

**FLAME 2:  
An Analysis of Aerosol  
Emissions from Biomass  
Burning**

**Jennifer McInnis, Cornell University**

**Mentor: Tim Onasch, Aerodyne  
Research, Inc.**

# Outline

- Introduction to biomass burning and aerosols
- FLAME-2: A study to characterize biomass burning emissions
- Particle physical properties measured
  - Particle size
  - Effective density
  - Particle phase
  - Chemical composition
  - Volatility
- Summary and conclusions

# Introduction to Biomass Burning

- Natural and anthropogenic causes
- Releases “stored” carbon into the atmosphere
  - greenhouse gases and particulate matter
- Global radiation budget
- National ambient air quality standards and visibility
- Still large uncertainty/ source of error in models
  - Flaming/smoldering
  - Dilution effects



[http://newsdesk.si.edu/photos/sites\\_earth\\_from\\_space.htm](http://newsdesk.si.edu/photos/sites_earth_from_space.htm)



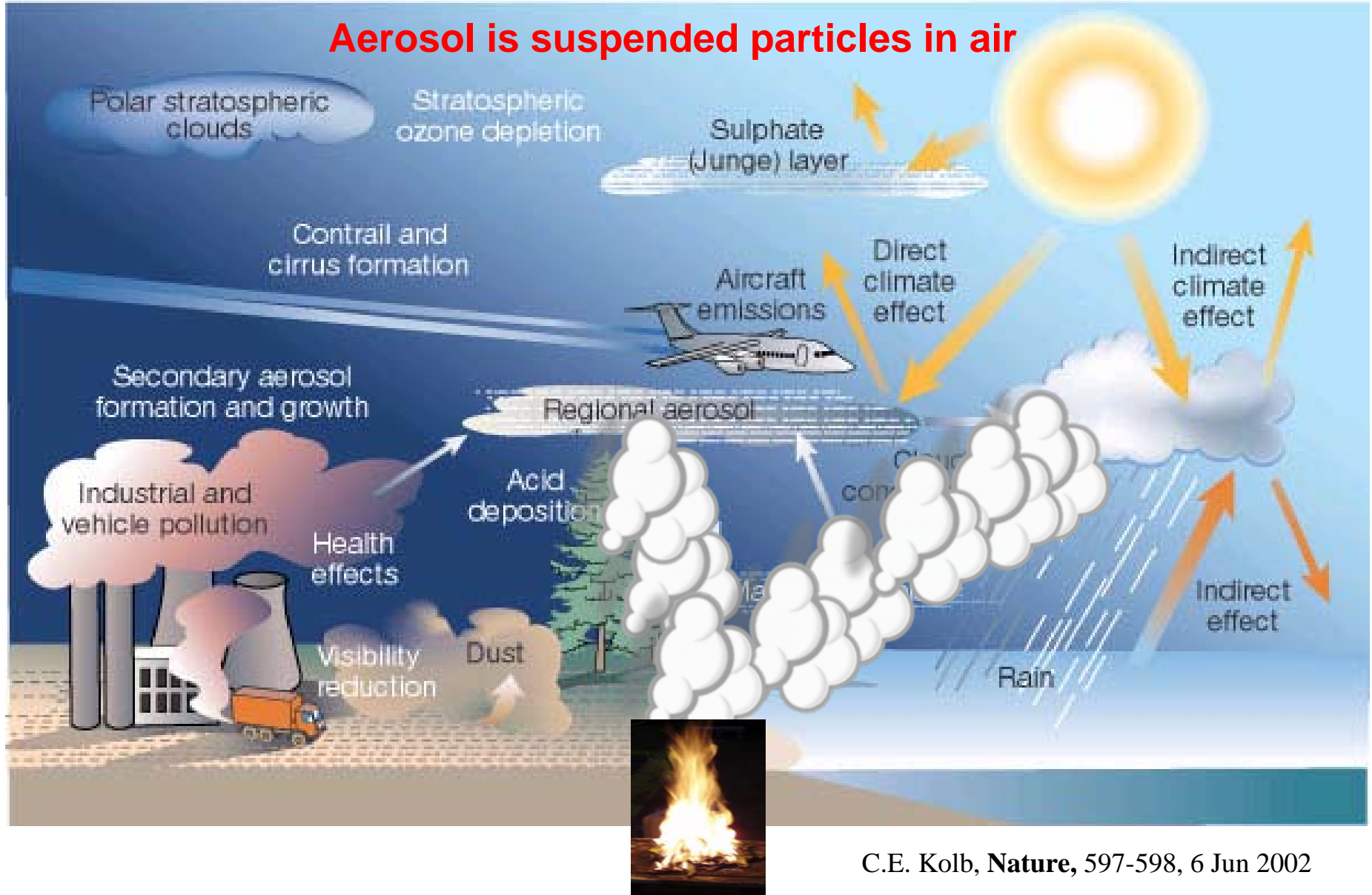
flaming



smoldering

# Aerosols in the Atmosphere

**Aerosol is suspended particles in air**



# FLAME-2: Fire Science Lab in Missoula, MT



<http://www.firelab.org/>

- 21 controlled experimental burns of North American wildfire fuels
- Wide variety of instrumentation to characterize the physical, optical, and chemical properties of gaseous and particulate emissions

# Physical Properties Analyzed

- Particle Size Distribution
  - AMS, SMPS
- Effective Density
  - AMS+SMPS
- Chemical Composition
  - AMS
- Volatility
  - Thermal Denuder + AMS

# Experimental Setup

Burn Chamber



To other particle and gas instrumentation

Thermal Denuder (TD)-volatility



Valve

SMPS

number and volume distributions by size



Aerosol Mass Spectrometer (AMS)

