Size-dependent Transmission of Aerosols in an ARI Aerosol Mass Spectrometer

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Outline

• Aerosols
• ARI Aerosol Mass Spectrometer
• NEAQS-ITCT 2004
• Supermicron Aerosol Project
  – Particle Transmission
  – Preliminary Conclusions and Future Work
• Acknowledgements
Aerosol: solution of particles suspended in a gas

Sources and Effects of Particles in the Atmosphere

- Stratosphere
- Tropospheric Clouds
- Rain
- Wet Deposition
- Green House Effect
- Ozone Depletion
- Aerosol nucleation
- Health Effects
- Visibility
- Fog
- Smog
- Ocean

Effects depend critically on size & chemical composition
ARI Aerosol Mass Spectrometer

Particle Beam Generation

Aerodynamic Sizing

Particle Composition

Quadrupole Mass Spectrometer

TOF Region

Chopper

Aerodynamic Lens (2 Torr)

Particle Inlet (1 atm)

Turbo Pump

Turbo Pump

Turbo Pump

Thermal Vaporization & Electron Impact Ionization

AMS Schematic
ARI Aerosol Mass Spectrometer

• Definitions
  – Geometric diameter – true diameter, $D_p$
  – Classical Aerodynamic diameter –

\[
D_a = \sqrt{\frac{\rho}{\chi \rho_0}} D_p
\]

– Vacuum Aerodynamic diameter –

\[
D_{va} = \frac{\rho}{\chi \rho_0} D_p
\]

Where $\rho$ is the particle density, $\rho_0$ is unit density ($\rho_0 = 1 \text{ g/cm}^3$), and $\chi$ is the particle dynamic shape factor.
NEAQS-ITCT 2004

• New England Air Quality Study - Intercontinental Transport and Chemical Transformation 2004
  – ARI set up an AMS on DOE’s G-1 Aircraft
  – ARI manned AMSs in Nova Scotia, Canada and on NOAA’s Ron Brown
Nova Scotia Site

- Design and install inlet system
- Spatially organize instruments
- Prepare trailer for shipping
Supermicron Aerosol Project

- Goal: Adjust the AMS inlet to pass particles larger than 1 µm
- Particles >~1 µm lost at orifice

- Objective: Make an orifice that transmits 1-10 µm particles

AMS Sampling Efficiency vs. Particle Size

- Graph showing AMS Collection Efficiency vs. Vac. Aerodynamic Diameter (nm)
- Comparison between FLUENT Model and Data
Particle Transmission

Orifice Size: 140 µm pinhole vs. 120 µm pinhole

More larger particles are able to pass through the 140 µm pinhole than the 120 µm pinhole => step in right direction
Particle Transmission

Compounds w/ different densities

- NaNO₃
- NH₄NO₃
- Pb(NO₃)₂

Particles w/ different densities and same diameter have different transmission efficiency => density likely plays a role

Densities

- NH₄NO₃ = 1.72 g/cm³
- NaNO₃ = 2.26 g/cm³
- Pb(NO₃)₂ = 4.53 g/cm³
Particle Transmission

Which diameter determines the cutoff?

Vacuum Aerodynamic diameter – loosely grouped transmission

Classical Aerodynamic diameter - closely grouped transmission

Geometric diameter - wide spread transmission
Preliminary Conclusions

- Larger orifice slightly increases transmission of larger particles
- Particle transmission cutoff determined by classical aerodynamic diameter

Future Experiments

- Larger orifices – 160+ µm
- Laser spectrometry system
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Auxiliary Information

Aerosol Generation System

- Creates particles from 50 nm to >25 µm
- Components
  - Medical Nebulizer
  - Dryer tube
  - PM$_{2.5}$ cyclone
Larger particles unable to move out as far with each succeeding plate/pinhole => focusing of particles

Based on work by Liu et al., 1995
References