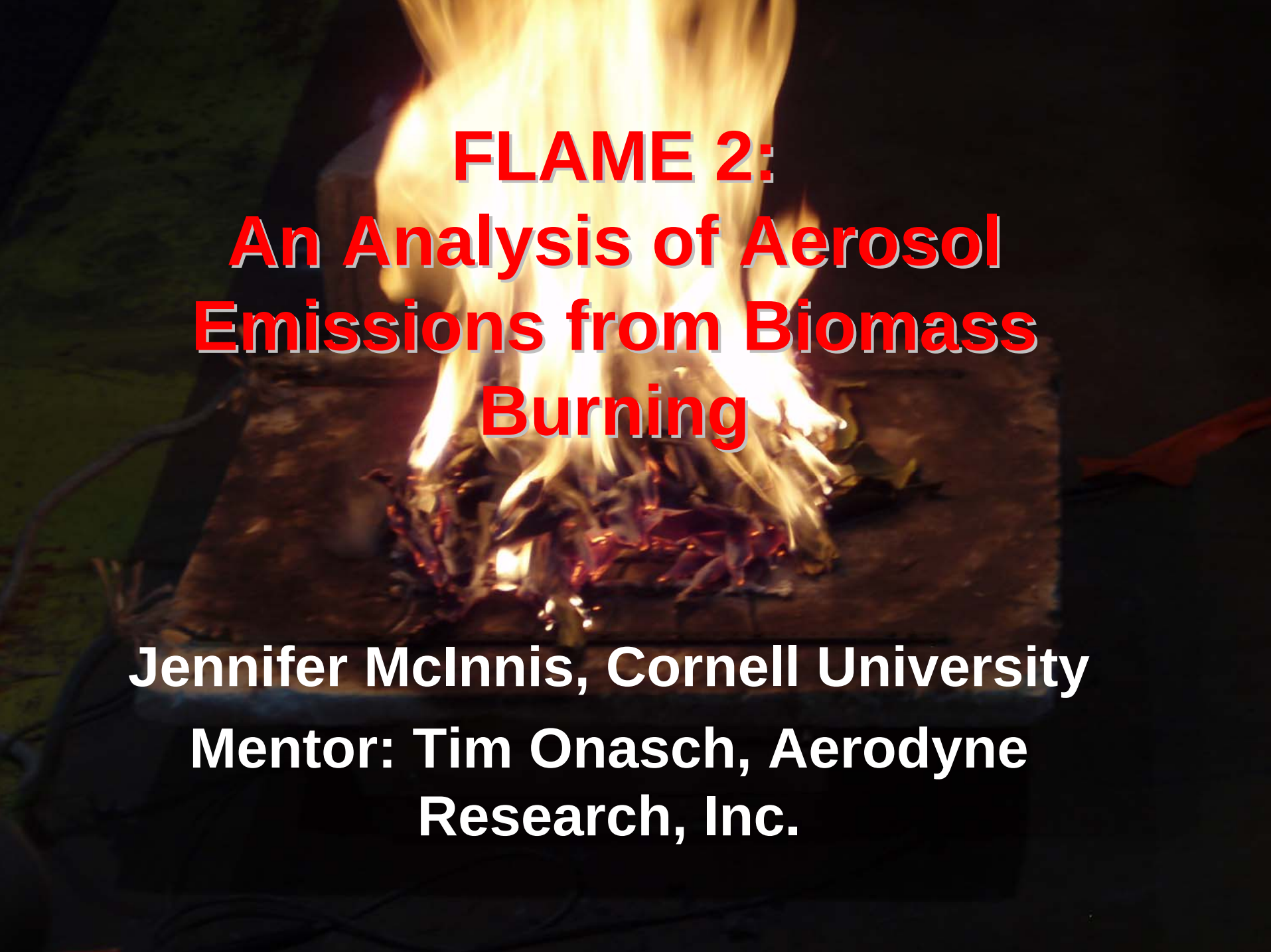


FLAME 2: An Analysis of Aerosol Emissions from Biomass Burning

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

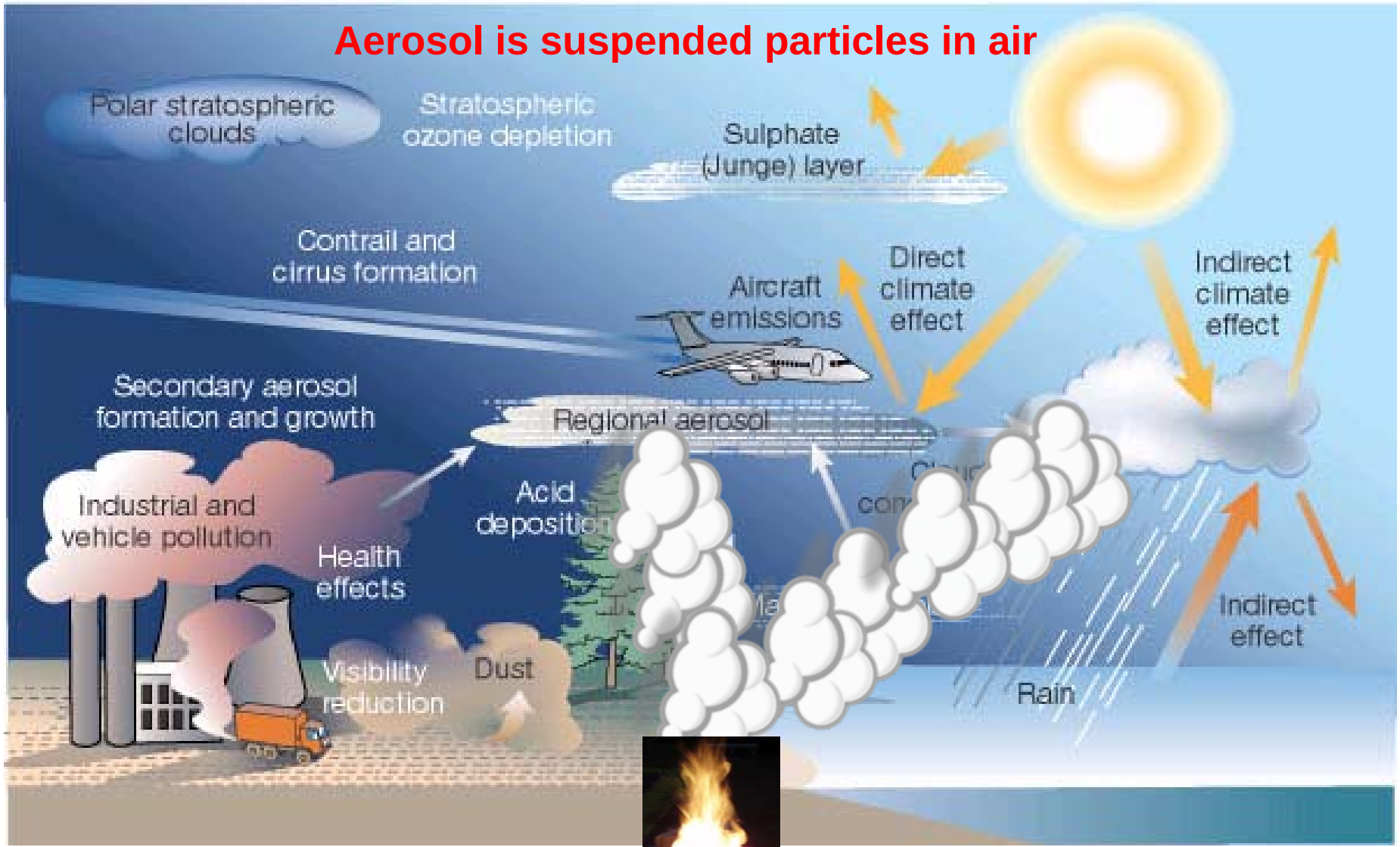
- Natural and anthropogenic causes
- Releases “stored” carbon into the atmosphere
  - greenhouse gases and particulate matter
- Global radiation budget
- National ambient air quality standards and visibility
- Still large uncertainty/ source of error in models
  - Flaming/smoldering
  - Dilution effects

http://newsdesk.si.edu/photos/sites_earth_from_space.htm

flaming

smoldering

Aerosols in the Atmosphere



C.E. Kolb, **Nature,** 597-598, 6 Jun 2002

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

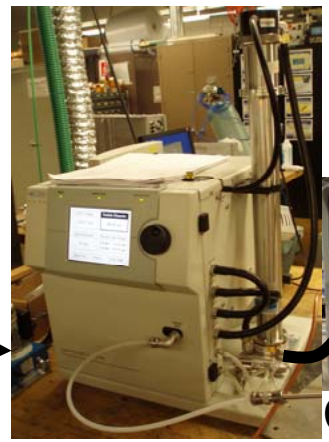
To other particle and gas instrumentation