Size, effective density, chemical composition

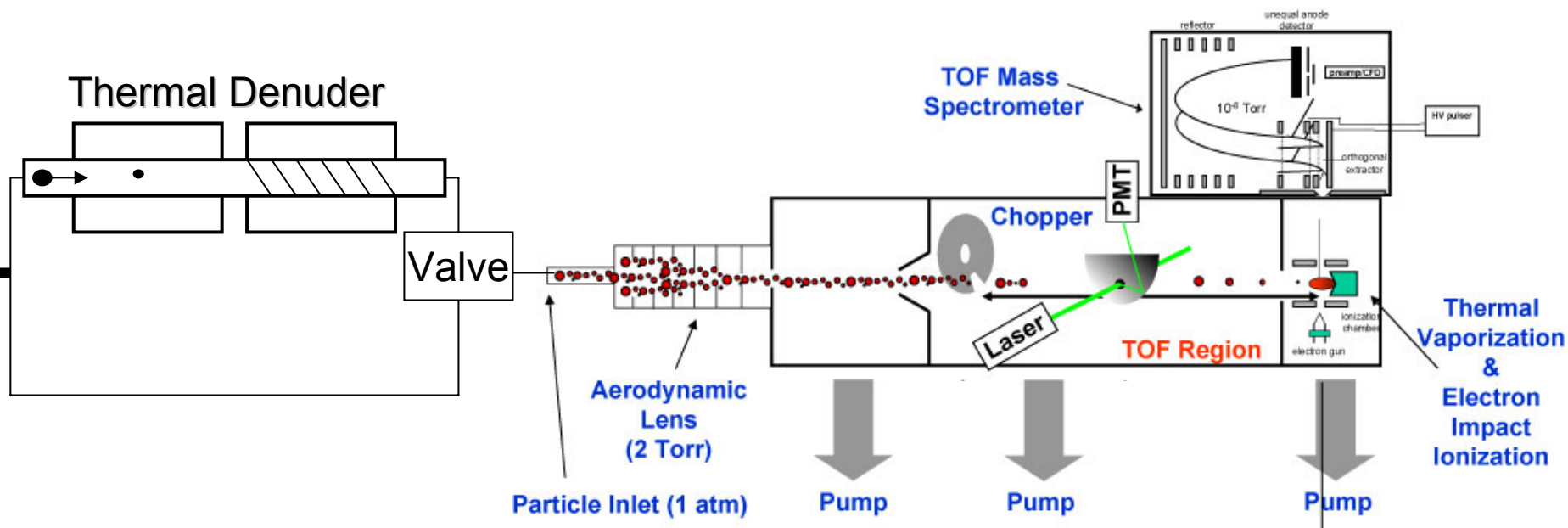


DMA-size



CPC-number

# Instrumental Jigsaw Puzzle

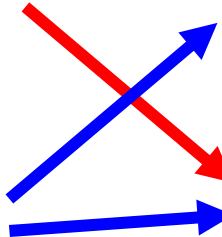


Particles go through the thermal denuder



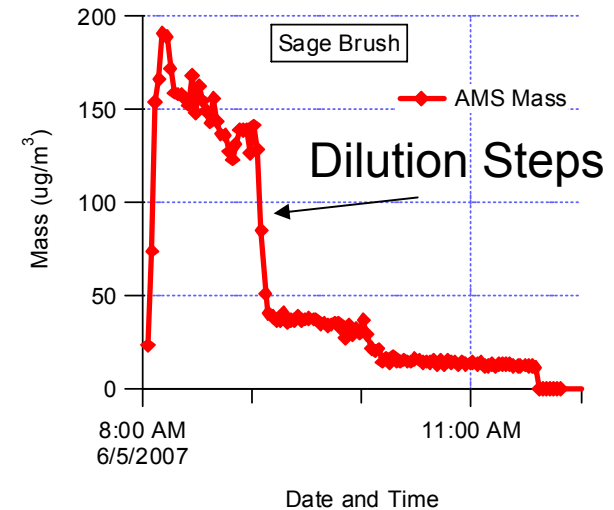
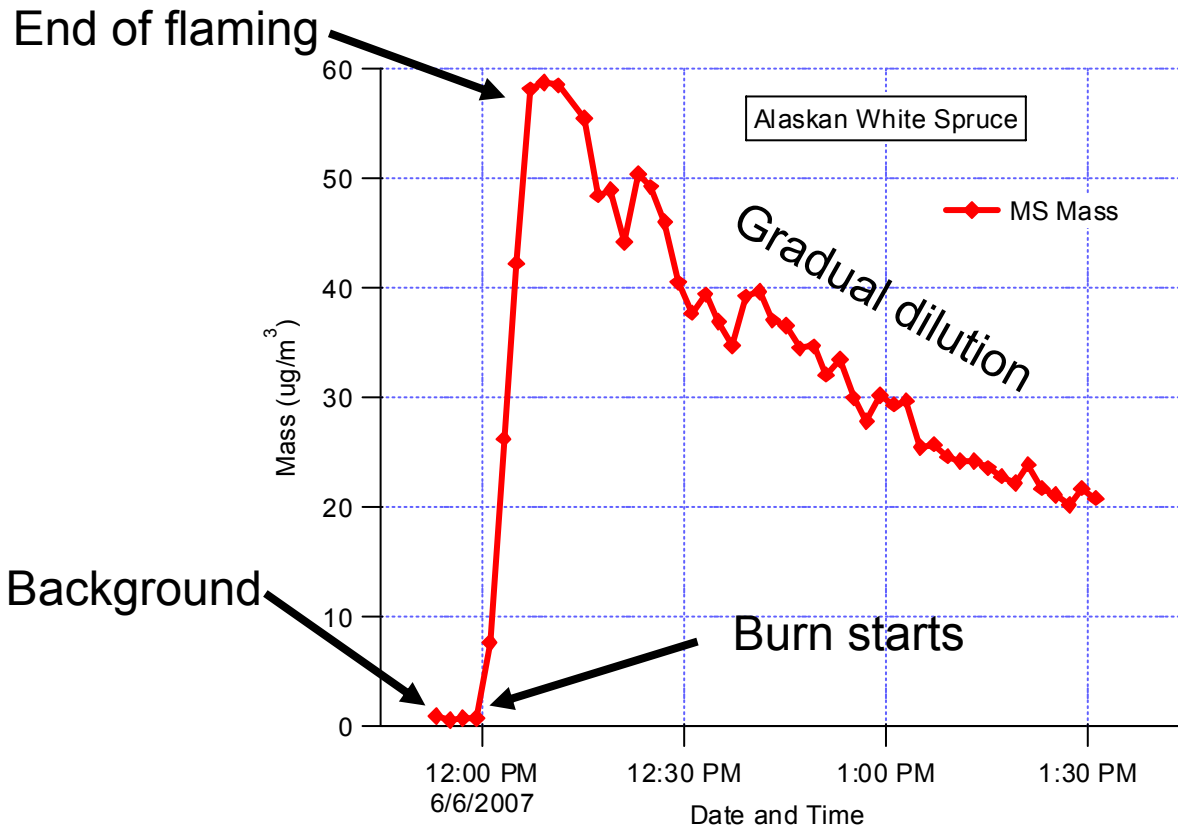
**AMS MS** -chemical composition and mass loading

Particles bypass the thermal denuder



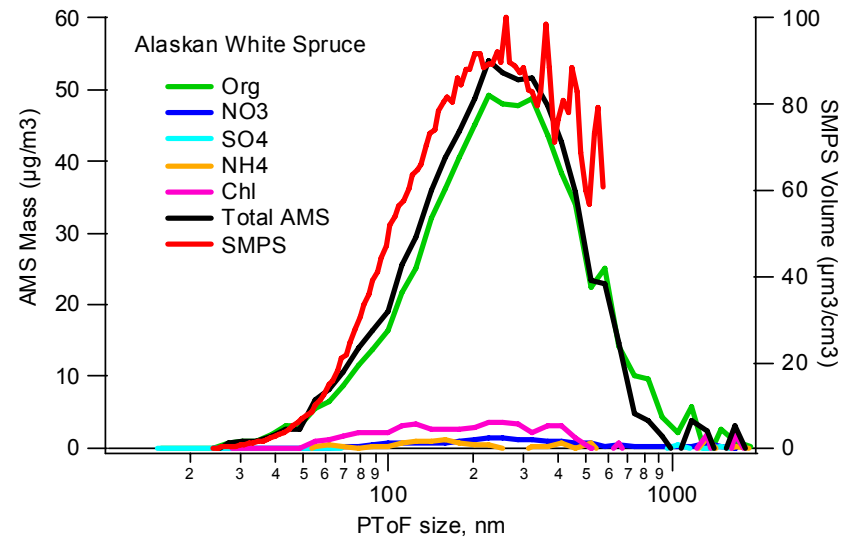
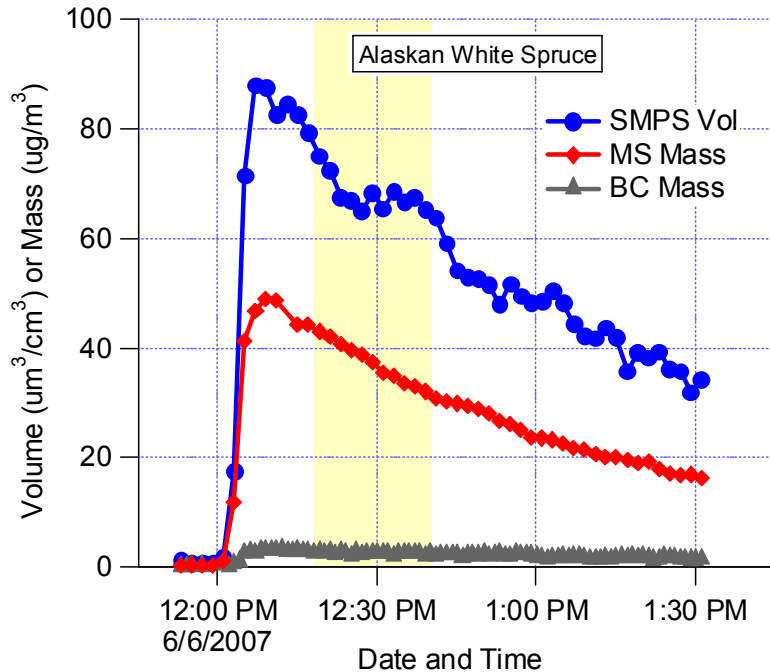
**AMS pToF** -mass distributions by size

