Behavior of Ultrafine Particles and Related Particulate and Gaseous Species at Two Geographically Distributed Sites in New York City

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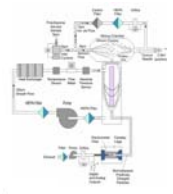
Abstract

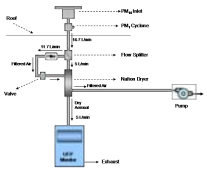
While there have been numerous short-term studies of ambient ultrafine particle behavior at single locations in urban environments, relatively little data has been gathered from long-term measurements at multiple geographical sites in such environments. In this study, ultrafine particle size distributions were measured at two locations in the New York State Air Monitoring Network at 15 minute intervals from June 2009 to June 2010, using an Ultrafine Particle Monitor (UFP Monitor, Model 3031, TSI, Inc.) designed for long-term ambient monitoring of six bins over the size range from 20 to 500 nm. The first monitor was installed at Queens College (QC), a well instrumented monitoring site representative of the New York City metropolitan area. Continuous monitoring of several gaseous and PM2.5 particle pollutant species was also conducted at this site. The second monitor was installed 17 miles east of QC at Eisenhower Park ("Ike Park", IP), a near-roadway site on Long Island located within 30 meters of a 4 lane roadway and backed by unoccupied parkland, with various stationary sources also located in the vicinity. Data from the UFP Monitors at both sites are interpreted in the context of other collected particulate, gaseous, and meteorological measurements. While ultrafine particle size distributions from both sites corresponded well with each other, the correlations of ultrafine particles at both sites with other particulate and gaseous species was highly dependent on particle size. In particular, particle measurements in the 20-50 nm size bin exhibited little to no correlation with any of the other species, implying that there are no surrogates for ultrafine particles < 50 nm and they must be directly measured. For particles in the range from 50-200 nm, the correlation with species such as SO_2, NOx, and particle-phase sulfate was highly dependent on seasonal behavior.

TSI Model 3031 Ultrafine Particle Monitor

The Ultrafine Particle Monitor (UFP Monitor, Model 3031, TSI, Inc.) has been specifically designed for long-term ambient monitoring of ultrafine particles in urban environments. It measures the size distribution and number concentration of particles between 20 to ~500 nm, with six channels of size resolution and continuously provides the number concentration for each size channel every 11 minutes.

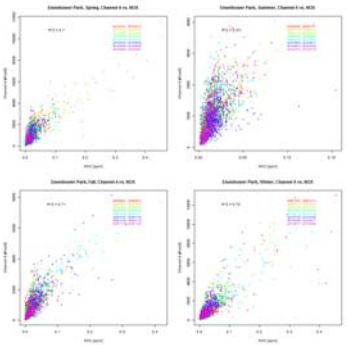


The operating principle of the UFP Monitor is based on diffusion charging of particles, followed by size segregation within a Differential Mobility Analyzer (DMA) and detection of the aerosol via a sensitive electrometer. The charging device in the UFP Monitor is a "Corona-Jet" charger. Within the charger, the total flow of 5.0 L/min is split into 1.0 L/min passing through two filters (a carbon and a HEPA) and an ionizer and 4.0 L/min of aerosol remaining as sample flow. The flow streams are merged in a mixing chamber where particles in the aerosol flow mix with the ions carried by the filtered clean air. The charged aerosol then moves on to the DMA for size segregation. After leaving DMA, the aerosol enters a faraday cage where the particles, and their charge, are collected on a particle filter. The filter is conductive, and is electrically connected to the input of a sensitive electrometer amplifier. One measurement cycle takes approximately 10 minutes with one minute zeroing time between cycles.

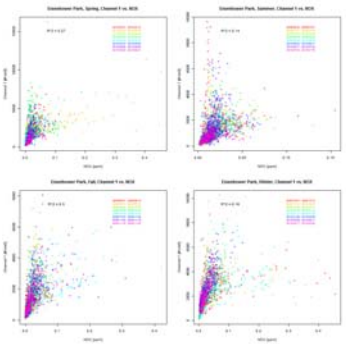


The UFP Monitor was deployed in concert with the TSI Model 3031200 Environmental Sampling System. A representative sample of ambient air is continuously drawn through a size selective PM10 inlet at a standard flow rate of 16.7 L/min. Next, the sample passes through a PM1 cyclone which removes larger particles. The main sample stream is subsampled into the UFP Monitor at a flow rate of 5 L/min. A Nafion dryer upstream of the UFP Monitor ensures proper conditioning of the aerosol to minimize effects due to relative humidity. The remaining 11.7 L/min of make-up air is routed through the Nafion dryer as purge air and drawn through a vacuum pump and exhausted.

NO_X Versus Ultrafine Particles

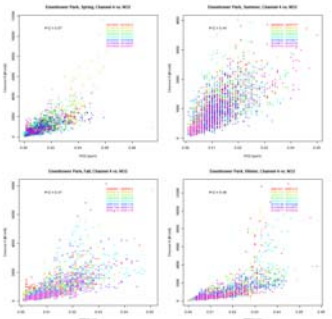


Eisenhower Park 70-100 nm (Channel 4) vs. NOx, All Seasons
The middle channels (50-200 nm) correlate well with NOx in Fall, Winter and Spring, but not in Summer. This effect may be due to the high temperatures in summer, which may cause particle-phase nitrate to evaporate even if it forms.

