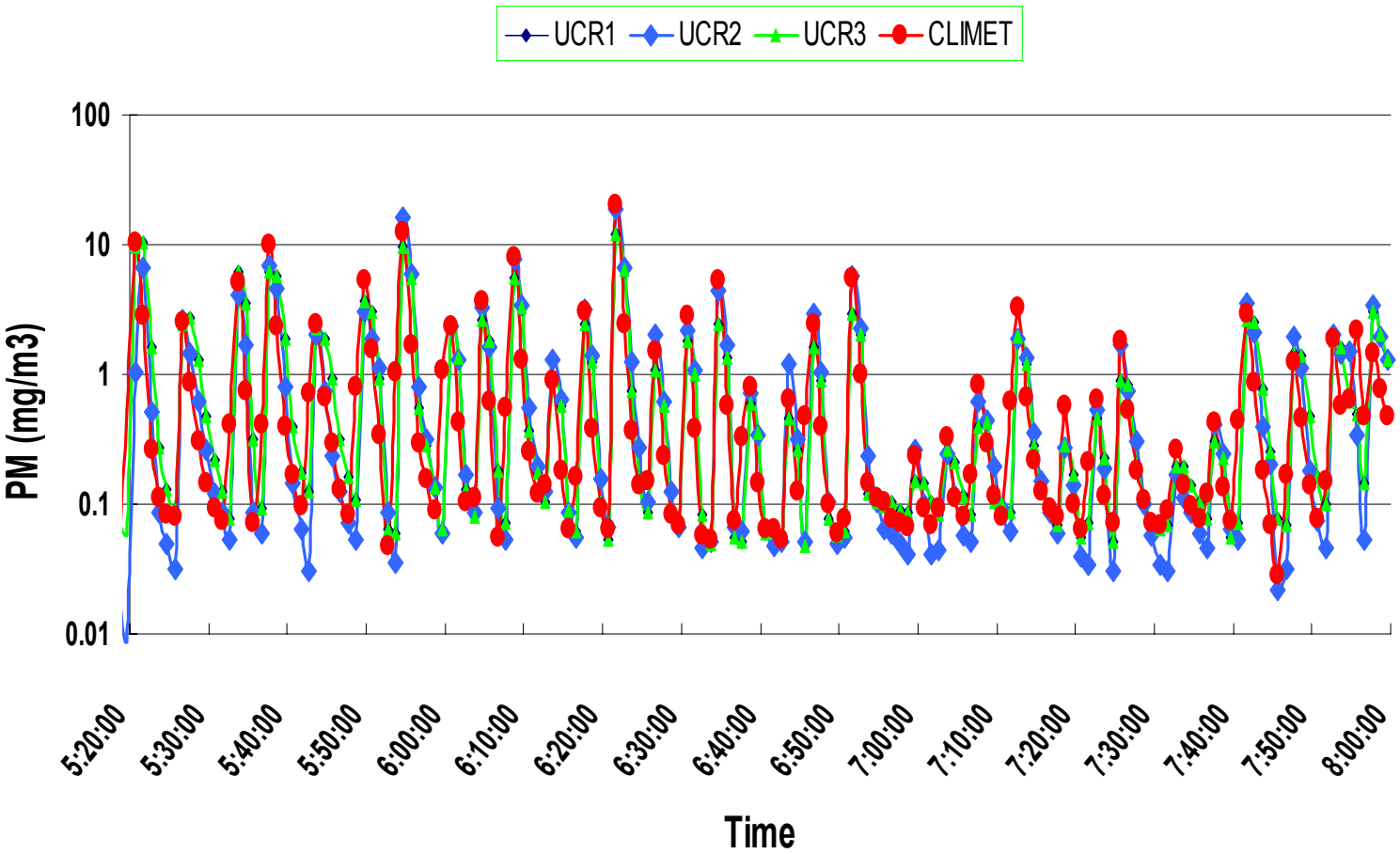

Comparison of UCR DustTrack & Lidar Test#12
800mg 10mm CACO3
UCR1
UCR2
UCR3
Lidar
100
10
1
0.1
0.01
0.001
5:54:0-
5:54:3-
5:55:0-
5:55:3-
5:56:0-
5:56:3-
5:57:0-
5:57:3-
5:58:0-
5:58:3-
5:59:0-
5:59:3-
6:00:0-
Dust Injected
Chamber Ends Opened