Thermal Denuder (TD)-volatility

Valve

SMPS
number and volume distributions by size

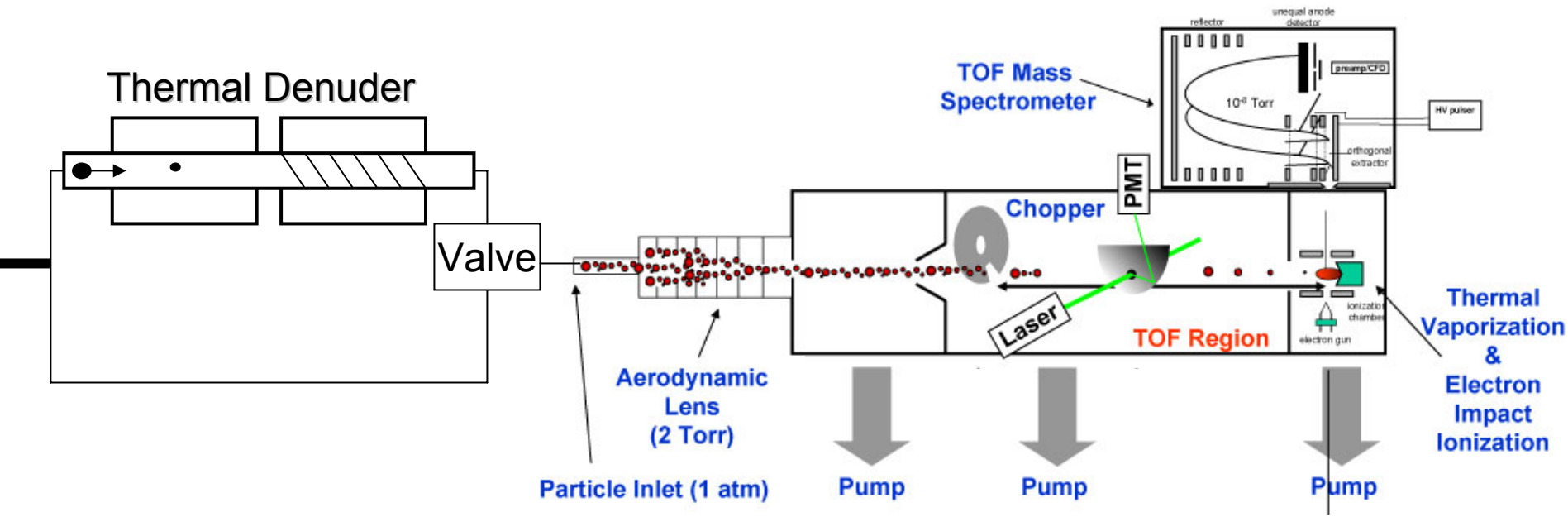
Aerosol Mass Spectrometer (AMS)
Size, effective density, chemical composition



CPC-number

DMA-size

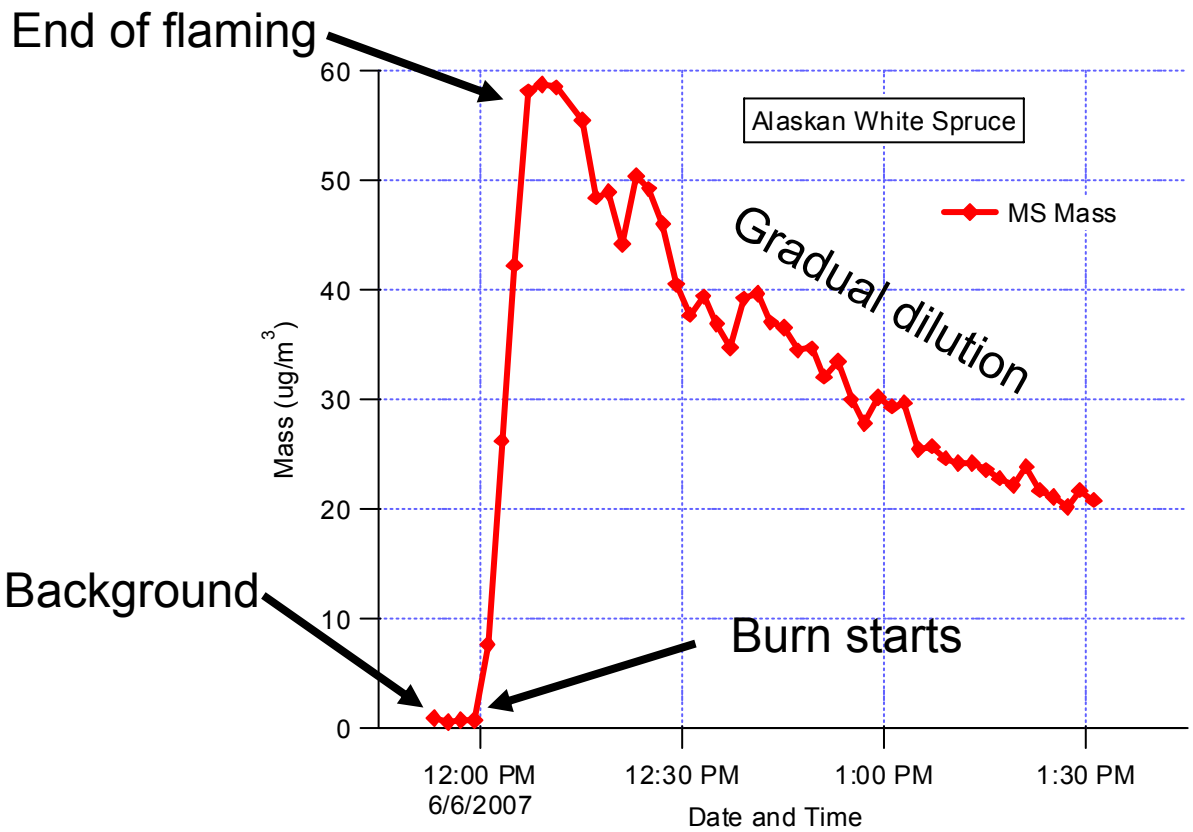
Instrumental Jigsaw Puzzle

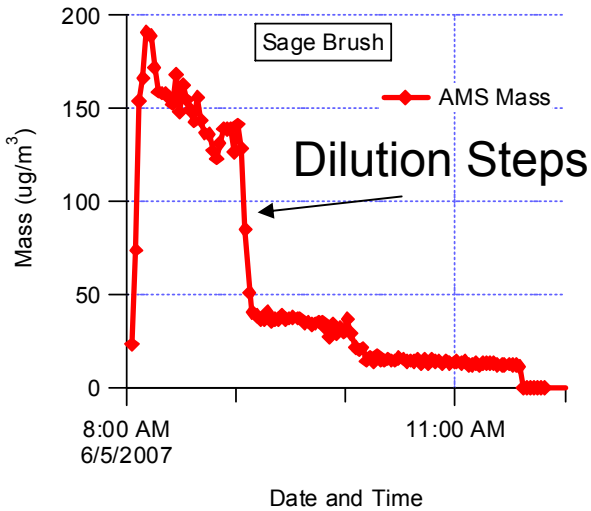


Particles go through the thermal denuder → **AMS MS** -chemical composition and mass loading