# Overview of a Burn



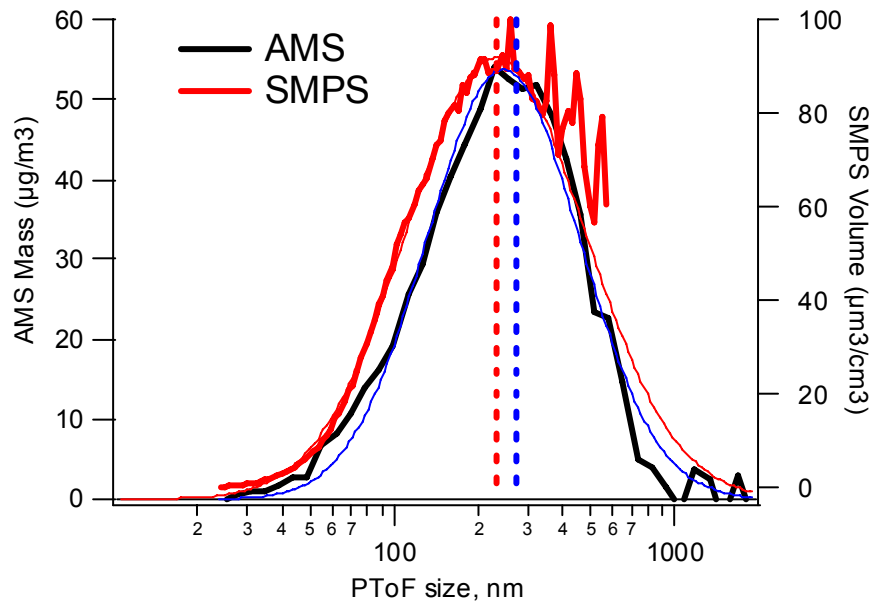
- 50-250g biomass material burned for several minutes
- Experiments ranged in time from 1 ½ hours to overnight
- Biomass aerosol diluted gradually or through multiple large dilution steps

# Size Distributions



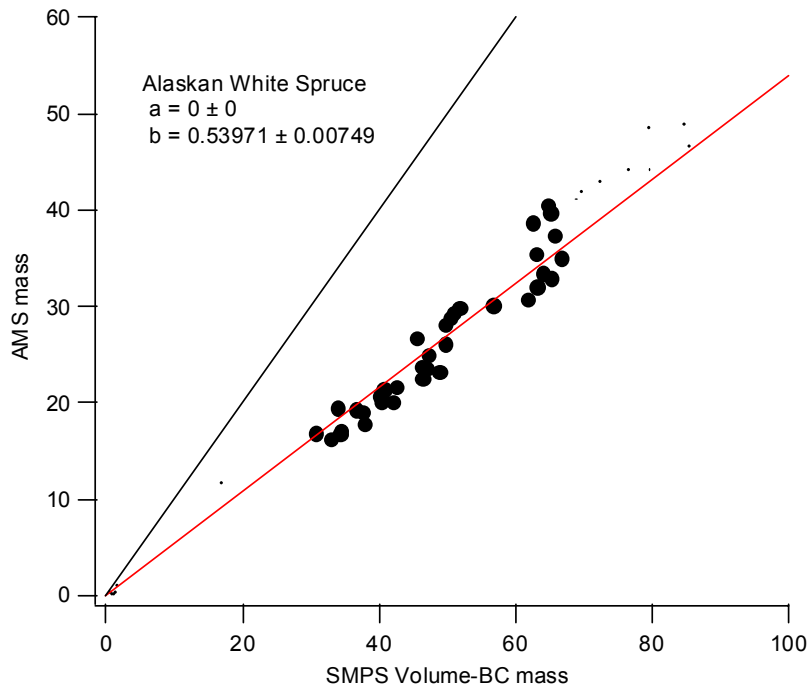
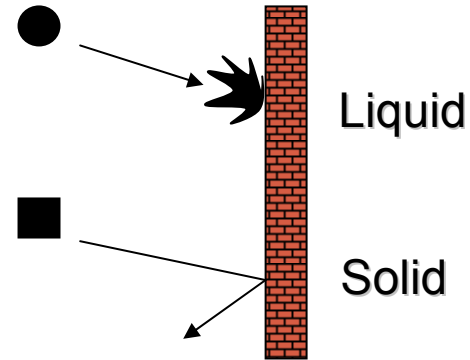
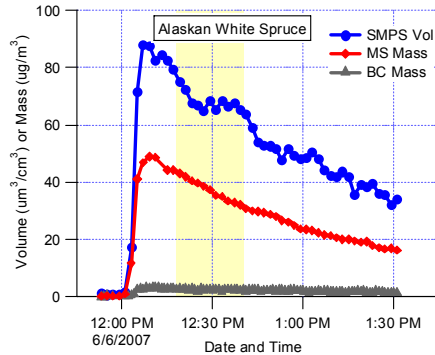
- Black carbon (BC) mass composition low
- Difference in SMPS volume and MS mass due to density?

# Effective Density



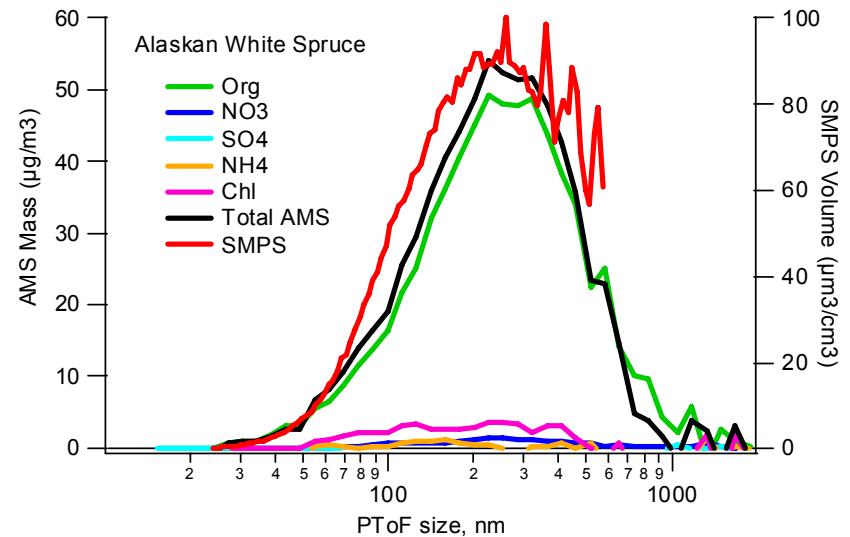
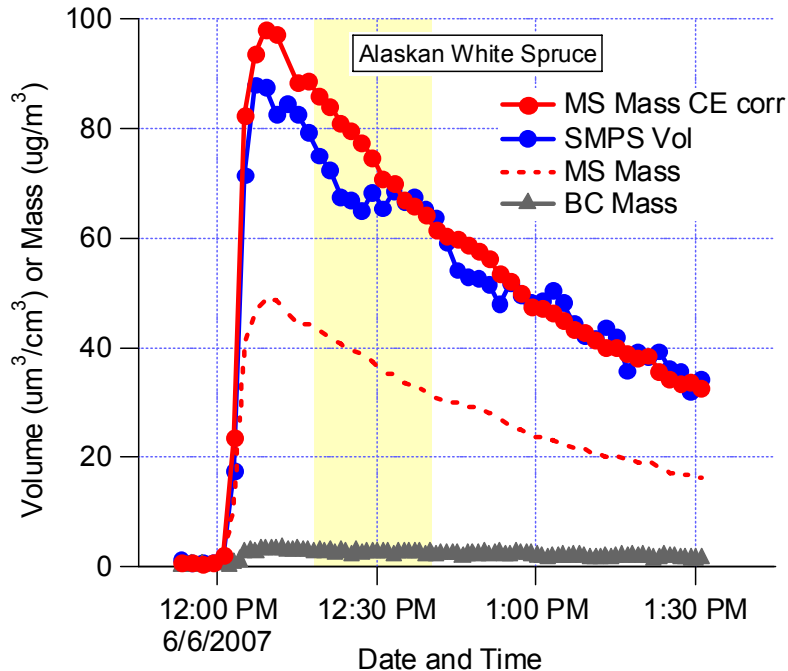
- Effective density depends on particle density and shape
- $\rho_{\text{eff}} = D_{\text{va}}(\text{AMS}) / D_{\text{mob}}(\text{SMPS})$
- Curve fitting to determine effective density
- In this case, effective density approximately 1.1 g/cm<sup>3</sup>