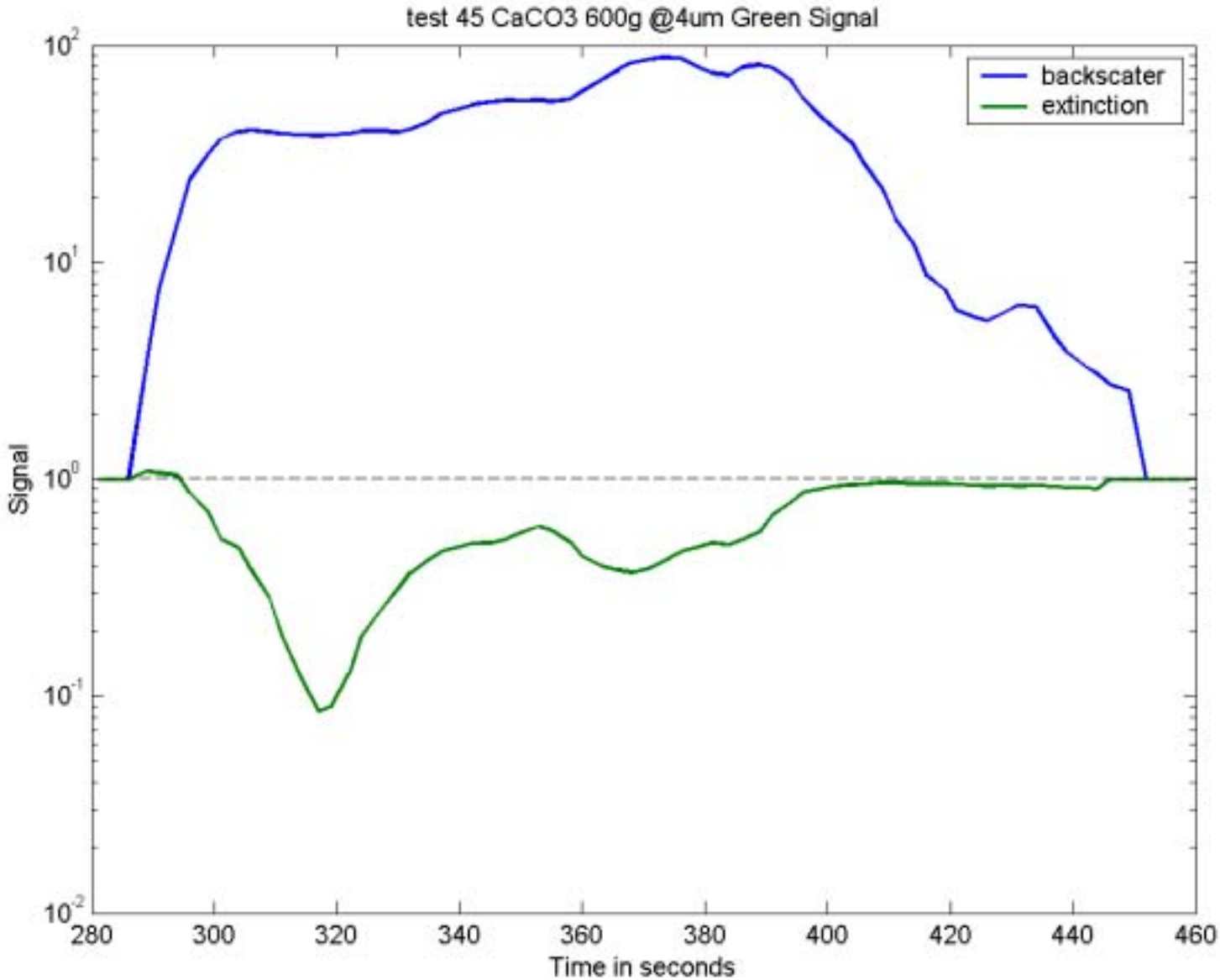
Field Dust Size Distributions For Chamber Test
Data Measured by Climet Dec 19 - 2001 PST