Particles bypass the thermal denuder → **AMS pToF** -mass distributions by size

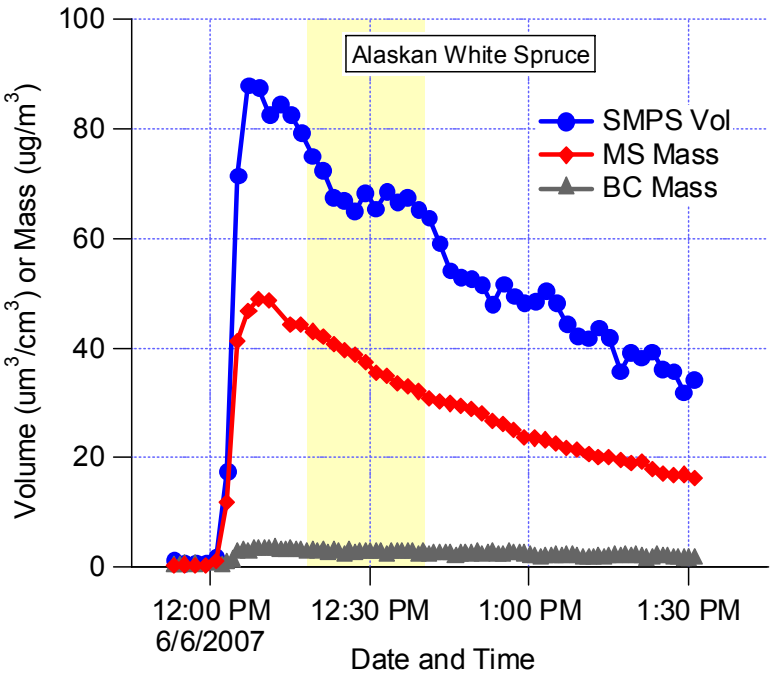
Overview of a Burn

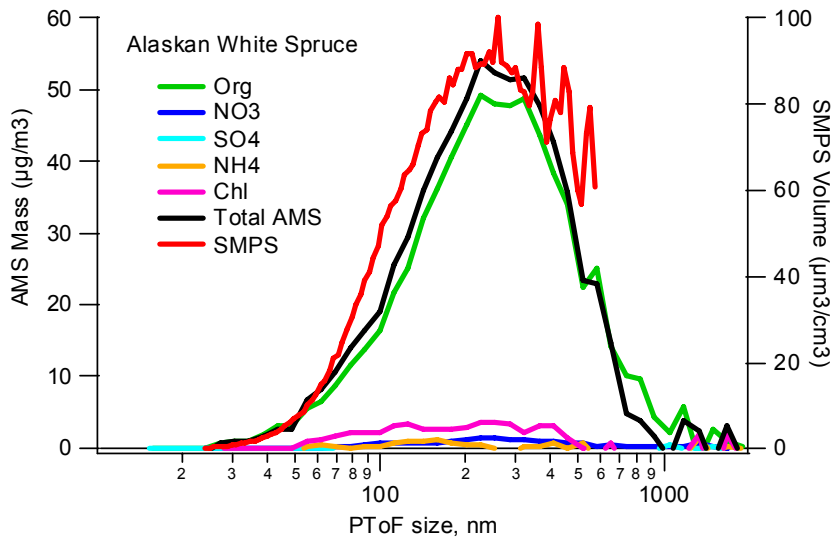




- 50-250g biomass material burned for several minutes
- Experiments ranged in time from 1 ½ hours to overnight
- Biomass aerosol diluted gradually or through multiple large dilution steps

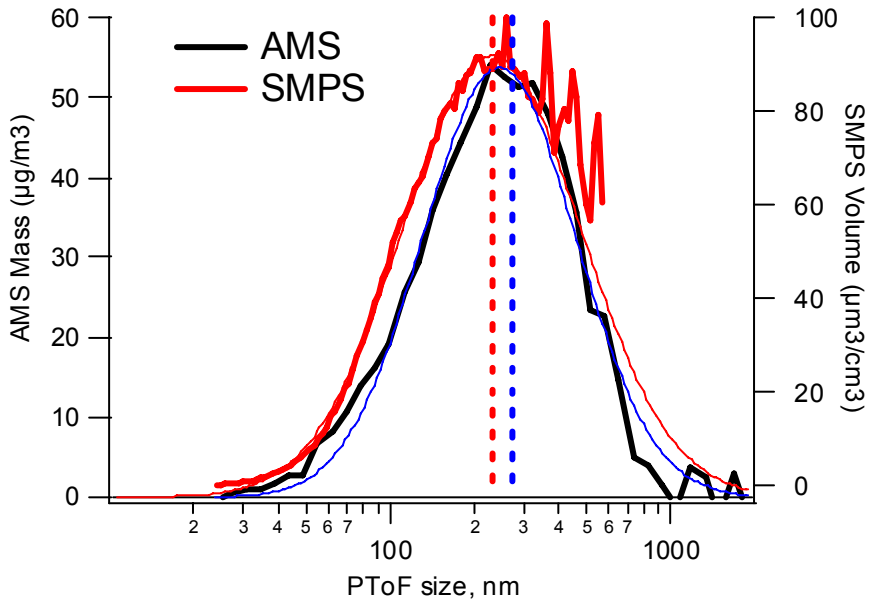
Size Distributions





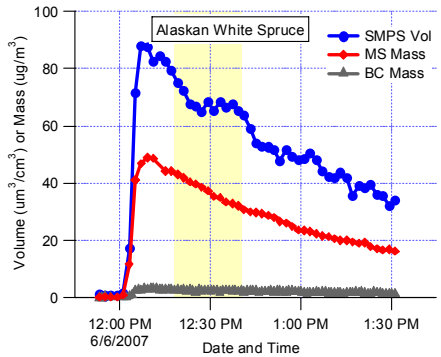
- Black carbon (BC) mass composition low
- Difference in SMPS volume and MS mass due to density?

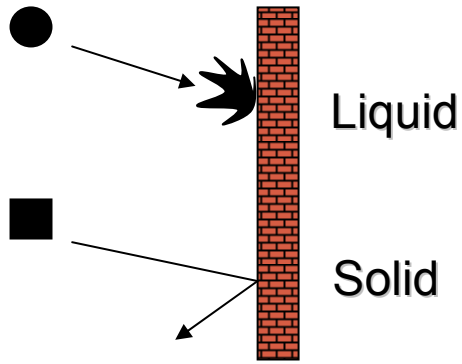
Effective Density

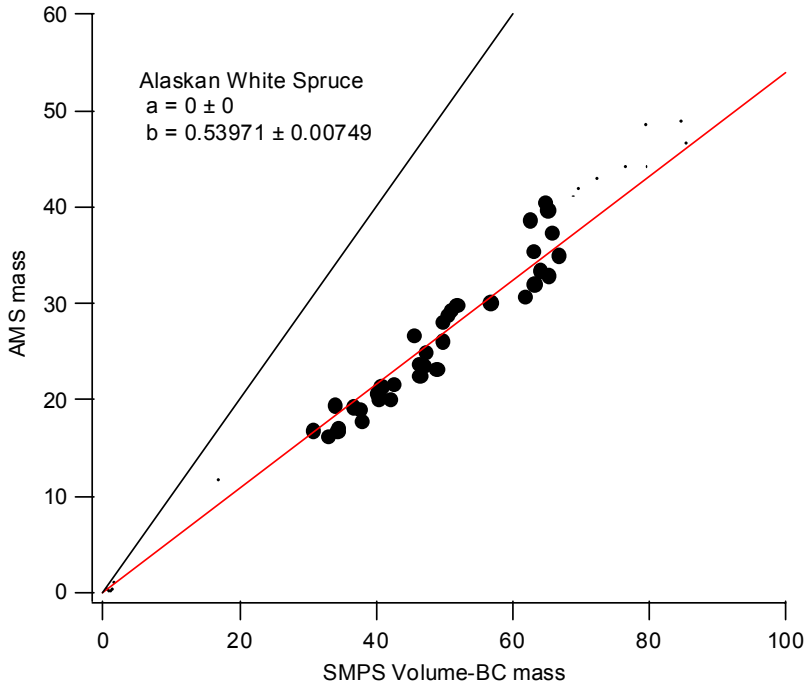


- Effective density depends on particle density and shape
- peff=Dva(AMS)/Dmob(SMPS)
- Curve fitting to determine effective density
- In this case, effective density approximately 1.1 g/cm3