# Collection Efficiencies: The Case of the “Missing Mass”



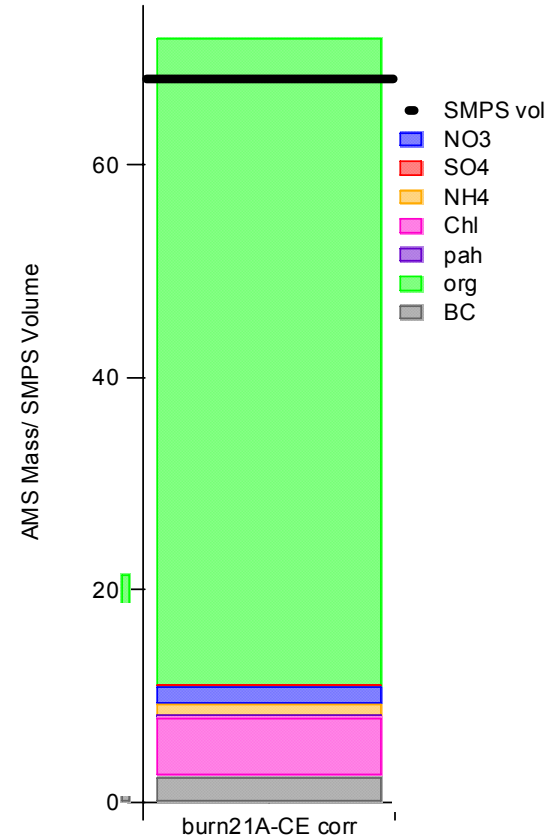
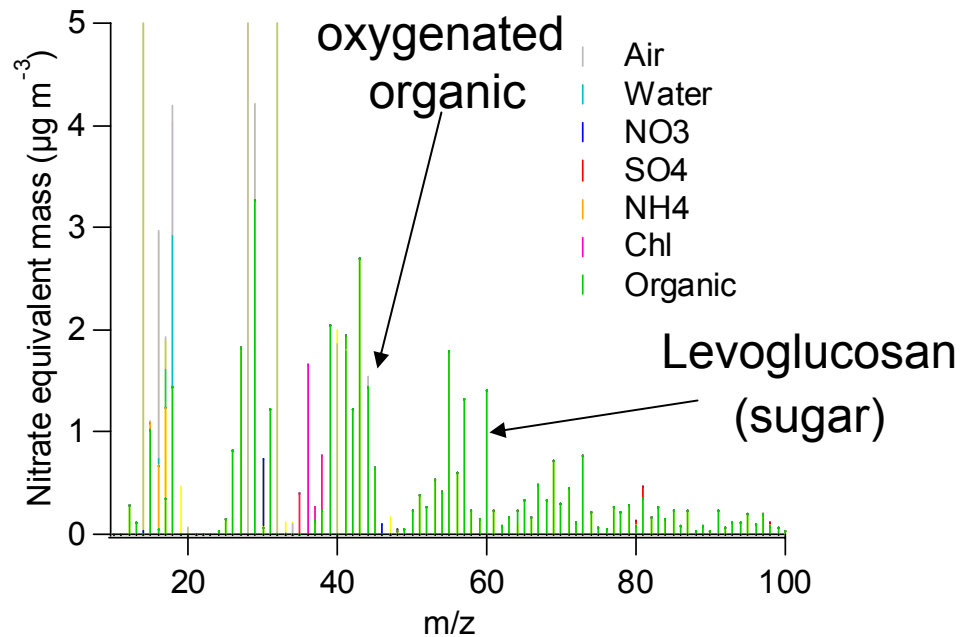
- Collection Efficiency (CE) 54%; reasonable agreement with normal approximation for ambient of 50%
- Suggests particles are solid or mixed solid-liquid phase

# What information do we get from a burn?



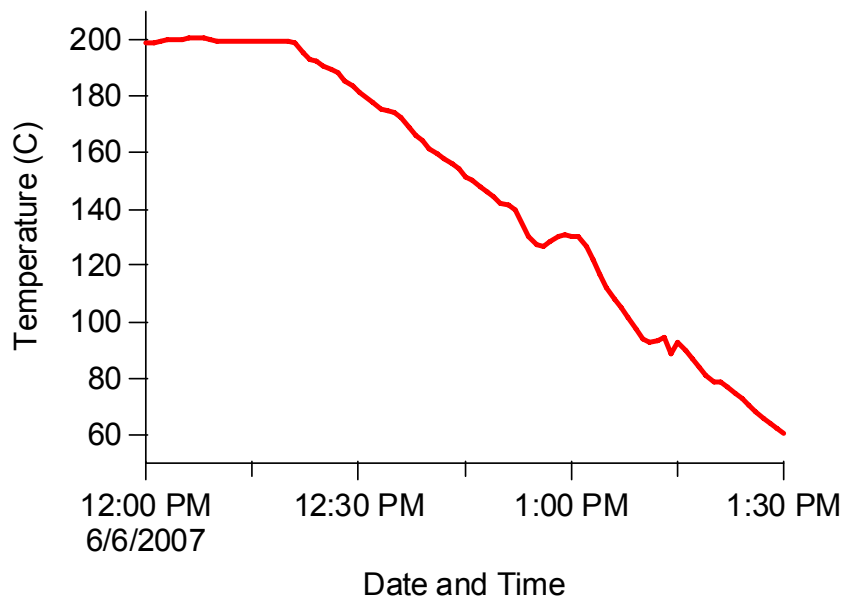
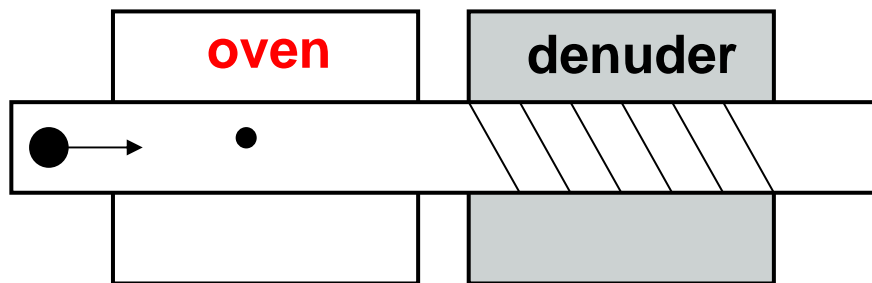
- SMPS volume higher than AMS mass; Collection Efficiency (CE)
- Information on particle phase, size, effective density, **chemical composition, and volatility**