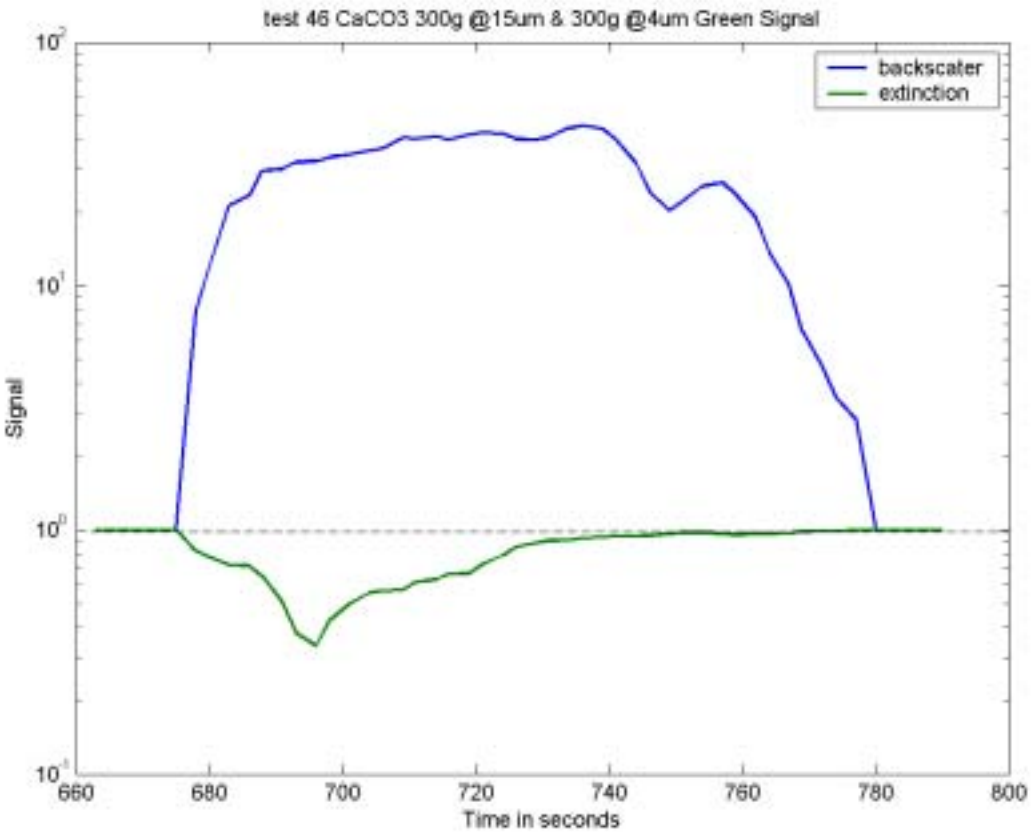


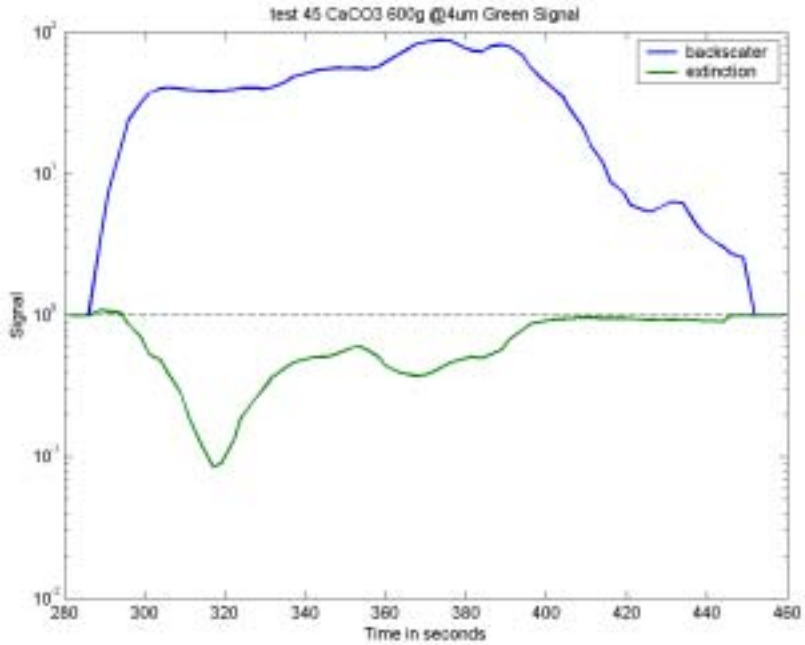

CaCO3 Sample 2μm
50mg
200mg
800mg
10000000
1000000
100000
10000
1000
100
Counts
0
2
4
6
8
10
12
Size (μm)

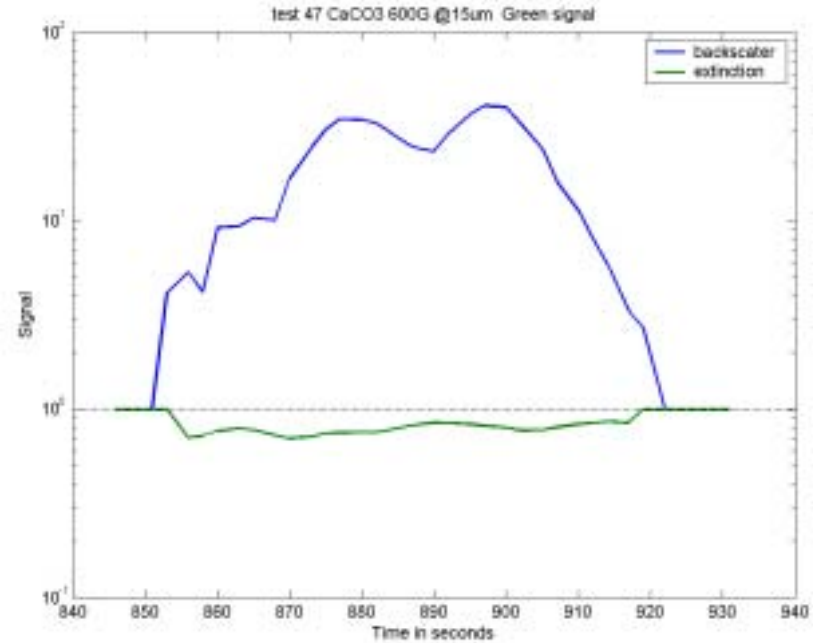
Comparison of Dust Track PM measurements with Climet data
Dec 19 2001 5:20-8:00 PST