Collection Efficiencies: The Case of the "Missing Mass"

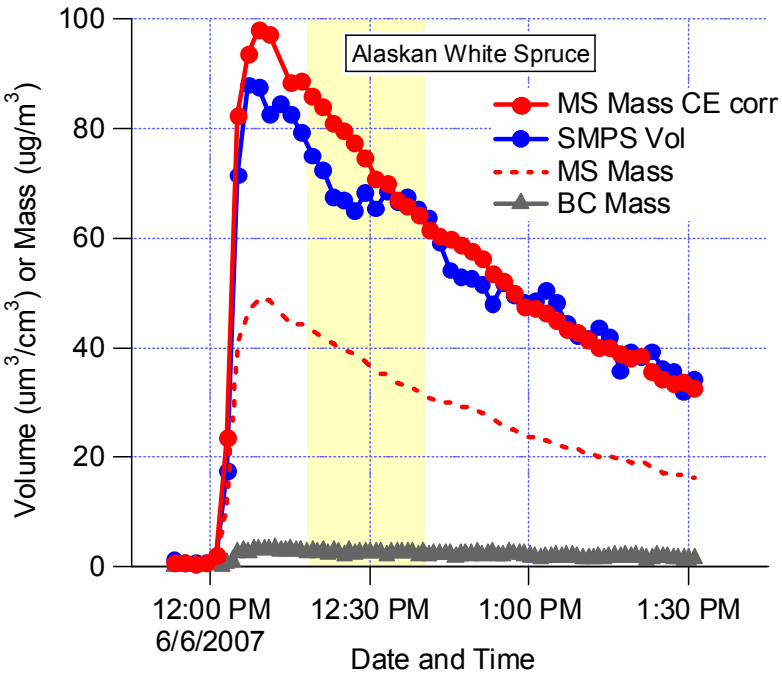


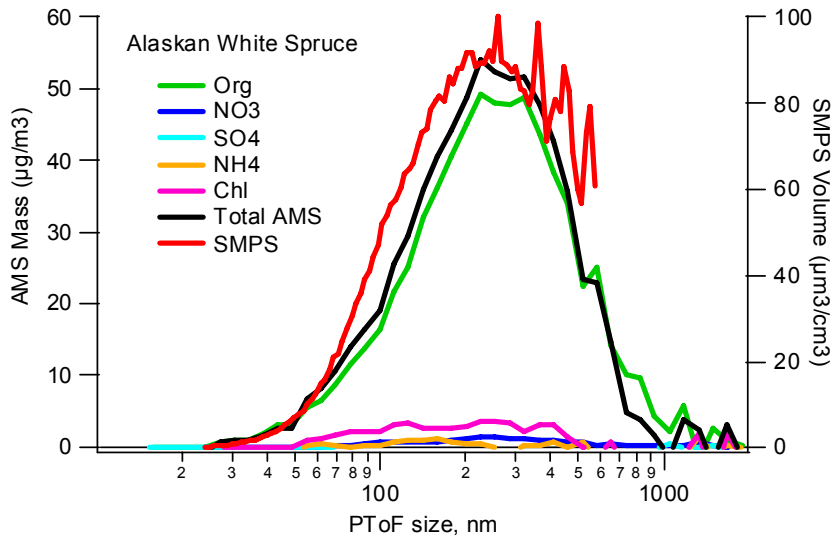




- Collection Efficiency (CE) 54%; reasonable agreement with normal approximation for ambient of 50%
- Suggests particles are solid or mixed solid-liquid phase

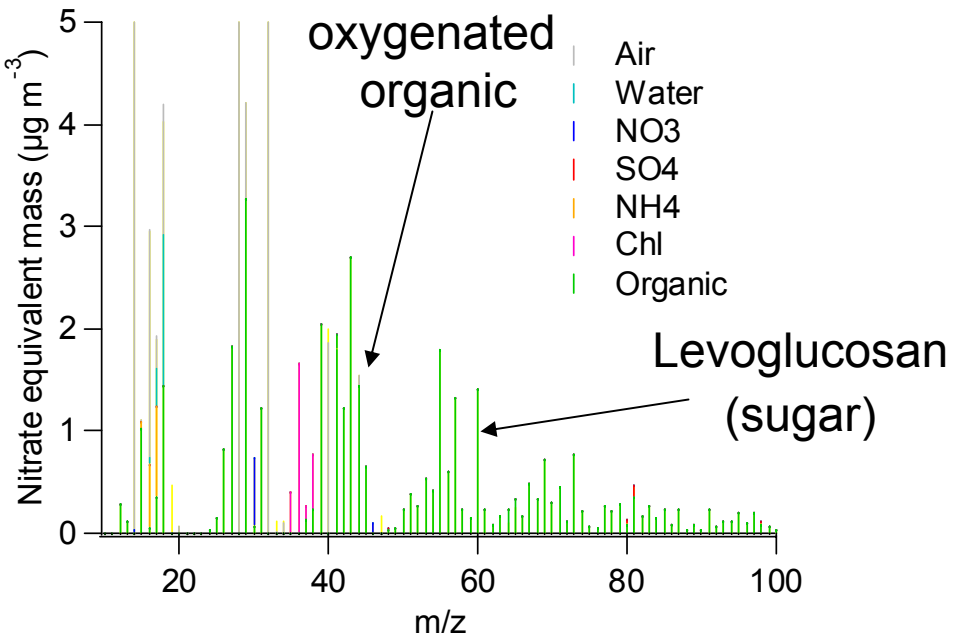
What information do we get from a burn?

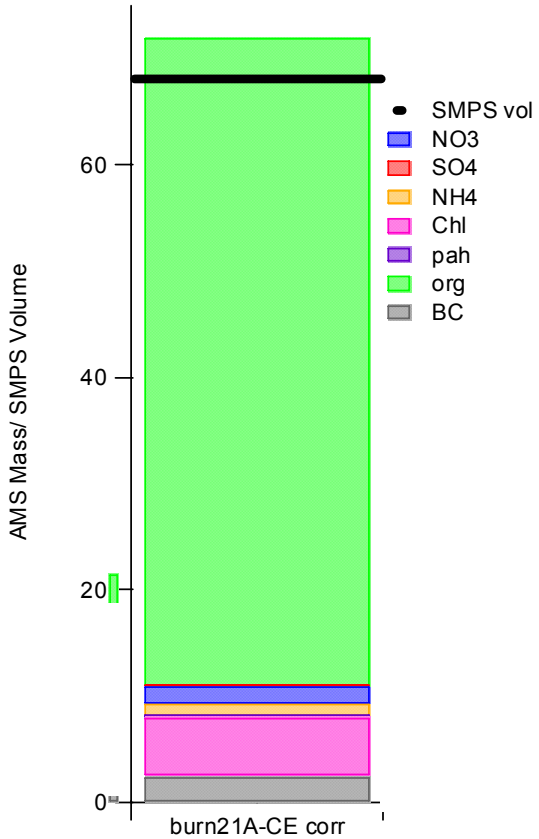




- SMPS volume higher than AMS mass; Collection Efficiency (CE)
- Information on particle phase, size, effective density, chemical composition, and volatility