# Chemical Composition



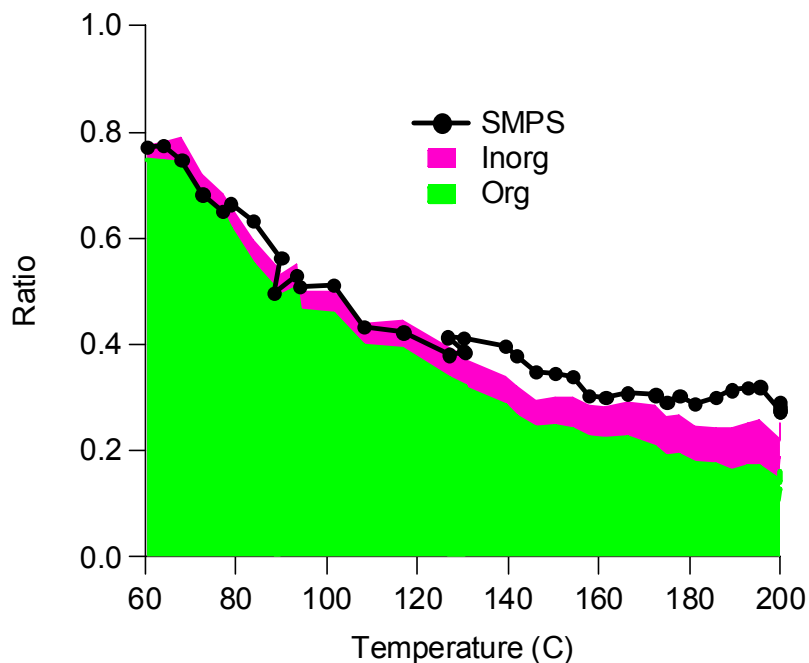
- MS mode: Mass Spectra
- Mostly organic species
- Low black carbon mass for this burn

# Volatility: The Thermal Denuder



- Valve switched between TD and ambient every minute during the burn
- Temperature in TD decreased during the burn
- Only particles not volatilized that make it through the TD

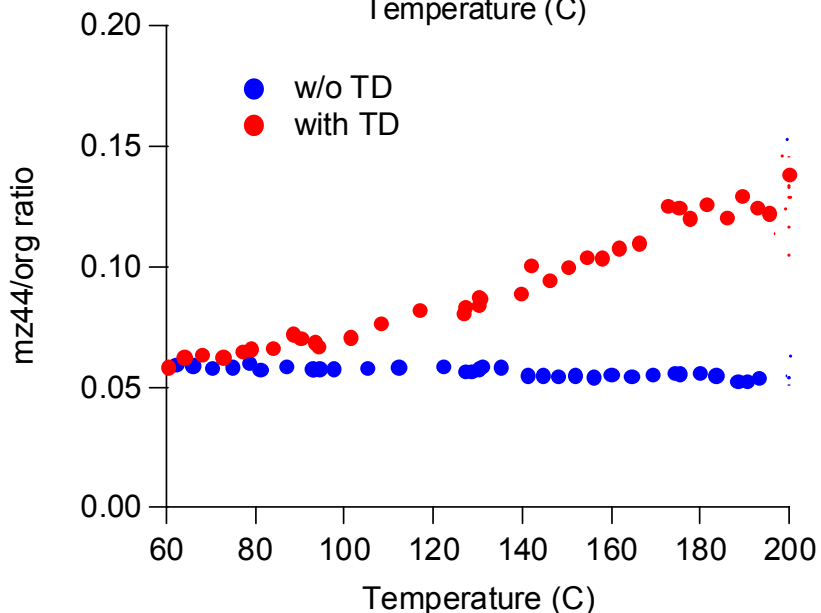
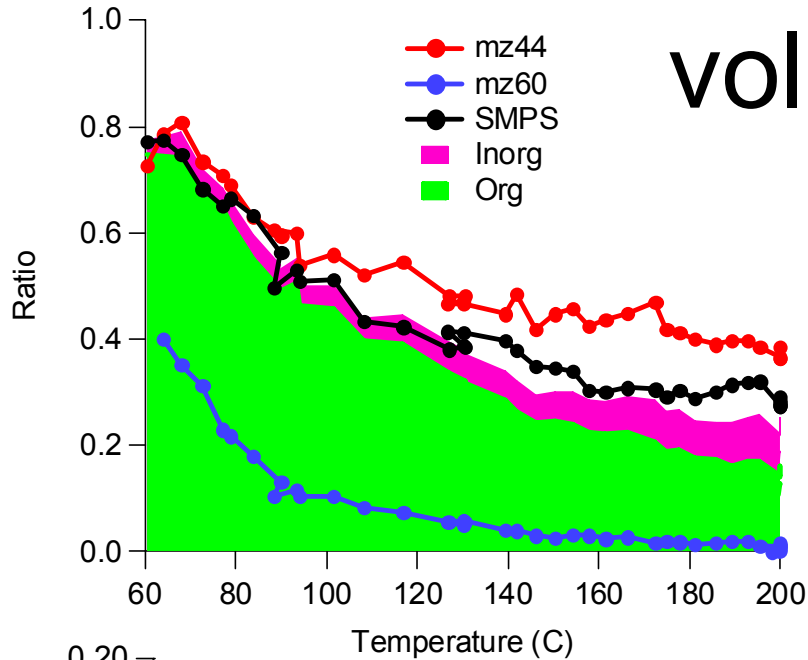
# What does this tell us about volatility?



$$\bullet \text{Ratio} = \frac{\text{Mass coming from TD}}{\text{Mass bypassing TD}}$$

- Decrease in mass ratio with increase in temperature
- Organics more volatile than inorganics
- SMPS ratio shows similar behavior—good agreement with total

# What does this tell us about volatility?



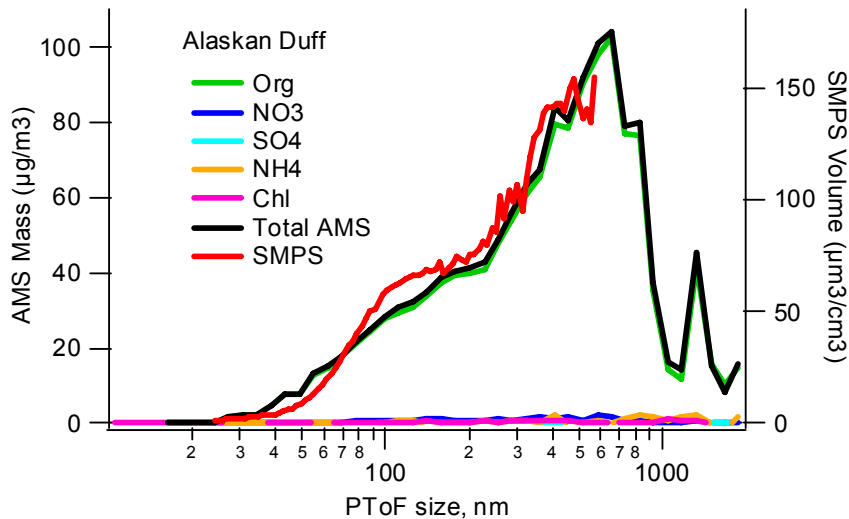
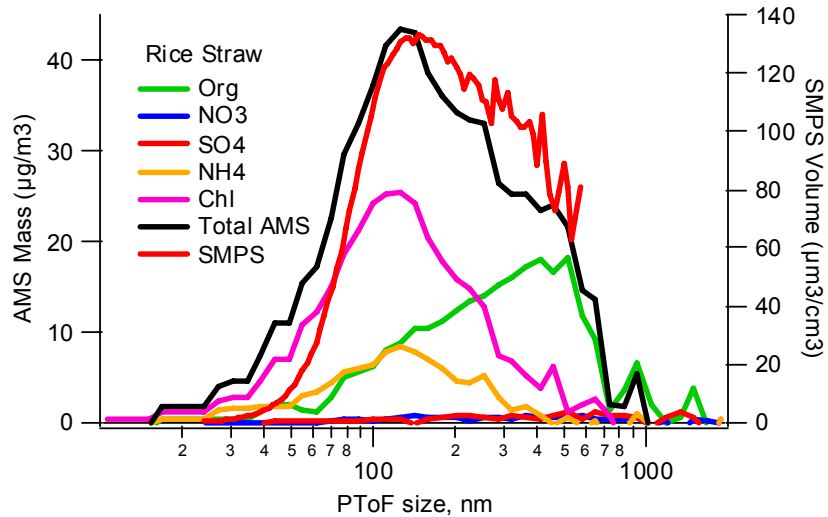
$$\text{Ratio} = \frac{\text{Mass coming from TD}}{\text{Mass bypassing TD}}$$