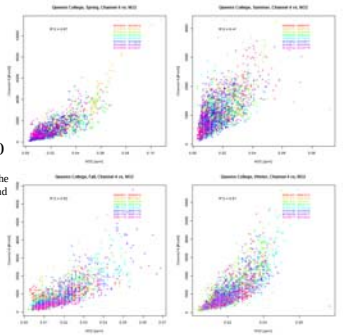


Eisenhower Park 20-30 nm (Channel 1) vs. NOx, All Seasons
Particle measurements in the 20-30 and 30-50 nm size bins exhibited little to no correlation with any of the other species (such as both NOx and SO_2), implying that there are no surrogates for ultrafine particles < 50 nm and they must be directly measured.

NO_2 Versus Ultrafine Particles

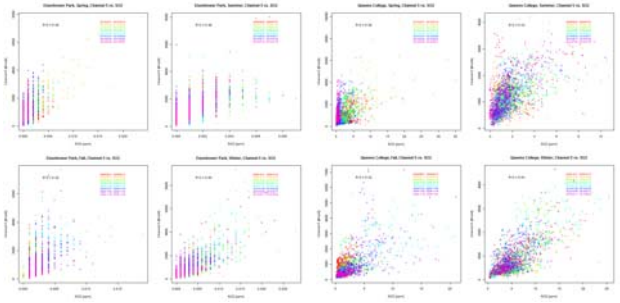


Eisenhower Park 70-100 nm (Channel 4) vs. NO_2, All Seasons
Similar seasonal behavior is seen for NO_2, which is an intermediate for nitrate formation.

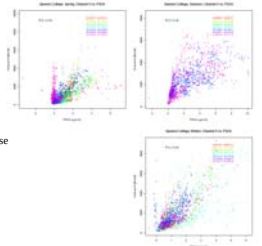


Queens College 70-100 nm (Channel 4) vs. NO_2, All Seasons
The seasonal dependence of the relationship between UFPs and NO_2 is stronger at Queens College than at Eisenhower Park.

SO_2 Versus Ultrafine Particles

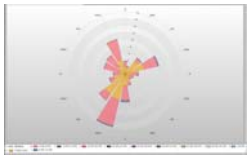


Eisenhower Park & Queens College, 100-200 nm (Channel 5) vs. SO_2, All Seasons
The middle channels (50-200nm) correlate well with SO_2 in Winter, but not in Spring, Summer, and Fall. Winter has the highest correlations and Summer has no correlations (i.e., $R^2 < 0.5$).



Queens College 100-200 nm (Channel 5) vs. SO_4, All Seasons
For QC only (no IP data), particle phase SO4 also correlates with UFPs according to the same trend.

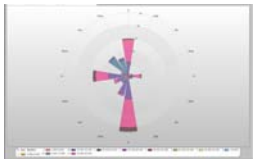
Queens College ("QC") Ambient Monitoring Site



Hourly wind rose for Queens College averaged over the analysis period.

The Queens College monitoring site is a well instrumented monitoring site representative of the New York City metropolitan area located on the campus of Queens College in New York City. The site is bordered by a mix of sources, including mobile sources from the Long Island and Horace Harding Expressways, as well as local campus parking. It is located 27 kilometers NW of the Eisenhower Park monitoring site.

Eisenhower Park ("IP") Ambient Monitoring Site



Hourly wind rose for Eisenhower Park averaged over the analysis period.

The Eisenhower Park monitoring site is located at a near-roadway site on Long Island, 27 kilometers SE of the Queens College Site. The site is backed by unoccupied parkland and is adjacent to a 4 lane roadway that runs parallel to the site in a NNW direction. The site is within 22 meters of the roadway in a W-WSW direction, and within 53 meters of the roadway in a S direction. A waste-to-energy conversion plant and several restaurants are also proximate to the site.

Conclusions

- While ultrafine particle size distributions from both sites corresponded well with each other, the correlations of ultrafine particles at both sites with other particulate and gaseous species was highly dependent on particle size.
- Particle measurements in the 20-50 nm size bin exhibited little to no correlation with any of the other species, implying that there are no surrogates for ultrafine particles < 50 nm and they must be directly measured.
- For particles in the range from 50-200 nm, the correlation with species such as SO_2, NOx, and particle-phase sulfate was highly dependent on seasonal behavior.:
- **NOx versus UFPs**
  - Does not correlate well with the largest (200-500nm) or smallest (20-50nm) channels.
  - The middle channels (50-200 nm) correlate well with NOx in Fall, Winter and Spring, but not in Summer. This effect may be due to the high temperatures in summer, which cause particle-phase nitrate to evaporate even if it forms.
  - This explanation is supported by the finding that we see the same seasonal behavior for NO_2, which is an intermediate for nitrate formation , although it is less pronounced at IP than at QC
- **SO_2 versus UFPs**
  - As for all other species studied, consistently low correlations (R^2 always < 0.5) for the smallest (20-50 nm) size bin.
  - The middle channels (50-200nm) correlate well with SO_2 in Winter, but not in Spring, Summer, and Fall. Winter has the highest correlations and Summer has no correlations (i.e., $R^2 < 0.5$).
  - For QC only (no IP data), particle phase SO_4 also correlates with UFPs according to the same trend.

Future Work

- Examine seasonal and diurnal correlations of 3031 measurements with elemental carbon, total carbon, and other species.
- Assess pollution roses for evidence of local source contributions.

Acknowledgements

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