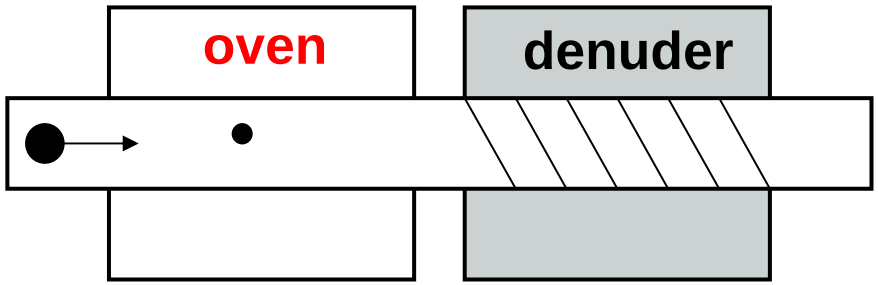
Chemical Composition

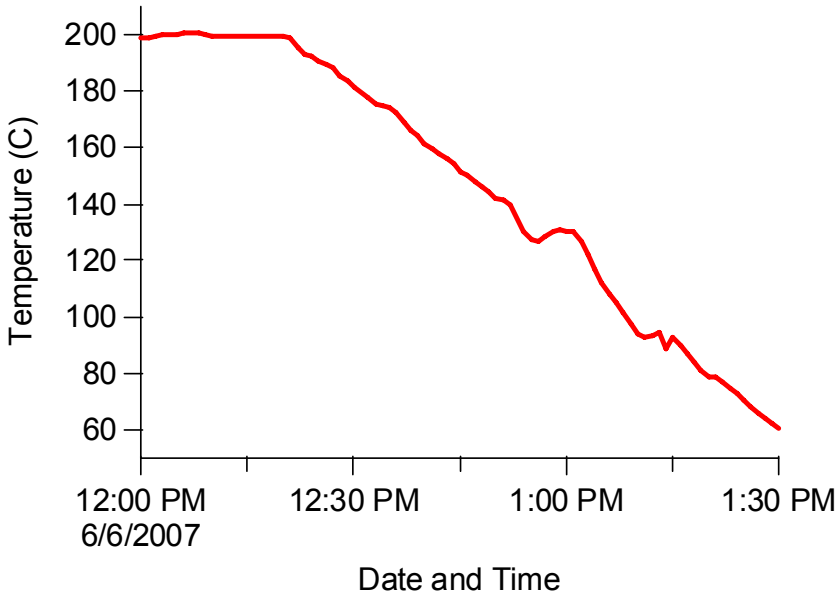




- MS mode: Mass Spectra
- Mostly organic species
- Low black carbon mass for this burn

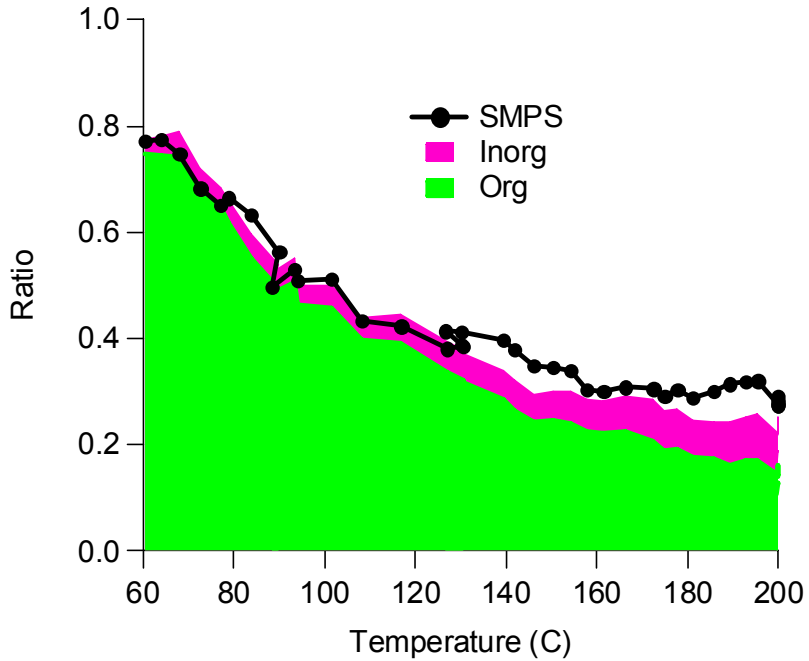
Volatility: The Thermal Denuder





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

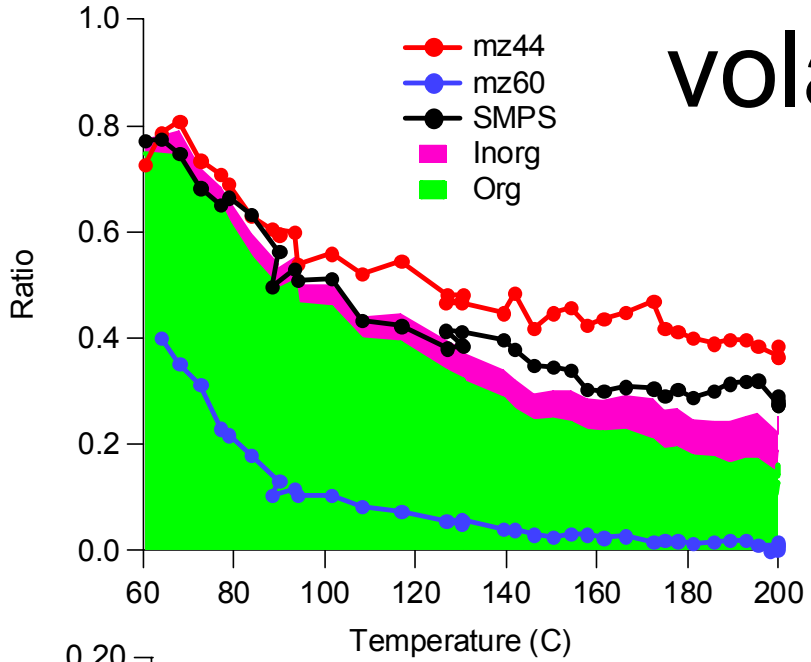
What does this tell us about volatility?

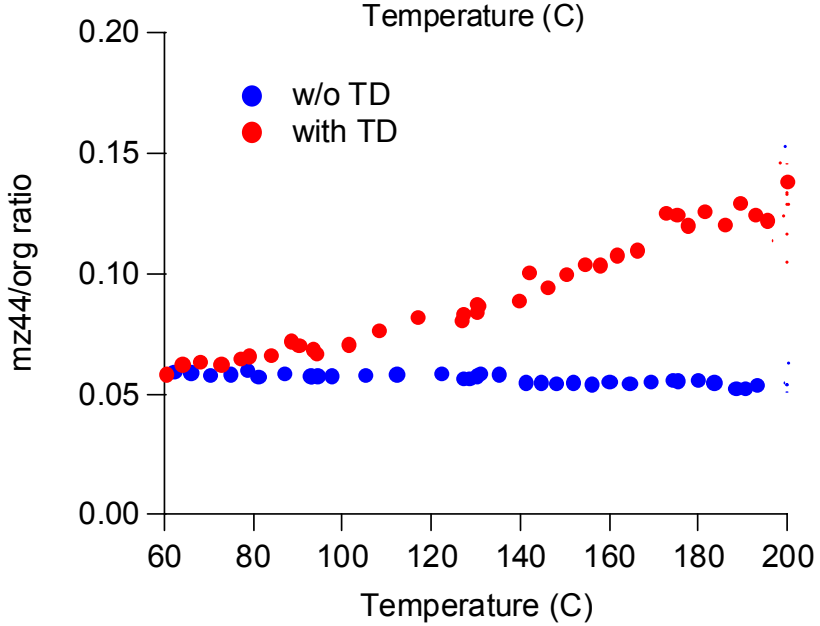


- Ratio = $\frac{\text{Mass coming from TD}}{\text{Mass bypassing TD}}$

- 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?