- mz60(sugars) more volatile than total organic which is more volatile than mz44(oxygenated organics)
- Ratio mz44/org increases with temperature as the more volatile components of org vaporize

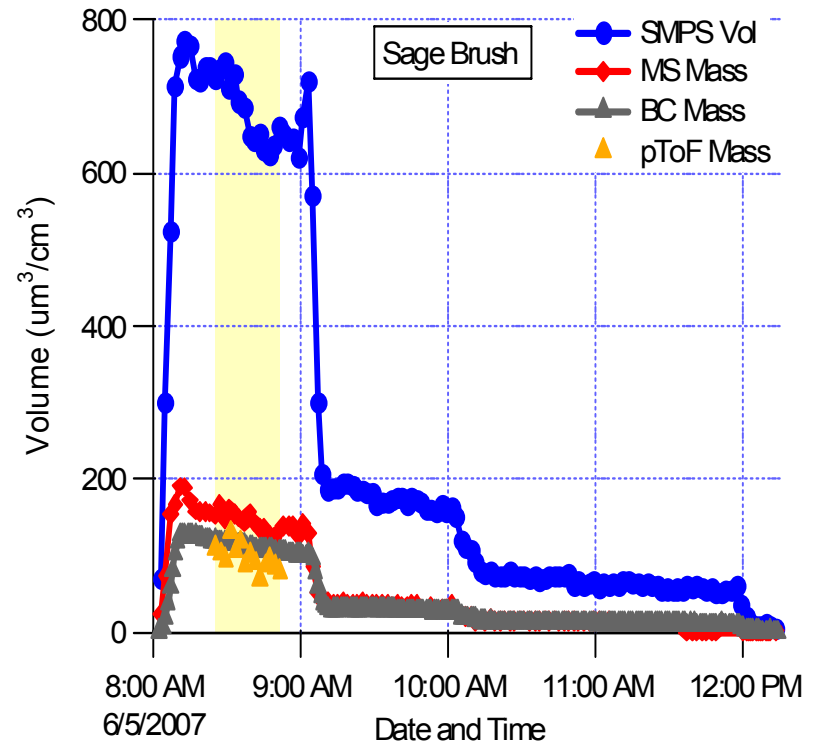
# Conclusions/Summary

- Biomass burning particles emitted from Alaskan White Spruce:
  - One mode mass distribution peaking ~250 nm
  - Effective density of ~1.1 g/cm<sup>3</sup>
  - Low fraction of black carbon mass
  - Dominated by organic hydrocarbon-like particles
  - Solid or mixed phase particles
  - Oxidized organic fraction less volatile than total organics – implying O/C ratio increases with thermal denuder temperatures
  - Sugar marker (m/z 60) more volatile than total organics
- We still have a lot to study!

# The Future



## Fuel, flame condition, dilution



# Acknowledgements

Jesse Kroll, Tim Onasch, Achim Trimborn, Leah Williams, Doug Worsnop, CACC Group  
*Aerodyne Research, Inc.*

Jeff Collett, Sonia Kreidenweis, Taehyoung Lee, Ezra Levin, Gavin McMeeking  
*Colorado State University*

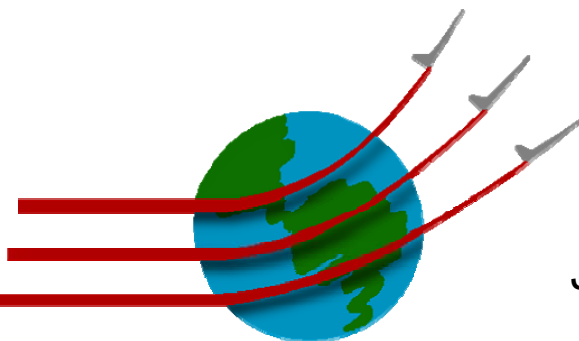
Alex Huffman, Jose-Luis Jimenez, Claudia Mohr  
*University of Colorado at Boulder*

Patrick Arnott  
*Desert Research Institute*

Wei-Min Hao, Cyle Wold  
*Fire Science Lab*

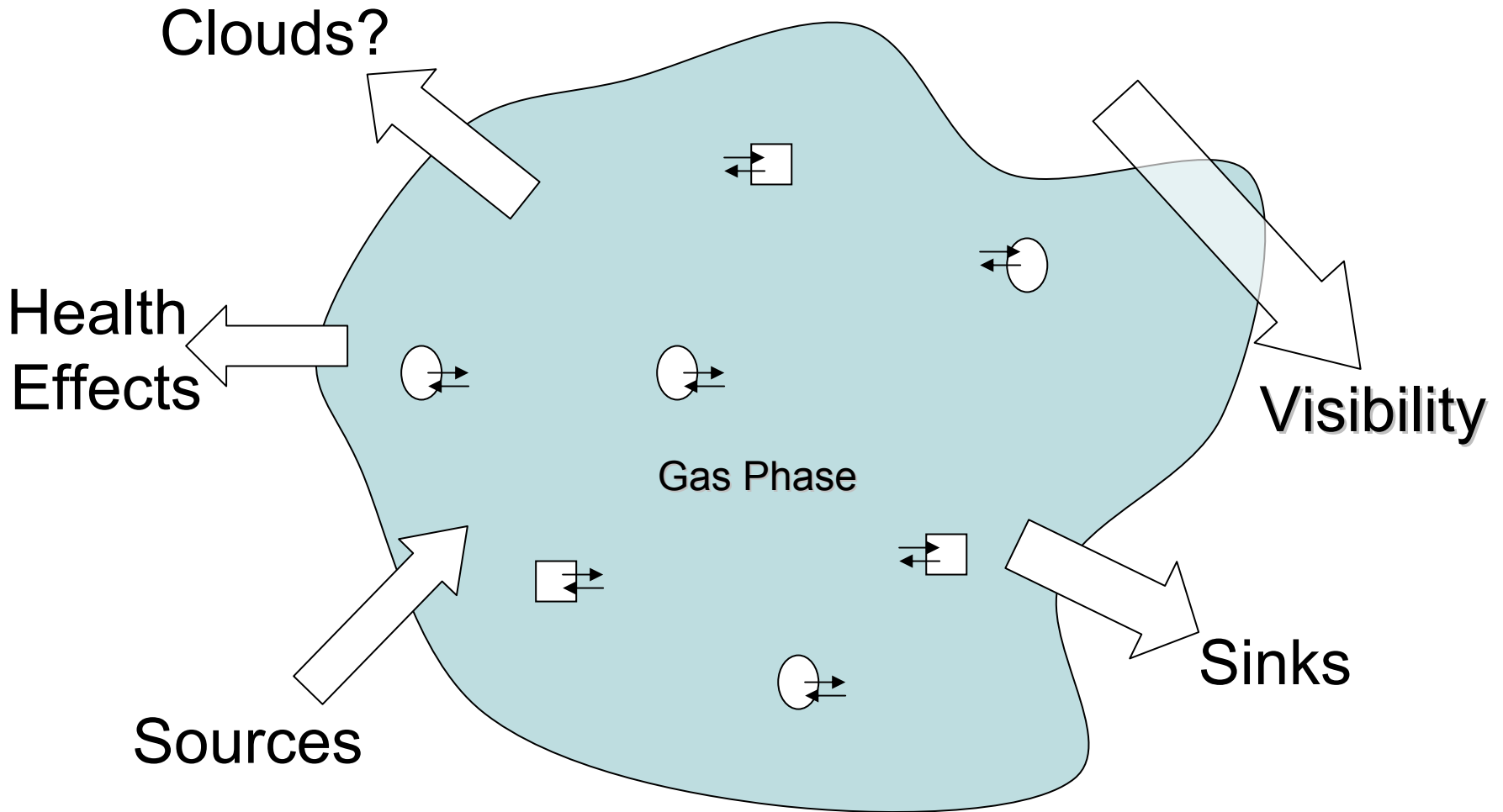
EVERYONE AT FLAME-2!