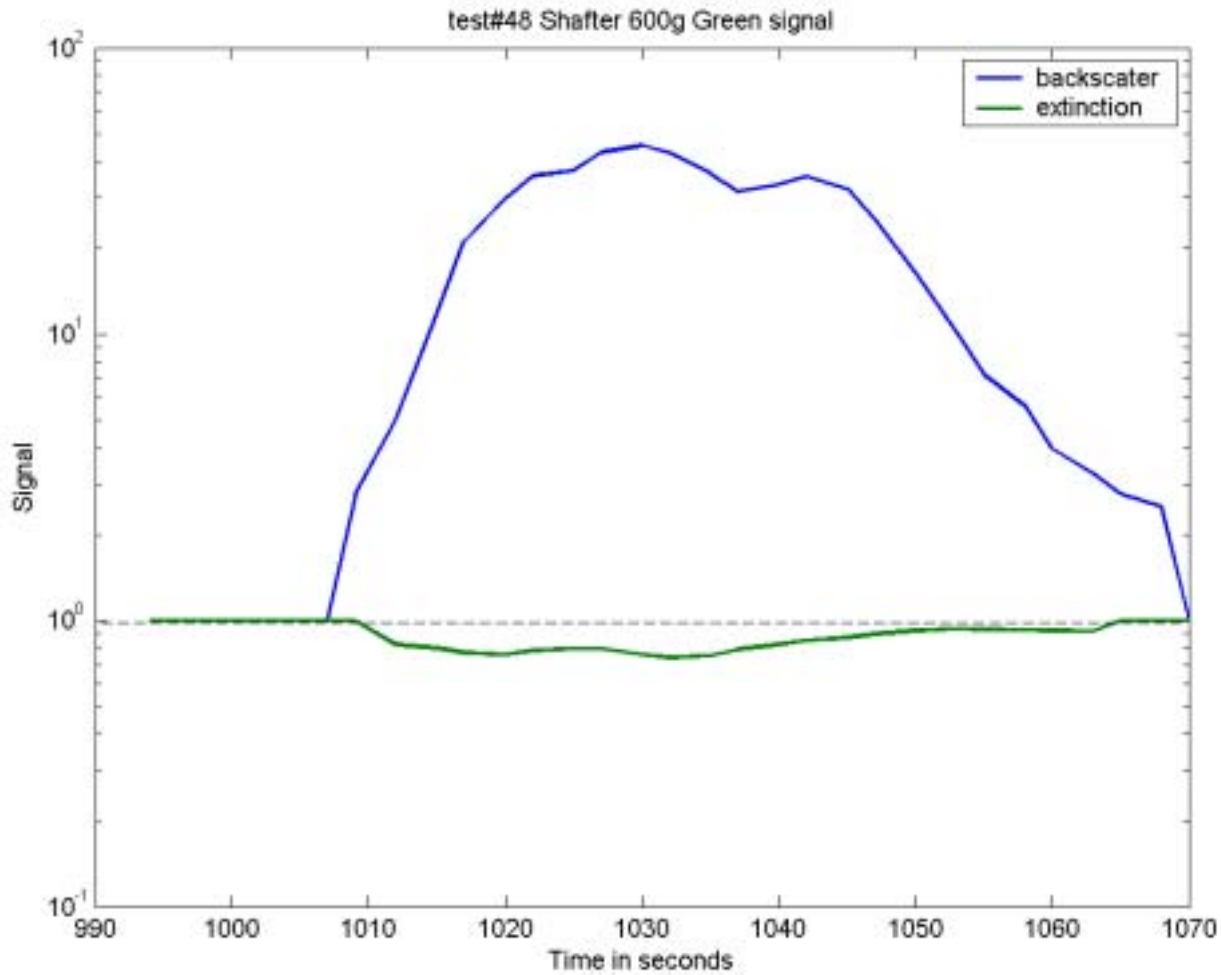


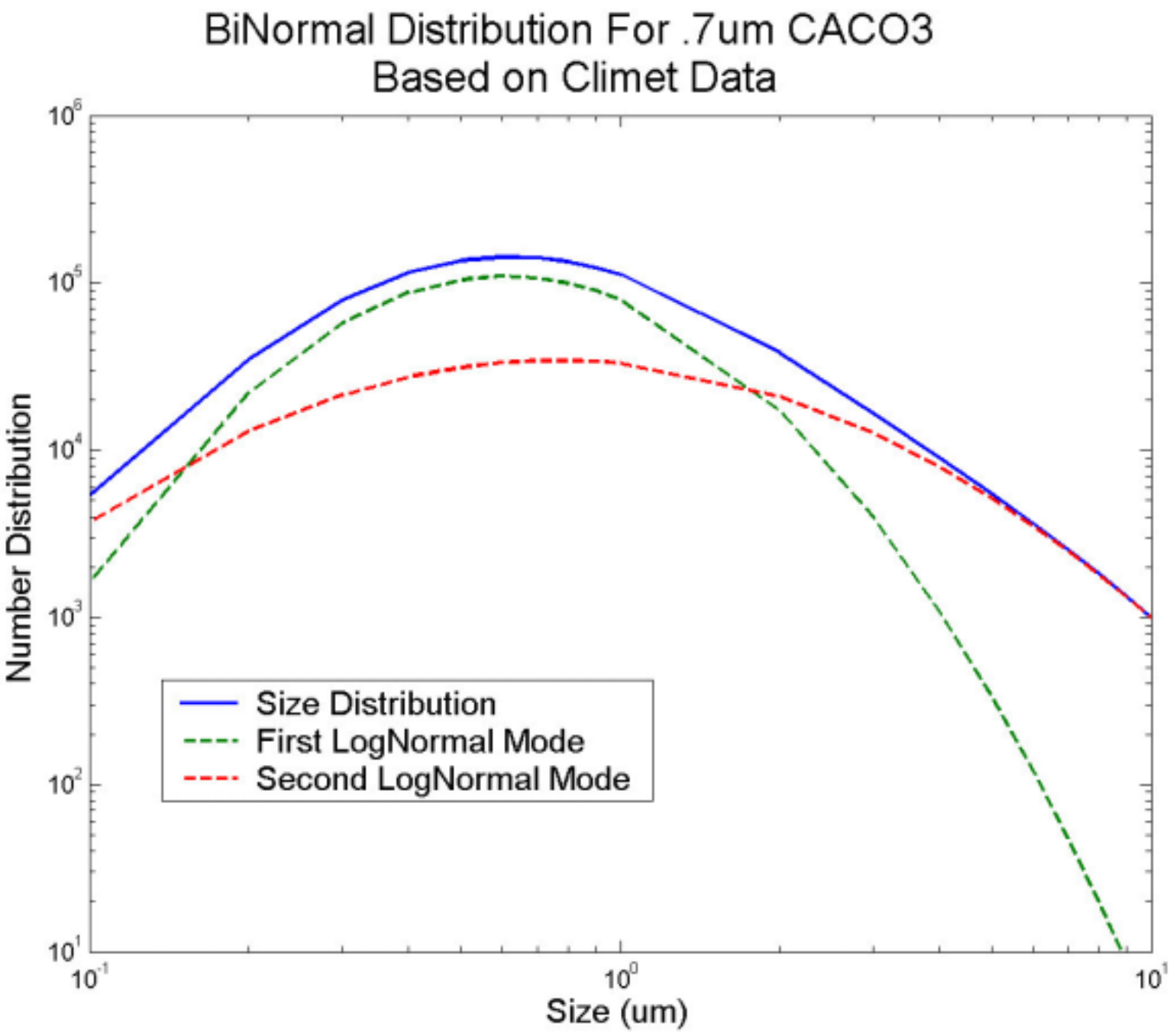

test 45 CaCO3 600g @4um Green Signal
backscater
extinction
Signal
Time in seconds
10^{2}
10^{1}
10^{0}
10^{-1}
10^{-2}
280
300
320
340
360
380
400
420
440
460