- 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)

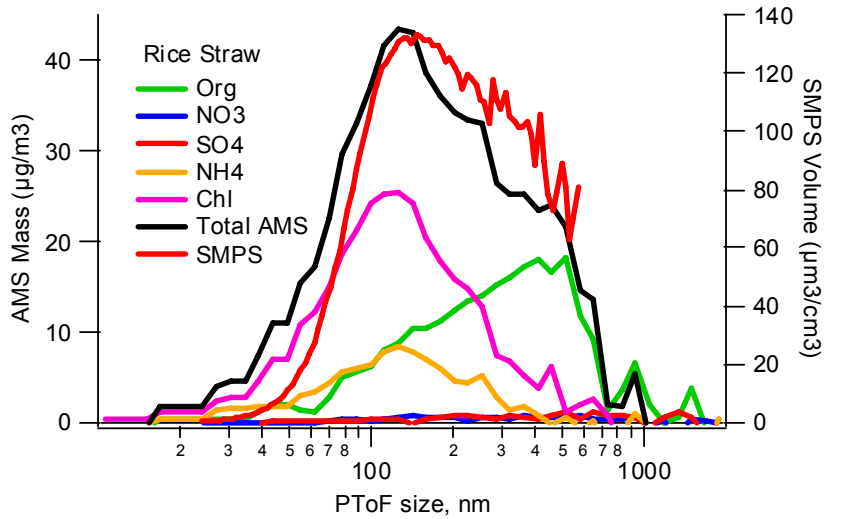
- Ratio mz44/org increases with temperature as the more volatile components of org vaporize

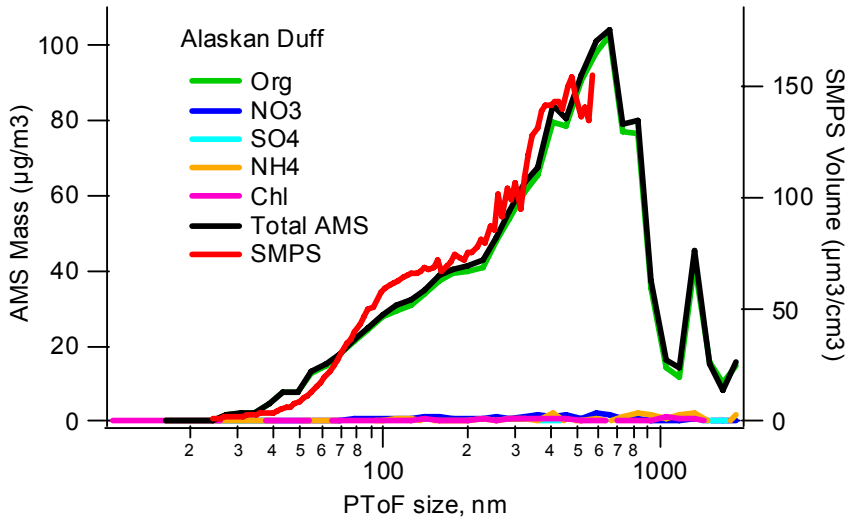
Conclusions/Summary

- Biomass burning particles emitted from Alaskan White Spruce:
  - One mode mass distribution peaking ~250 nm
  - Effective density of ~1.1 g/cm3
  - 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

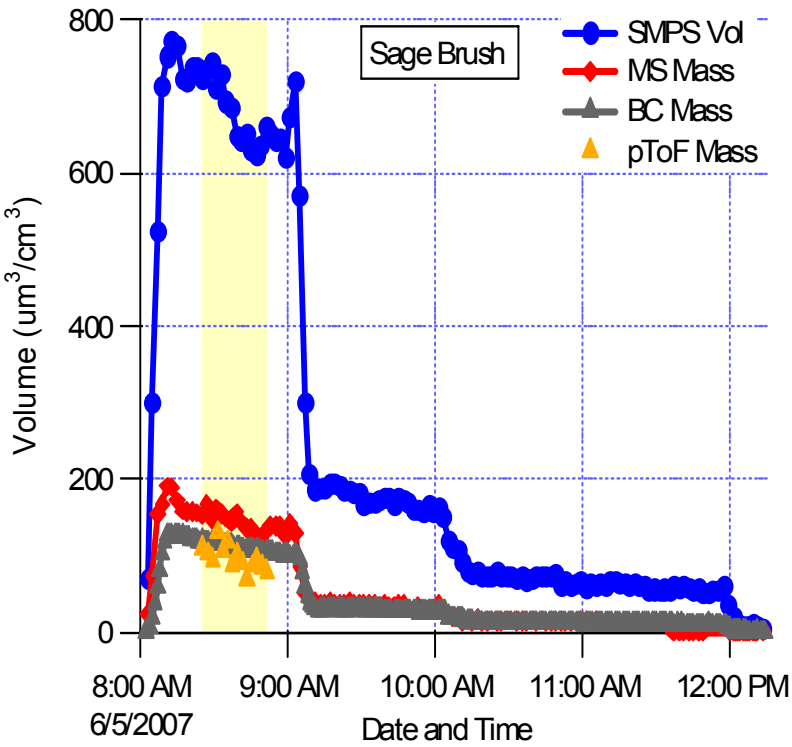
- We still have a lot to study!

The Future





Fuel, flame condition, dilution



Acknowledgements

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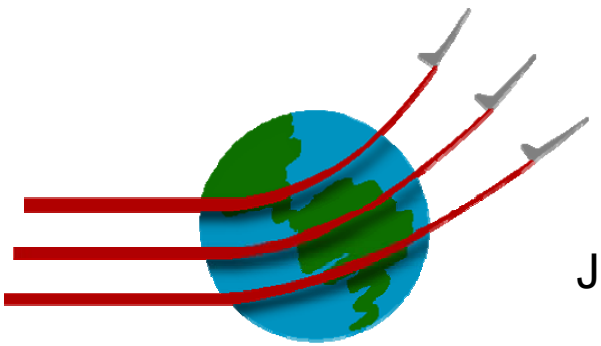
Patrick Arnott

Desert Research Institute

Wei-Min Hao, Cyle Wold

Fire Science Lab



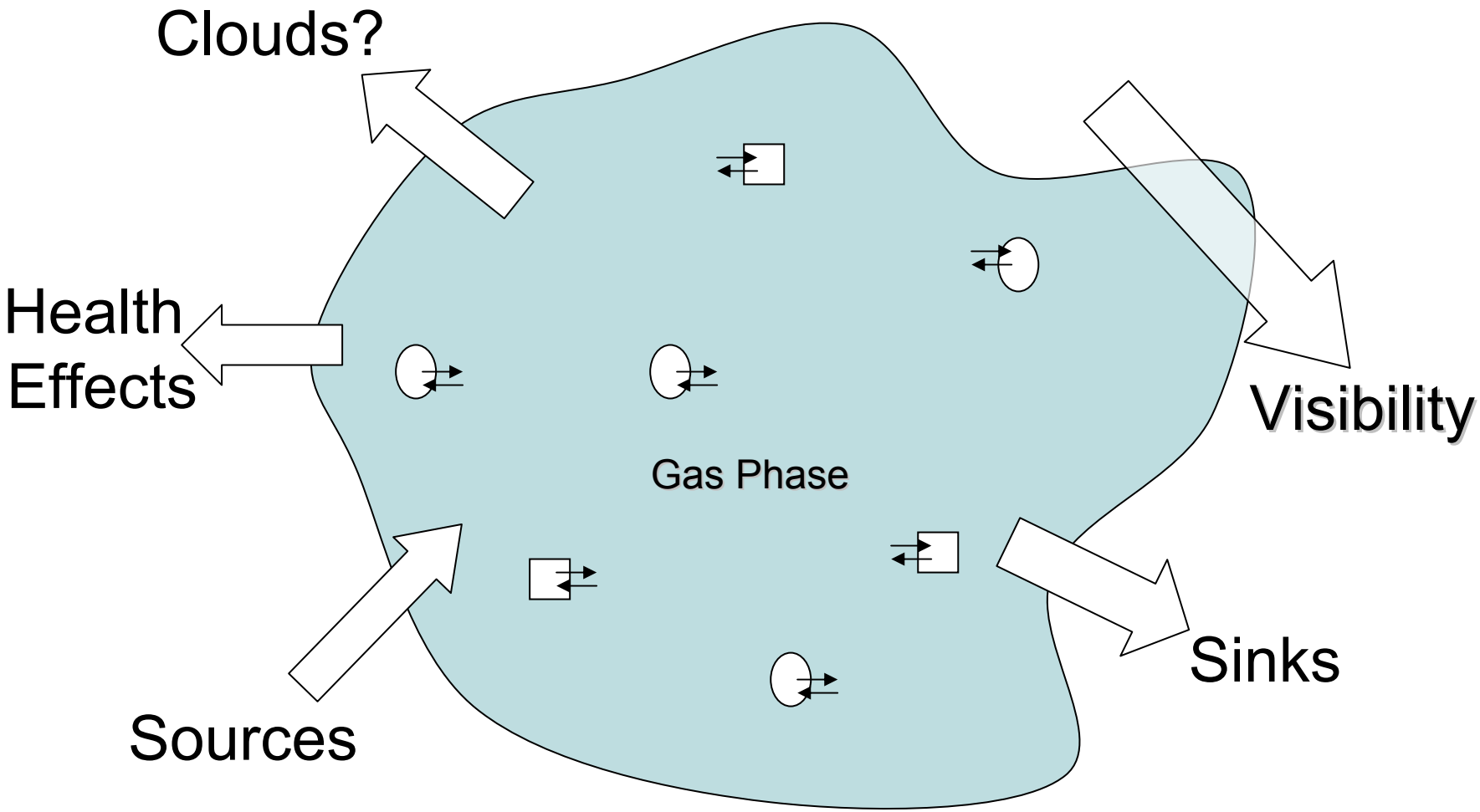
EVERYONE AT FLAME-2!