Jeff Gaffney and Milton Constantin  
*DOE OBER GCEP SURE Program*



Extra Slides

# Aerosol: A Definition



Solid and liquid particles in suspension with the gas phase

# Ambient aerosols are *complicated*: size, shape, and composition

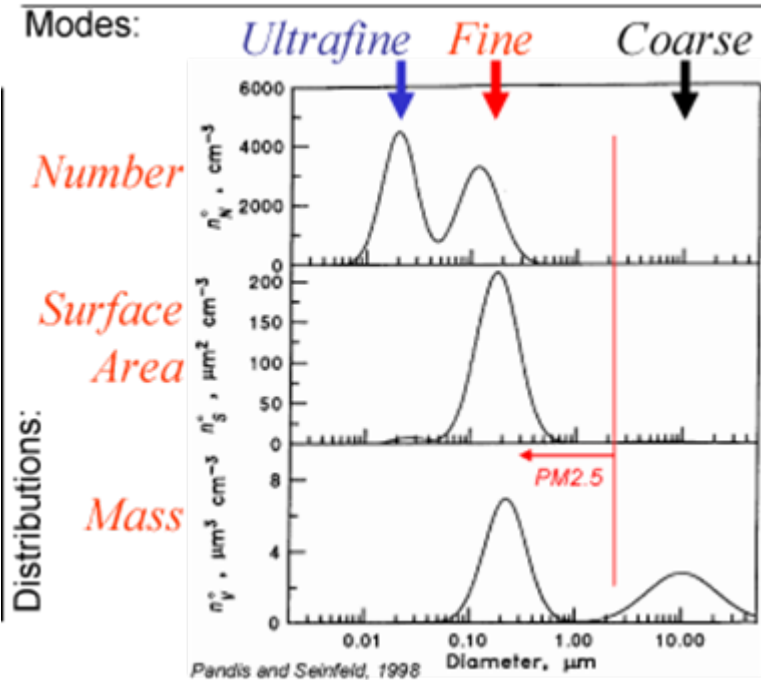
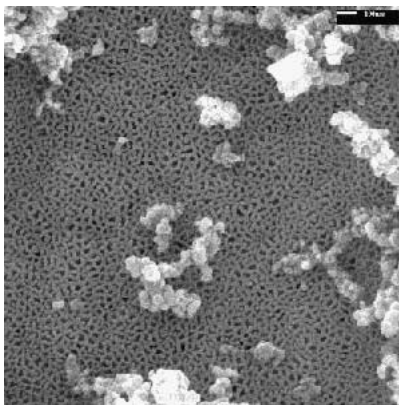
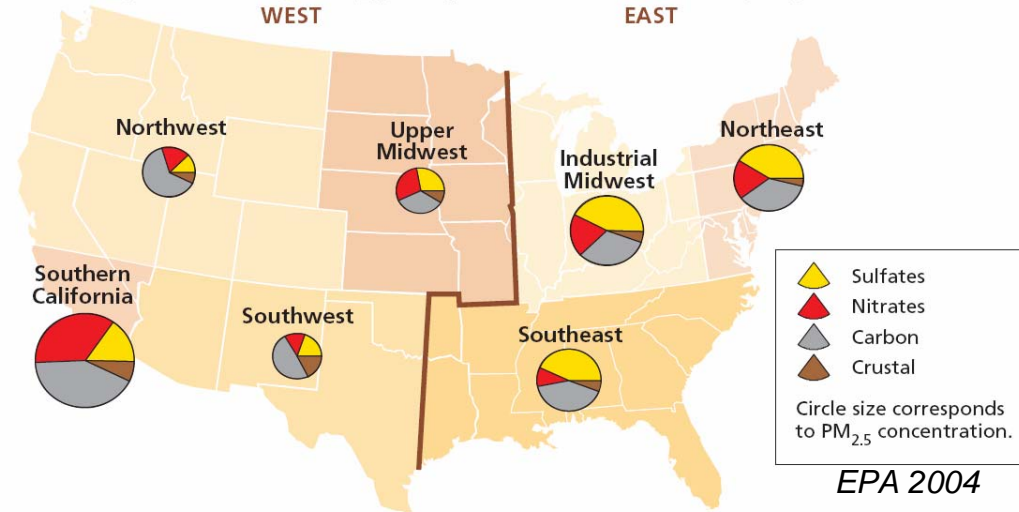
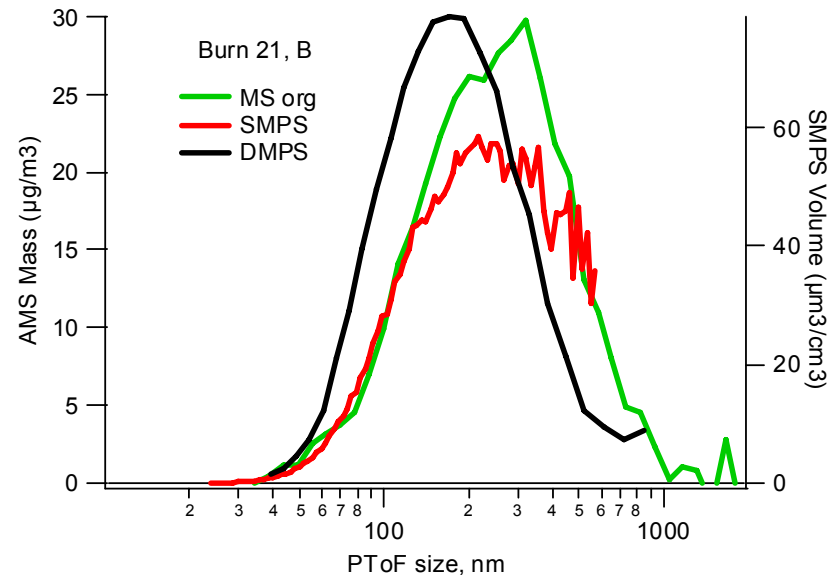
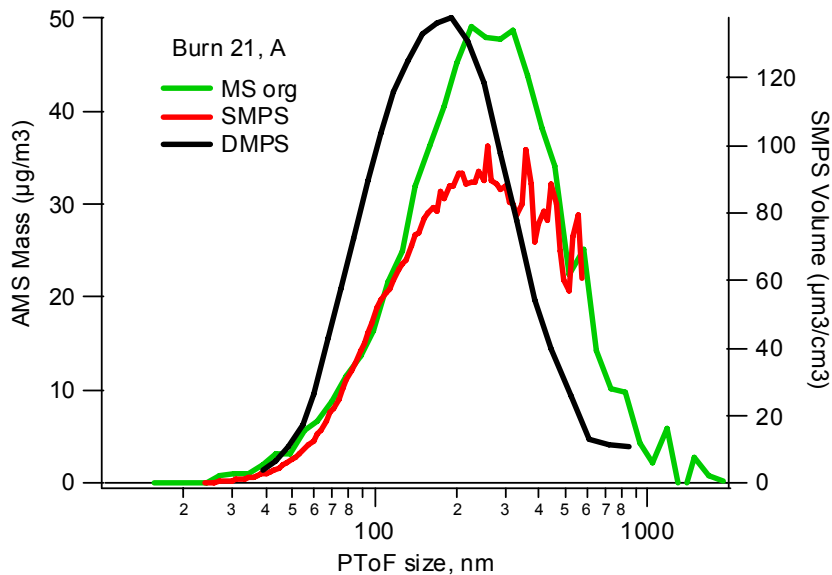