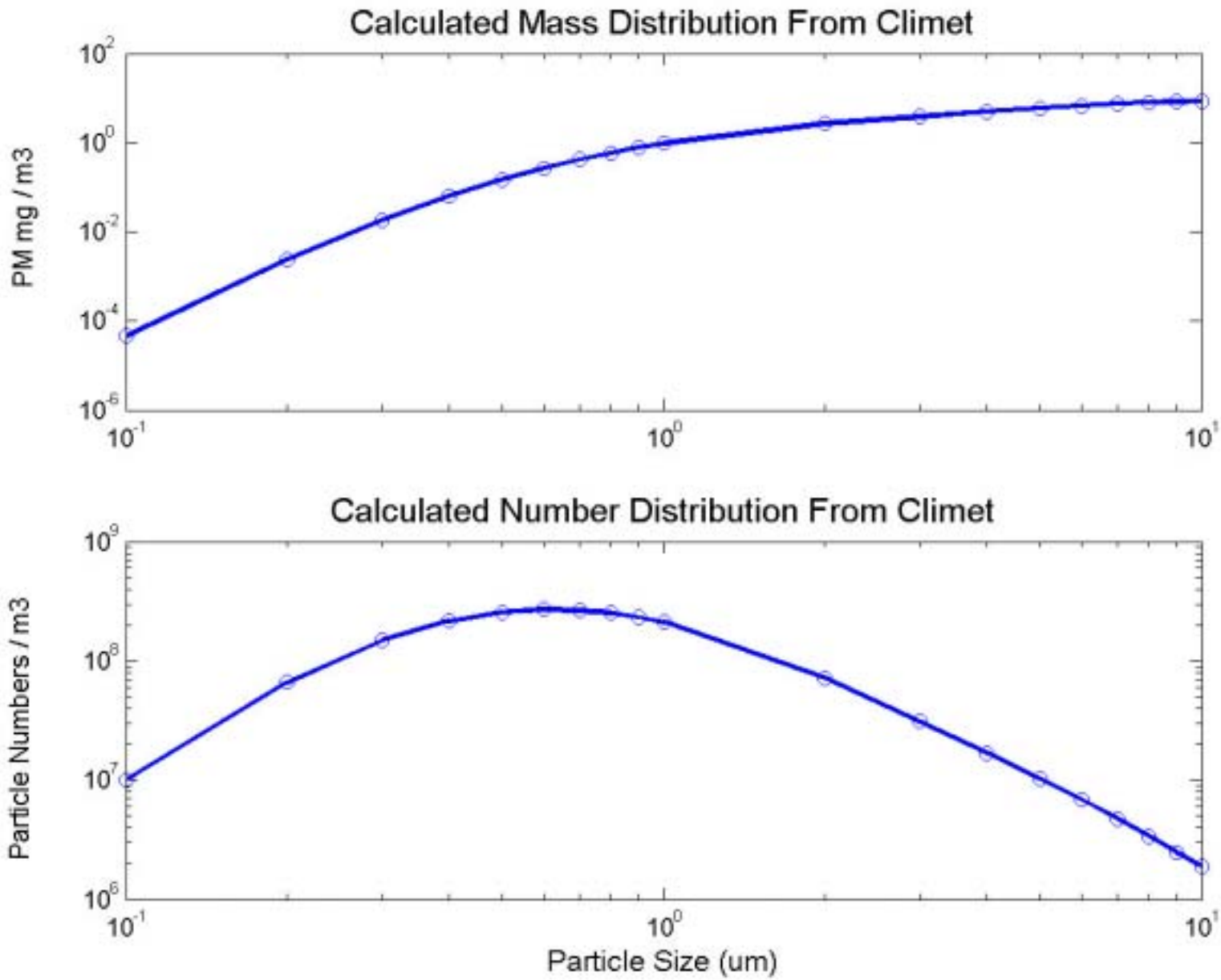

test 46 CaCO3 300g @15um & 300g @4um Green Signal
backscater
extinction
Signal
Time in seconds