Jeff Gaffney and Milton Constantin

DOE OBER GCEP SURE Program

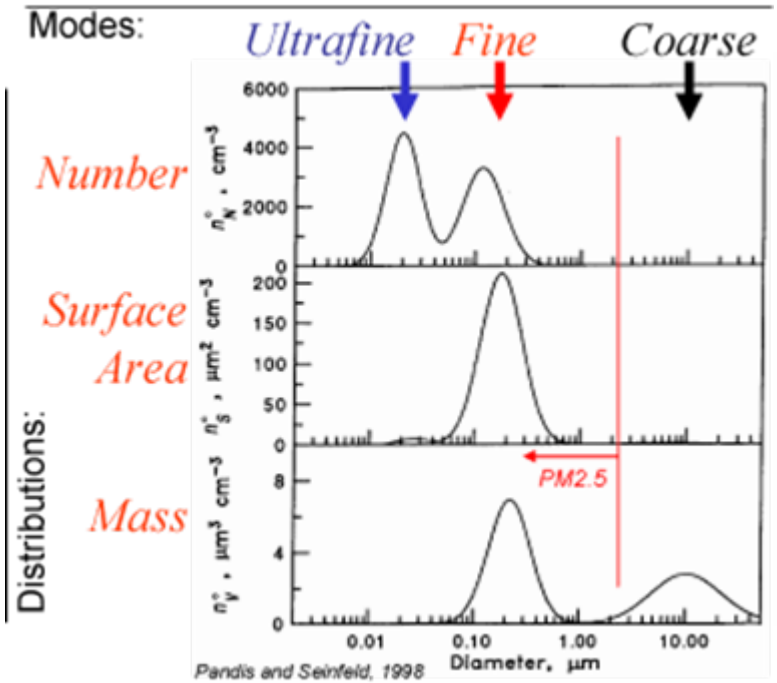
Extra Slides

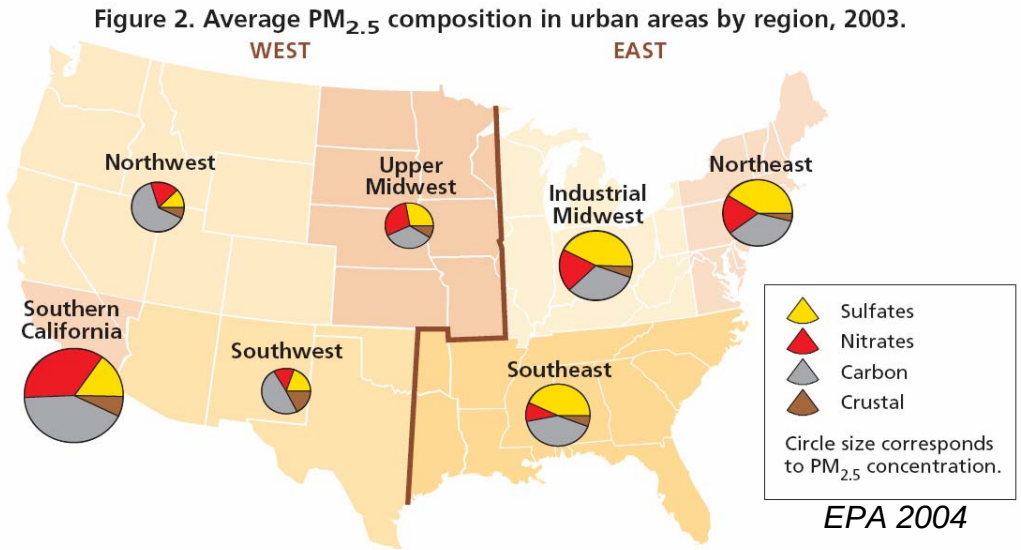
Aerosol: A Definition



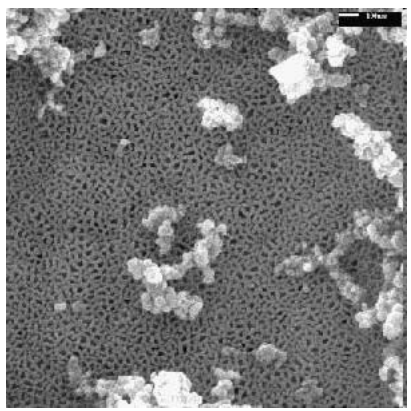
Solid and liquid particles in suspension with the gas phase

