A21B-0069:Variations In Aerosol Size And Number During DISCOVER-AQ

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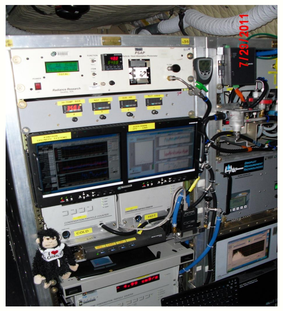
Introduction

The Deriving Information on Surface Conditions from Column and Vertically Resolved Observations Relevant to Air Quality (DISCOVER-AQ) mission is a multi-year campaign designed to improve the use of satellites to monitor surface-level air quality. DISCOVER-AQ is addressing its goals by conducting a series of coordinated ground-based and flight experiments over urban areas with well-established air quality issues to obtain vertically resolved measurements of trace gas and aerosol components for comparing with satellite observations of column-integrated quantities. The first flight mission was conducted over the Washington D.C. - Baltimore metropolitan area during July, 2011. It consisted of 14 science flights by the NASA Wallops Flight Facility P-3B aircraft over 6 highly-instrumented ground sites located around Baltimore. This region frequently violates ambient air quality standards for particulate matter as well as ozone and has a complex mixture of biogenic and anthropogenic sources. A large suite of aerosol instruments were flown onboard the P-3B aircraft to measure the microphysical, optical and chemical properties of aerosols during spirals over the ground sites and during low level flights over Interstates 95 and 695 connecting Washington and Baltimore. The package included condensation nuclei (CN) counters to provide measurements of total aerosols greater than 3 nm (UCN) and 10 nm (CN); a scanning mobility particle sizer (SMPS) to measure size in the 10 to 300 nm diameter range; an Ultra High Sensitivity Aerosol Spectrometer (UHSAS) for sizing 90 to 1000 nm diameter particles, and a Laser Aerosol Spectrometer for sizing 100 to 7500 nm particles. This presentation examines the variability of aerosol size and number in both time and space over the Baltimore metropolitan region.

Measurements

Typical flight track showing spiral points over ground sites. The flight track was normally repeated four times during each flight day.



NASA P-3B aircraft in-situ aerosol instrumentation rack #1

NASA P-3B aircraft

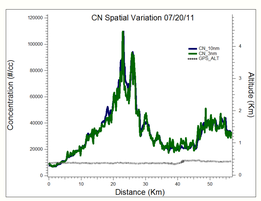
NASA P-3B aircraft in-situ aerosol instrumentation rack #2

NASA P-3B aerosol inlet

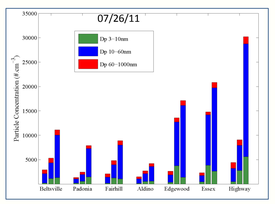
Measured Parameter	Instrument	Uncertainty	Size Range (μm)
Total Particle Concentration	TSI-3025 CPC	10 cm^{-3}	> 0.003
Particle Concentration	TSI-3010 CPC	10 cm^{-3}	> 0.01
Nonvolatile Particle Concentration	TSI-3010, heated and denuded	10 cm^{-3}	> 0.01
Dry Aerosol Size Distributions	TSI SMPS	N/A	0.01 – 0.5
	DMT UHSAS	N/A	0.06 – 1
	TSI LAS	N/A	0.01-7
	TSI-3321 APS	N/A	0.5 – 5
Dry Total Scattering Coefficients at 450, 550, and 700 nm	TSI-3563 Nephelometer	0.1 Mm^{-1}	< 5
f(RH) for Scattering at 450, 550, and 700 nm	TSI-3563 Nephelometer w/ 80 % humidification	0.2 Mm^{-1}	< 5
Total Absorption Coefficients at 467, 530 and 660 nm	PSAP	0.5 Mm^{-1}	< 5
Nonvolatile Absorption Coefficients at 467, 530 and 660 nm	PSAP, heated and denuded pretreatment	0.5 Mm^{-1}	< 5
CCN Concentration (as a function of supersaturation)	CCN counter	10 cm^{-3}	< 5

NASA P-3B aerosol instruments

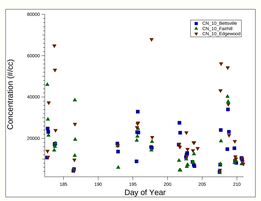
Concentration Variability



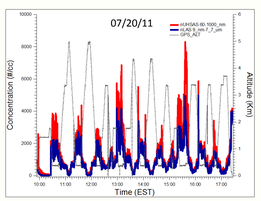
• Concentrations of UCN varied considerably over a short distance over Interstate 95 highway.
• Concentrations varied by more than a factor of 16 within 10 Km. Concentrations are higher near roadways and lower with altitude



• Average of number distributions during each pass over the individual site separated into various size ranges over a period of a day from 08:30 to 14:00 demonstrate the variability of aerosol number distributions as a function of time and location
• Highest number distributions occurred near roadways and urban centers