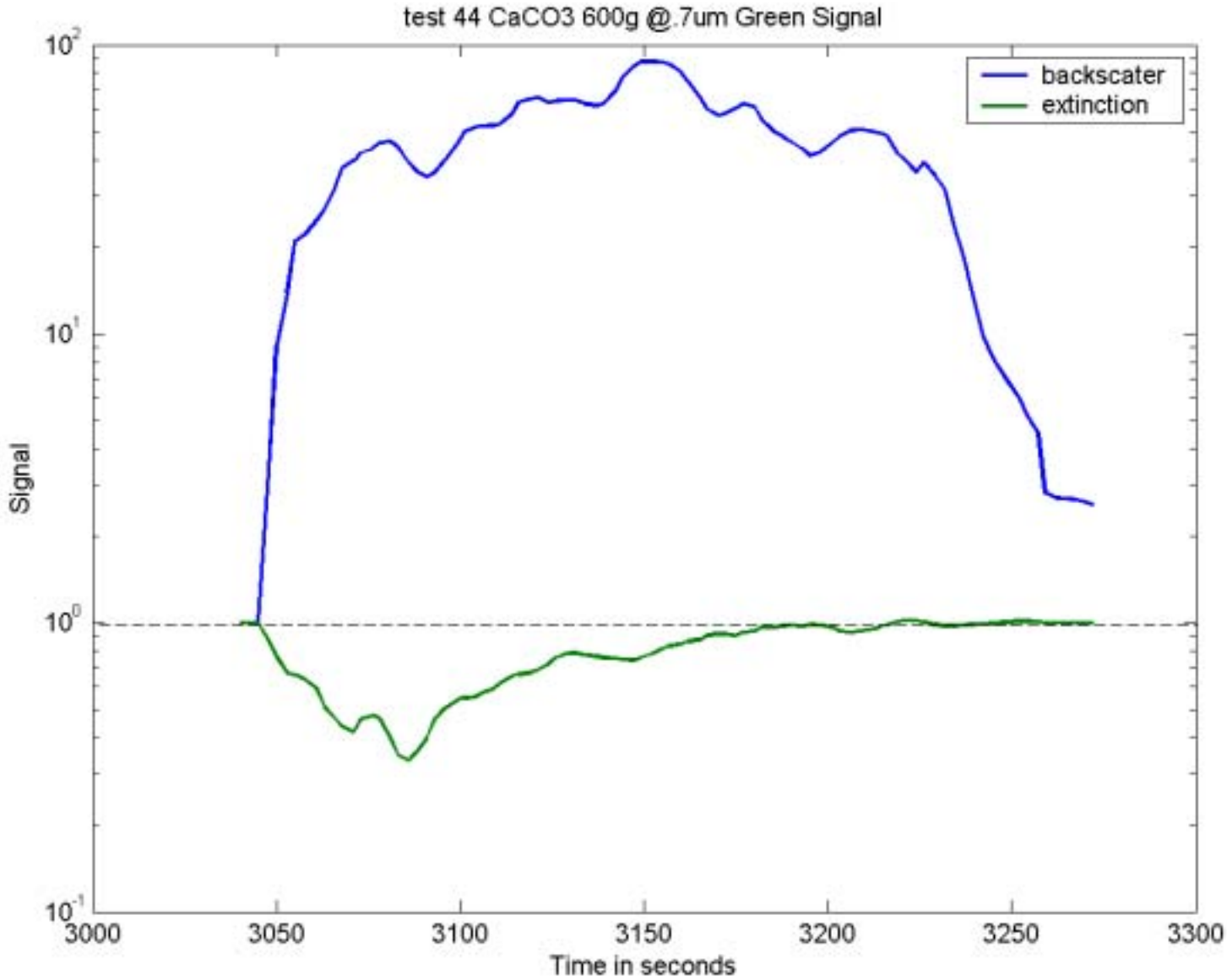

test 45 CaCO3 600g @4um Green Signal
backscater
extinction
Signal
Time in seconds

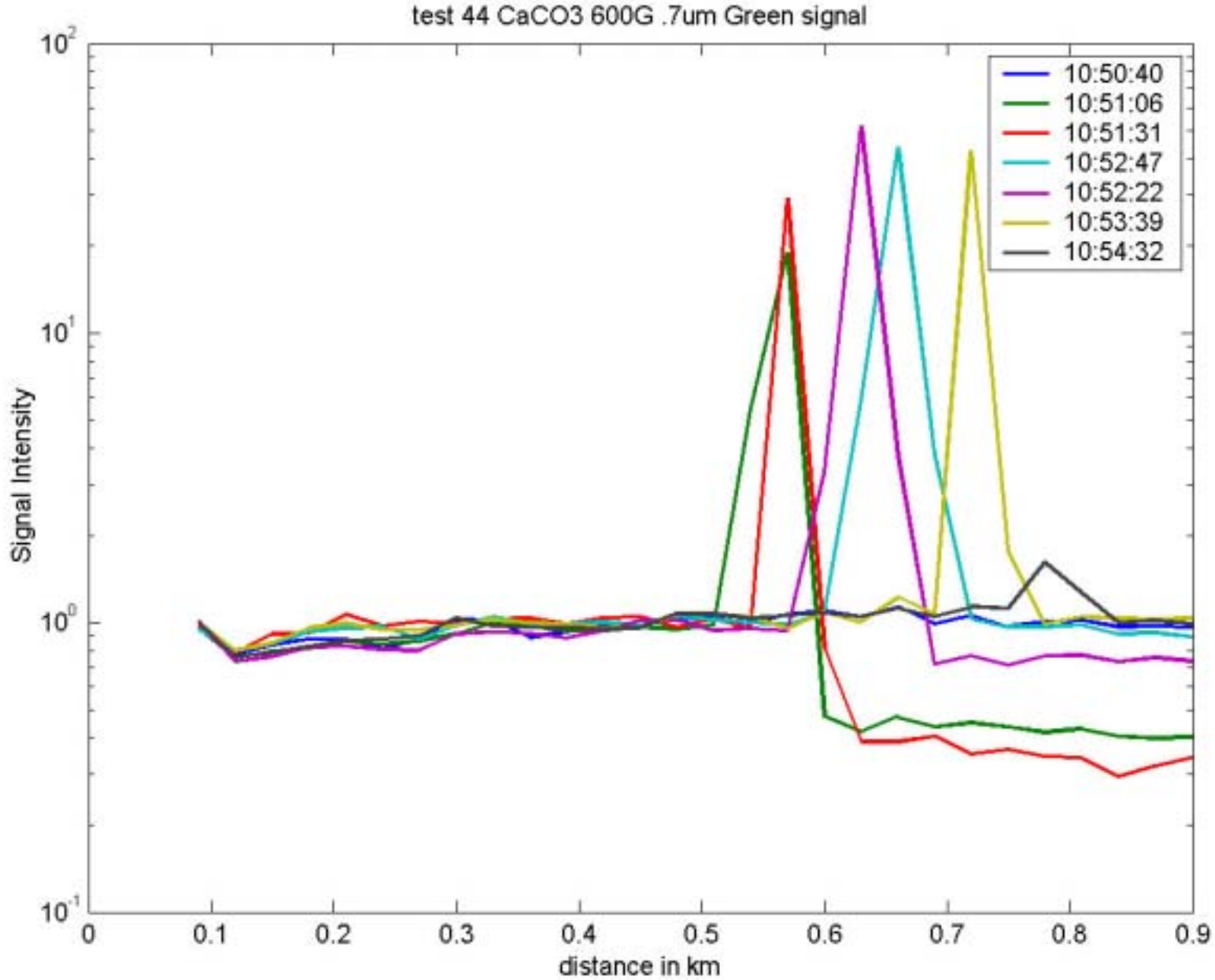

test 47 CaCO3 600G @15um Green signal
backscater
extinction
Signal
Time in seconds