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





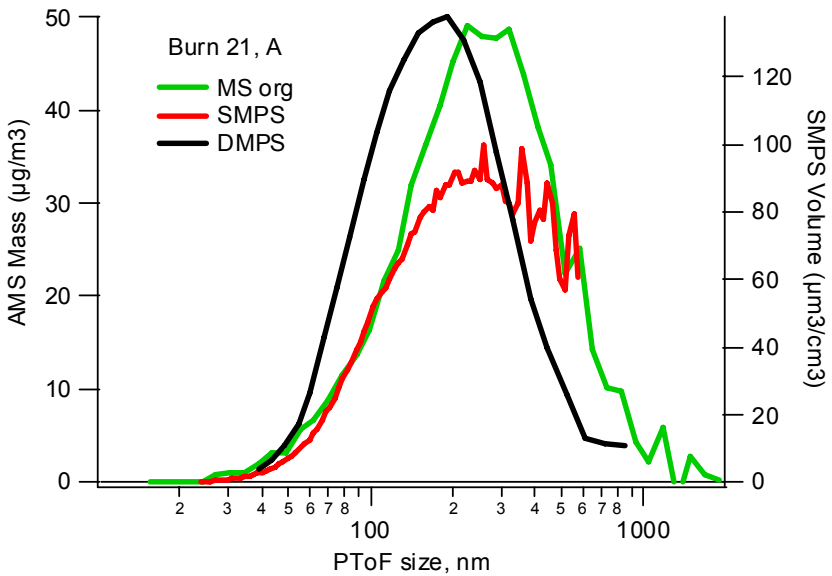
EPA 2004

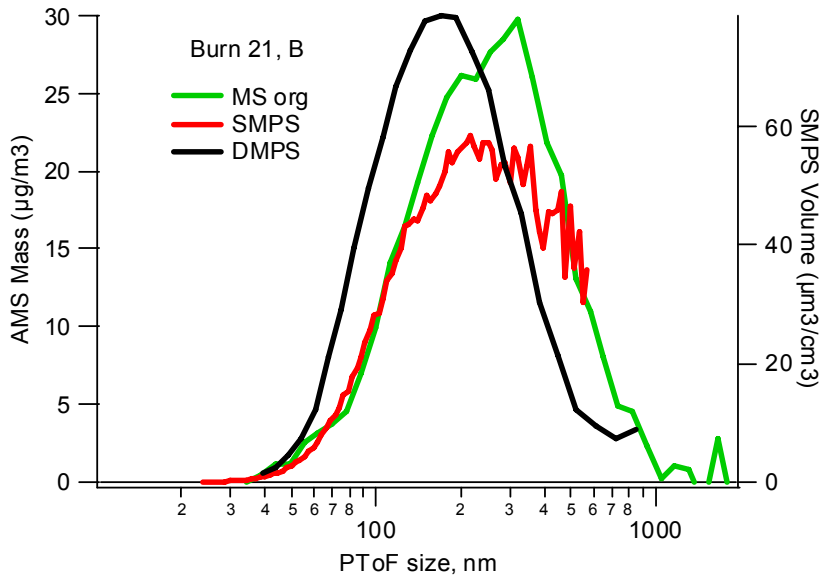


Goal: Size-Resolved Chemical Composition of Ambient Aerosol

Slide: Tim Onasch

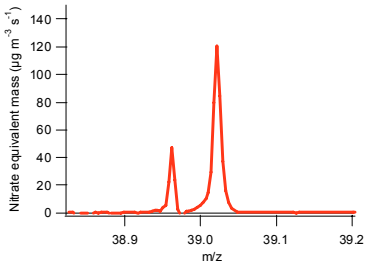
Comparison with CSU DMPS



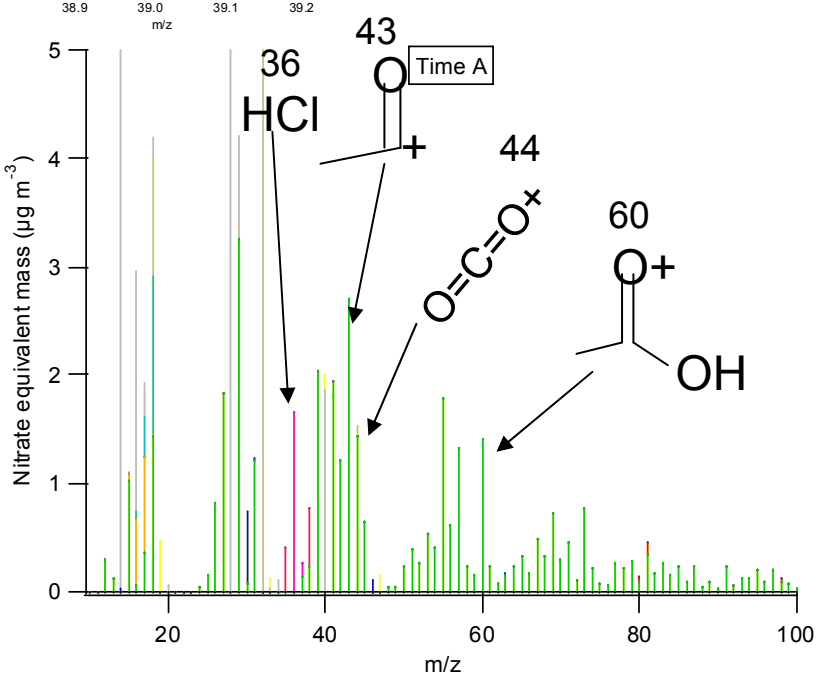


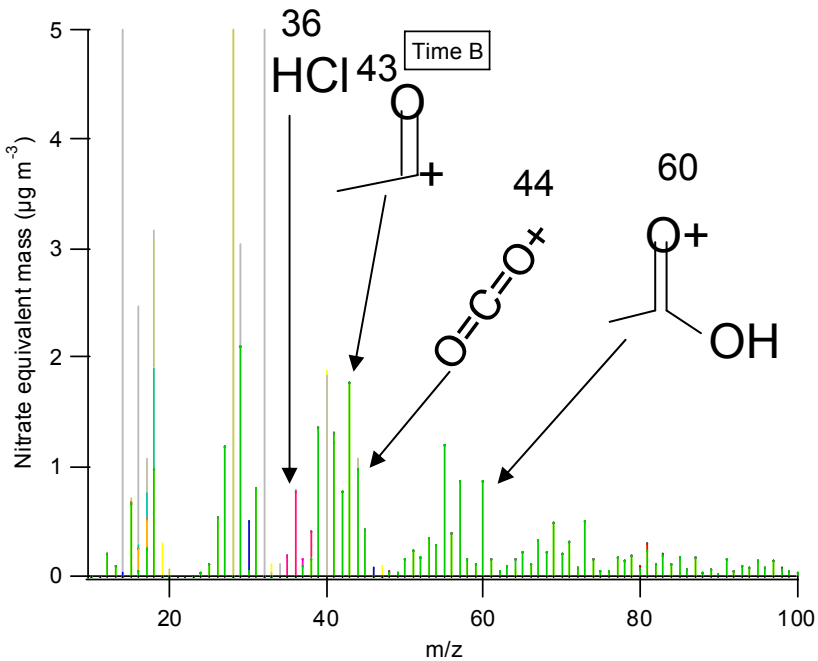
- CSU DMPS and SMPS do not agree very well in mode diameters or mode volume loadings, but do agree in monomodal characteristics
- Assume that DMPS and SMPS do not agree due to different locations in sampling line.
- Use SMPS and AMS for comparisons here

K~25% mz39



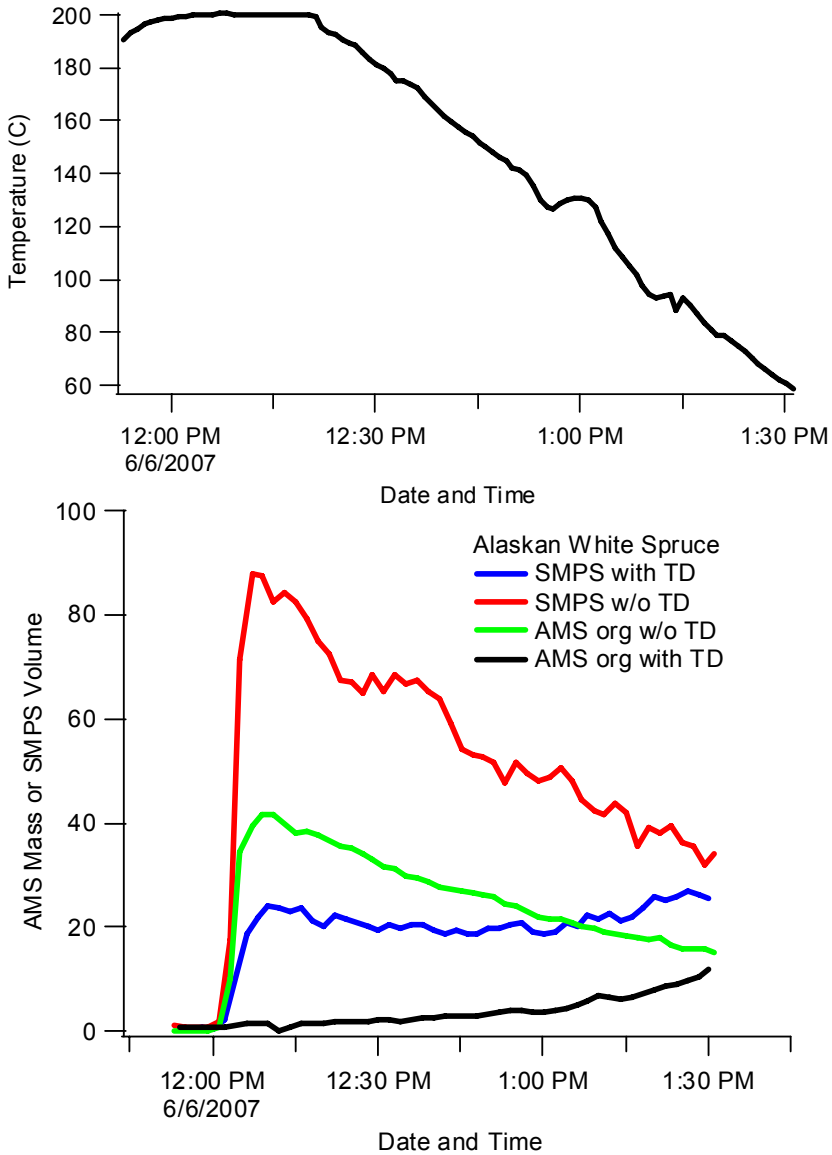
Mass Spectra





- 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)