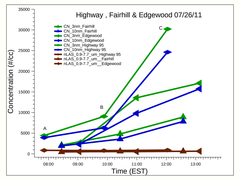


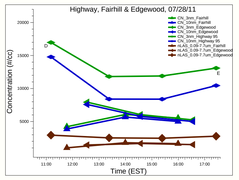
• Concentration data averages of aerosols greater than 10 nm for each site over the entire field campaign time period show the variation over space and time

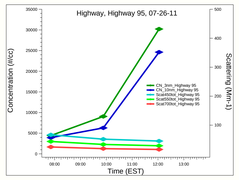


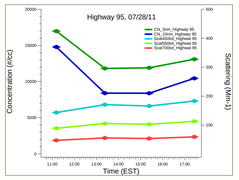
• Number distributions of aerosols larger than 60 nm and larger than 90 nm also varied considerably over short time periods and distances
• Accumulation mode aerosols increased later in the day as smaller particles coagulated

New Particle Formation





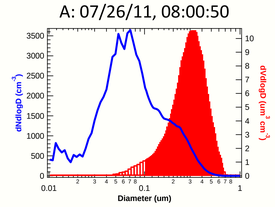


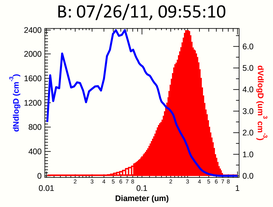


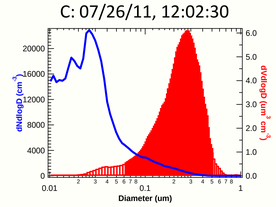
• Separate flights 2 days apart with second flight starting approximately 3.5 hours later than first flight provides data over an extended time of day with 3.5 hours time of day overlap
• Data points are averages of 1 second data collected during the time spent at three of the ground site locations for each flight track loop.
•The three colored traces are aerosol concentrations >3nm, >10 nm and between 90 nm and 7.7 um.
•Data point letters correspond to the size distribution plots below with the same letter.
•Ultrafine aerosol concentrations from motor vehicle emissions increased during the day to a peak and then begin to decline.

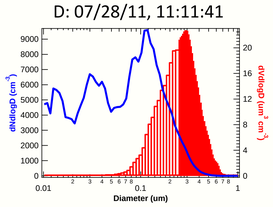
• Plots are of the same 2 day time period showing scattering at 450, 550 and 700 nm along with the aerosol concentrations of particles >3nm and >10 nm for the highway portion of the flight tracks.
• CN concentrations increased during the day as new particles were formed by photochemical oxidation of gas phase precursors.
• Scattering showed a slight decrease during the new particle formation
• As nucleation mode aerosols coagulated later in the day to form larger particles, CN decreased and scattering increased

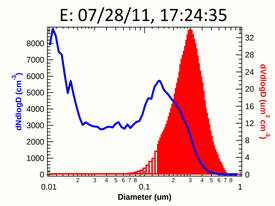
Aerosol Size Distributions





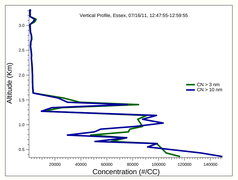


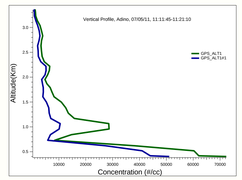


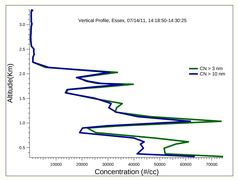


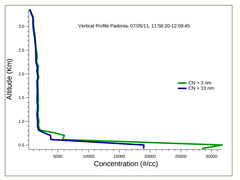
• Plots show combined size distribution data from a SMPS, UHSAS and LAS providing continuous size distribution data from 10 nm to 7.7 um
• On each day there is a progression of aerosol size and volume as the time of day progressed from plot A to plot E
• The number size mode shifted to smaller aerosols as new particles were formed
• The number size distribution mode and volume mode increased as particles coagulated later in the day

Vertical Distribution









• During spirals over individual locations, aerosol concentrations decreased rapidly with increasing altitude
• Layers of aerosol were encountered during some spirals

Conclusion

Within the atmospheric boundary layer between 0.3 and 1 km, particle number densities and size distributions varied considerable over short time periods and across horizontal distances as short as 1 km. Over the entire experiment, UCN values ranged from 700 to 130,000 cm^{-3} while particles in the 90 to 1000 nm size range varied from less than 50 to more than 7500 cm^{-3}. The high UCN values typically occurred at times when aerosol scattering and hence surface area was relatively low. Values also tended to increase during the day as gas phase precursors were photochemically oxidized to form less volatile species, which in turn condensed to form new particles. This process was more pronounced on days when background aerosol surface area was relatively low. Accumulation mode number concentrations often increased during the day, as the nucleation mode particles coagulated and aerosol surface increased to the point where deposition of low volatility precursors on existing particles was favored over new particle formation. Particle number concentrations and size also varied considerably from site to site across the 100-by 30-mile study area as a consequence of variations in local sources.