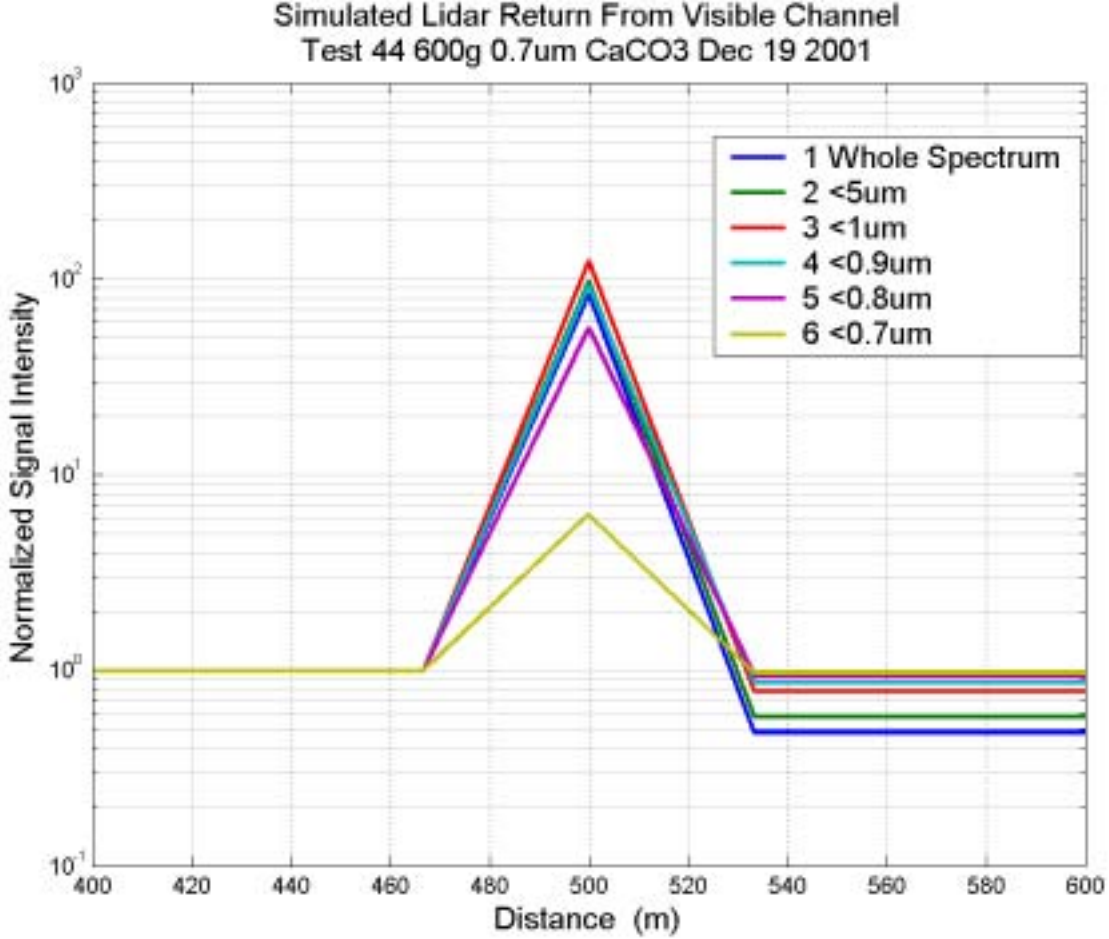

test#48 Shafter 600g Green signal
backscater
extinction
Signal
Time in seconds
10^2
10^1
10^0
10^{-1}
990
1000
1010
1020
1030
1040
1050
1060
1070

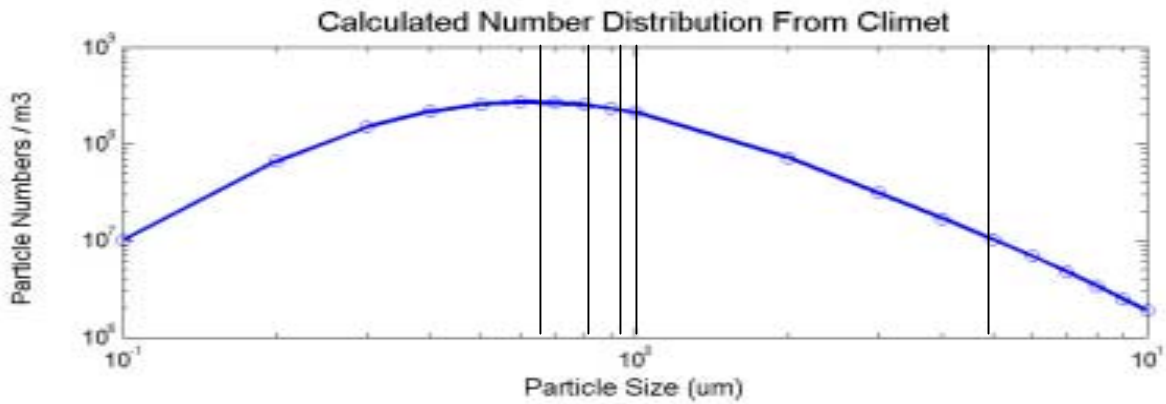

BiNormal Distribution For .7um CACO3
Based on Climet Data
Number Distribution
Size (um)
Size Distribution
First LogNormal Mode
Second LogNormal Mode
10^6
10^5
10^4
10^3
10^2
10^1
10^-1
10^0
10^1


Calculated Mass Distribution From Climet
PM mg / m3
10^{2}
10^{0}
10^{-2}
10^{-4}
10^{-6}
10^{-1}
10^{0}
10^{1}
Calculated Number Distribution From Climet
Particle Numbers / m3
10^{9}
10^{8}
10^{7}
10^{6}
10^{-1}
10^{0}
10^{1}
Particle Size (um)