Figure 2. Average  $\text{PM}_{2.5}$  composition in urban areas by region, 2003.



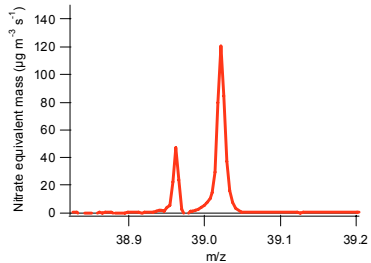
*Goal: Size-Resolved Chemical  
Composition of Ambient Aerosol*

# Comparison with CSU DMPS

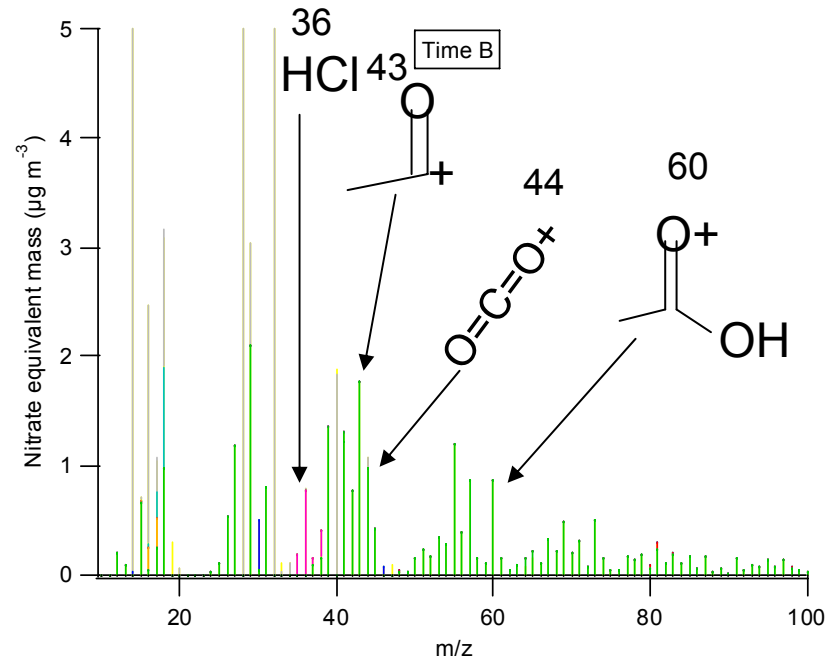
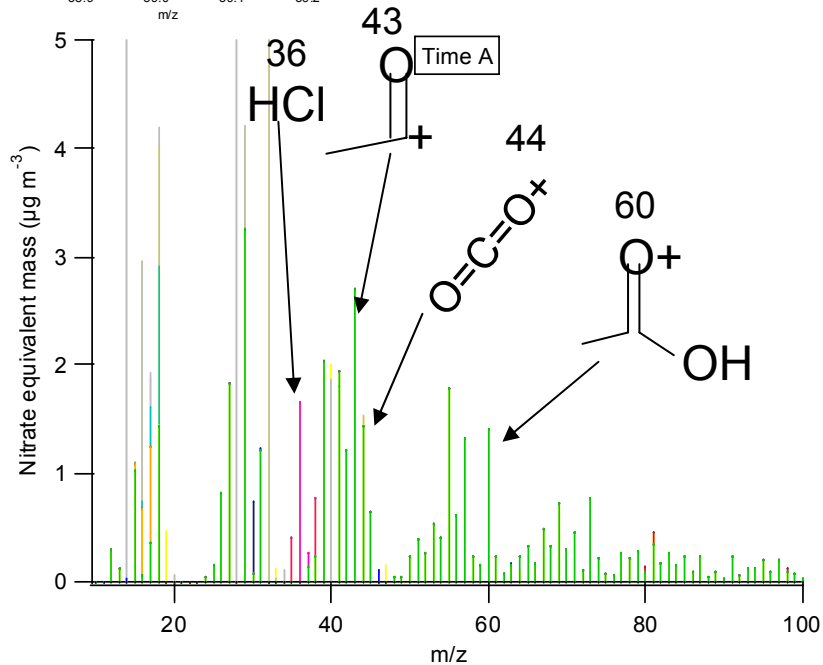


- CSU DMPS and SMPS do not agree very well in mode diameters or mode volume loadings, but do agree in monomodal characteristics
- Assume that DMPS and SMPS do not agree due to different locations in sampling line.
- Use SMPS and AMS for comparisons here

K~25% m/z39

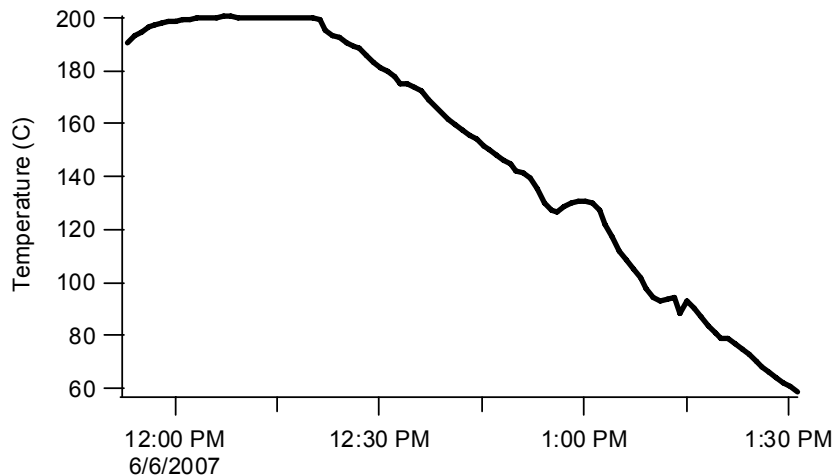


# Mass Spectra



- Mass spectra show composition relationships (e.g. chloride to organic ratios)
- Organics have oxygens associated, however, dominated by 43 and not 44 implying relatively hydrocarbon-like
- m/z 60 is strong for this burn, likely from cellulose breakdown into sugars such as levoglucosan
- Potassium is ~25% of m/z 39 signal

# Volatility: The Thermal Denuder



- Valve switched between TD and ambient every minute during the burn
- Temperature in TD decreased during the burn
- Only particles not volatized that make it through the TD
- Decrease in mass loadings from dilution for particles not going through the TD (with time)
- Increase in mass loadings from decrease in temperature for particles going through the TD (with time)

