A Novel Technique to Measure Ultrafine Particle Size Distributions for Environmental Science Applications

Carlos Gallar,1,2, Charles A. Brock,1,2, Craig Simons,1,2, and Jose-Luis Jimenez2,3

1Aeronomy Laboratory, National Oceanic and Atmospheric Administration, Boulder, CO 2Cooperative Institute for Research in Environmental Sciences, University of Colorado, Boulder, CO 3Department of Chemistry, University of Colorado, Boulder, CO

BACKGROUND

Importance of Ultrafine Aerosol Particles

• Definition: aerosol particles with diameters <100 nm in diameter
• Correlated with increased human mortality and morbidity
• Can include organic matter such as polycyclic aromatic hydrocarbons
• Larger ultrafine particles can be cloud condensation nuclei
• Serve as nuclei for growth to climate-relevant sizes
• Used for a variety of engineering “nanotechnology” applications

Measurement Issues

• Highly variable in time and space
• Highly diffusive
• Difficult to detect with optical methods
• Electric mobility spectrometers (SMPS) very expensive (>75 k$)

A New Approach: Sizing by Nucleation (Kelvin) Diameter

• Use existing condensation particle counter (CPC) design (counting only, no sizing)
• Vary the operating conditions of the CPC to vary the size nucleated (Kelvin diameter)
• Use inversion technique to recover size distribution

Potential Advantages of the New Technique

• Lower cost (< more units deployed)
• Smaller operation
• Better counting statistics (< faster time response)

Expected Limitations of the New Technique

• Size range more limited than SMPS
• More sensitive to ambient temperature and flow changes (temperature and flow stability critical)
• Working fluid is expensive and perfluorinated (potentially ozone depleting)

This project was focused on developing and evaluating this technique, called the scanning condensation particle sizer (SCoPS)

DESCRIPTION, OPERATION, AND CALIBRATION

SCoPS

• Aerosol flow and dilution flow are brought to identical temperatures of 49.0°C. The dilution and saturator flows are mixed, then used to sheath the aerosol flow prior to the condenser, which is chilled to 11.0°C. The vapor concentration is controlled by varying the ratio of saturator to dilution flows; total flow is constant.

PERFORMANCE: COMPARISON WITH SMPS

Figure 3. Detection efficiency of the SCoPS relative to a commercial TSI CPC for different conditions of vapor and dilution flow as a function of particle diameter.

Figure 4. Measured counting efficiency of the SCoPS relative to a commercial TSI CPC for different conditions of vapor and dilution flow as a function of particle diameter.

EVALUATION OF SCoPS

• Aerosol with ±10% diameter dispersion provided to SCoPS and
• Lag time to changes in flow ratio is ~2 sec
• Concentration time response to a large step function in flow ratio is ~10 sec
• Concentration data for different conditions of vapor and dilution flow as a function of particle diameter.

CONCLUSIONS

Performance of the SCoPS Technique

• The proof-of-concept was successfully demonstrated
• The diameter of nucleation (Kelvin diameter) can be controlled over a range from 5 to 30 nm with the current configuration (flows, temperatures, fluid properties)
• The time response of the system is ~1 second to changes in flows, meaning that scans of particle size distributions over this range can be accomplished in ~30 s with good counting statistics
• The inversion method can successfully recover the diameter and concentration of nearly monodisperse particle size distributions as well as polydisperse aerosols
• An unexplained shift in performance occurred near the end of the project, necessitating a complete recalibration of the response functions. Flow controller calibration change?
• The size resolution and size range is less than that of the competing SMPS technology
• Detection efficiencies for particles > 10 nm were reduced by dilution losses. All efficiencies <100% (7)

Needs for Further Development

• Extend diameter range by testing different flows, temperatures, and fluids
• Reduce particle losses to dilution by changing sample flow geometry and flow rate to accommodate smaller sample sizes
• Improve accuracy and robustness of response curves
• Develop time and/or develop true scanning mode algorithm for size distribution inversion

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