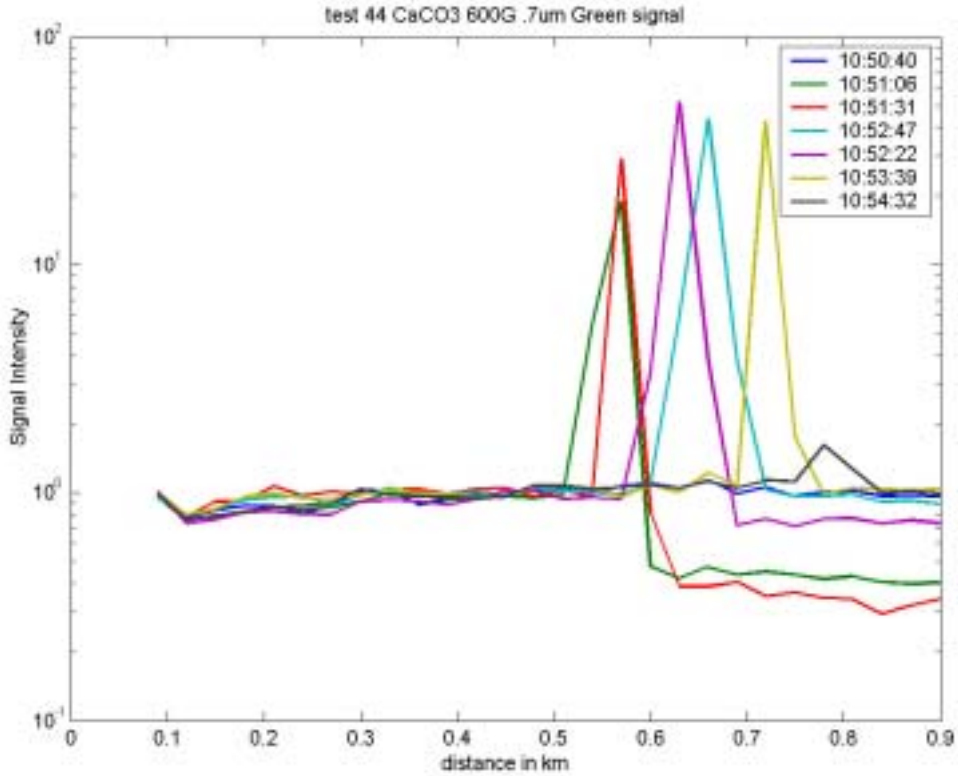

test 44 CaCO3 600g @.7um Green Signal
backscater
extinction
Signal
Time in seconds
10^2
10^1
10^0
10^{-1}
3000
3050
3100
3150
3200
3250
3300

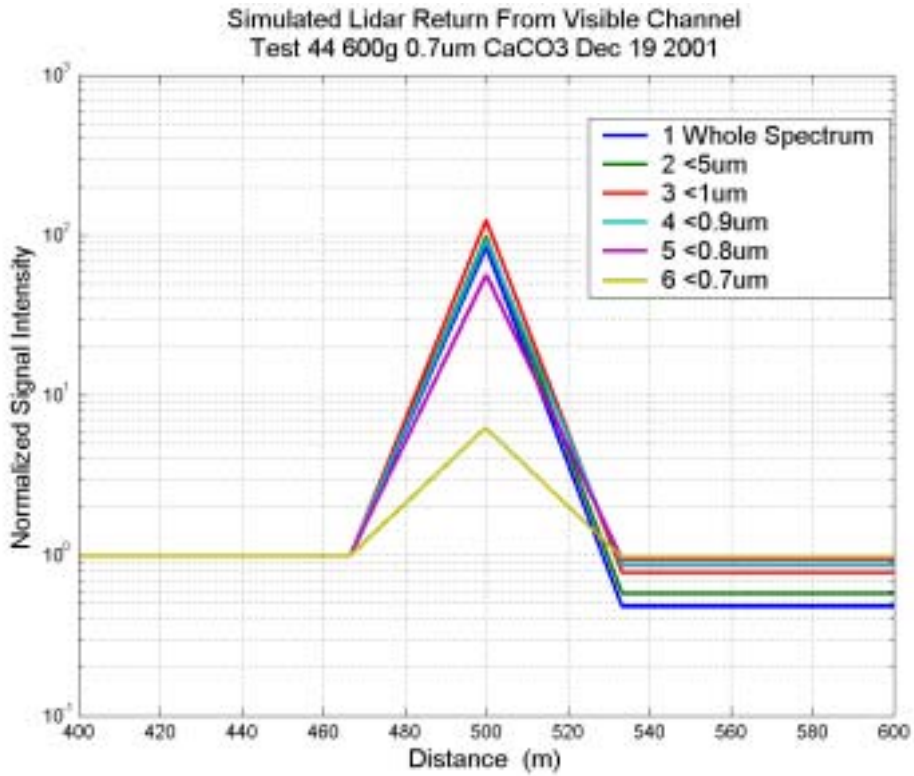

test 44 CaCO3 600G .7um Green signal
Signal Intensity
distance in km
10:50:40
10:51:06
10:51:31
10:52:47
10:52:22
10:53:39
10:54:32
10^2
10^1
10^0
10^{-1}
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9





Measured optical particle spectrum was segmented to discard larger particles and observe where a break in backscatter intensity occurs


test 44 CaCO3 600G .7um Green signal
10:50:40
10:51:06
10:51:31
10:52:47
10:52:22
10:53:39
10:54:32
Signal Intensity
distance in km


Simulated Lidar Return From Visible Channel
Test 44 600g 0.7um CaCO3 Dec 19 2001
1 Whole Spectrum
2 <5um
3 <1um
4 <0.9um
5 <0.8um
6 <0.7um
Normalized Signal Intensity
Distance (m)

CONCLUSIONS

- Lidar Can be Used to Monitor Plume Dimensions as it Disperses
- Extinction is More Dependent on Concentration
- Backscatter is More Dependent on Particle Size
- Determination of Settling as a Function of Size will Involve Further Deconvolution of the Backscatter and Extinction Characteristics
- Initial Results Indicate Rapid Settling of Larger Particles