Characteristics of Aerosol Growth Events at Urban and Rural Locations in New York

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INTRODUCTION

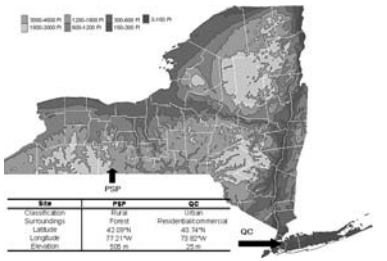
► **Measurements of particle number concentrations and size distributions were obtained using both nano- and long-tube scanning mobility particle sizers (SMPS) at the rural site of Pinnacle State Park (PSP) in upstate New York from July 12 through August 11 in 2004 and the urban site of Queens College (QC) in New York City from January 15 through February 5 in 2004. Due to the relatively high background levels of aerosols (and the associated condensation sink for new particles), new particle formation and growth events are much less common in these locations than reported by other groups for lower background sites.**

► **These measurements of particle number concentrations and size distributions have been analyzed along with co-located measurements such as ionic species from a PILS-IC, oxygenated/hydrocarbon-like organic aerosol (OOA / HOA) from an Aerodyne Aerosol Mass Spectrometer, organic & elemental carbon from a SUNSET (NIOSH5040) real time carbon aerosol analyzer, gaseous pollutants, PM2.5 using a tapered element oscillating microbalance (TEOM), and meteorological data. Analysis of the characteristics of particle growth (and specifically the growth rate) in conjunction with other observations can classify the events and illustrate that particle growth encompasses several different physical mechanisms – and may be related to different parameters for these sites.**

SITE DESCRIPTION

Pinnacle State Park (PSP)
- Low population density rural village of Addison, New York
- Surrounded by parklands, and forested areas

Queens College (QC)
- High population density section of New York City
- North is the Long Island Expressway (I-495)
- West is the Van Wyck Expressway (I-678)



Site	PSP	QC
Classification Surroundings Latitude Longitude Elevation	Rural Forest	Urban Residential/commercial

Characteristics of the instruments

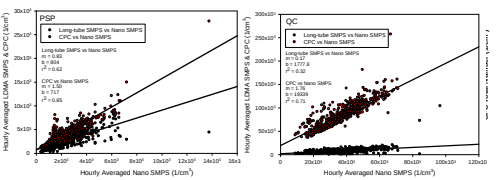
Table 1. Operation parameters for the particle sizing and counting instruments

PSP	Nano SMPS	Long-tube SMPS	CPC 3022
Cycle length, min	2.5	2.5	1
Inlet sample flow, l/min	0.3	0.3	1.5
Sheath flow, l/min	3	3	N/A
Diameter range*, nm	4.7 - 149 (1)	16 - 626 (2)	50% at 0.007 nm 90% at 0.015 nm
QC	**Nano SMPS**	**Long-tube SMPS**	**CPC 3022**
Cycle length, min	2.5	2.5	1
Inlet sample flow, l/min	0.6	0.3	1.5
Sheath flow, l/min	6	3	N/A
Diameter range*, nm	3.28 - 104 (3)	16 - 626 (4)	50% at 0.007 nm 90% at 0.015 nm

*** Midpoint of Diameter range**
(1) Number of Bins = 49 **(3) Number of Bins = 49**
(2) Number of Bins = 52 **(4) Number of Bins = 52**

FIGURE 1

► The pair-wise correlation scatter plots between hourly averaged Nano SMPS and LDMA SMPS & CPC at the PSP from July 12 to August 11 in 2004 and at the QC from January 15 to February 5 in 2004.



► The ambient aerosol between two sampling sites could be affected by different contributions related to different size ranges

Statistical characteristics of pollutants

Table 2. Statistical characteristics of $PM_{2.5}$ and aerosol/gaseous pollutants at the PSP (from Jul.12 to Aug.11 in 2004) and the QC (from Jan.15 to Feb.5 in 2004) sites.

PSP	Unit	Observed Hours (Hr)	Mean	Median	Standard Error	Standard Deviation	Sample Variance	Minimum	Maximum
$PM_{2.5}$	μg/m³	403	15.98	11.30	0.63	12.69	161.12	0.20	54.60
NO_3^-	μg/m³	403	0.11	0.05	0.01	0.19	0.03	0.00	1.11
SO_4^{2-}	μg/m³	403	5.99	4.03	0.31	6.15	37.77	0.04	32.01
NH_4^+	μg/m³	403	1.43	1.13	0.05	1.10	1.22	0.05	5.11
Organics	μg/m³	375	7.17	6.72	0.21	4.04	16.32	0.66	21.67
OOA (1)	μg/m³	375	6.80	6.40	0.20	3.96	15.69	0.63	20.82
HOA (2)	μg/m³	375	0.37	0.32	0.01	0.27	0.07	0.00	1.36
Elemental Carbon	μg/m³	386	0.21	0.18	0.01	0.10	0.01	0.04	0.66
O_3	ppb	311	29.06	28.70	0.65	11.41	130.13	5.60	65.90
SO_2	ppb	389	1.12	0.52	0.10	2.04	4.18	0.00	18.76
NO	ppb	413	0.15	0.09	0.01	0.18	0.03	0.00	2.09
NO_2	ppb	396	1.18	0.90	0.05	0.93	0.86	0.21	7.41
NO_x	ppb	415	1.27	1.00	0.05	1.02	1.05	0.00	8.02
Isoprene	ppb	331	2.25	1.51	0.14	2.51	6.29	0.08	18.89
HCHO	ppb	412	1.69	1.59	0.04	0.73	0.54	0.57	4.09
Temperature	°C	430	19.65	19.30	0.17	3.55	12.61	10.40	27.50
Relative Humidity	%	430	86.26	90.85	0.64	13.24	175.36	46.80	99.00
QC	**Unit**	**Observed Hours (Hr)**	**Mean**	**Median**	**Standard Error**	**Standard Deviation**	**Sample Variance**	**Minimum**	**Maximum**
$PM_{2.5}$	μg/m³	330	10.98	9.32	0.34	6.19	38.29	0.87	32.68
NO_3^-	μg/m³	335	1.72	1.27	0.08	1.41	2.00	0.32	7.86
SO_4^{2-}	μg/m³	319	2.49	2.26	0.05	0.87	0.76	1.13	6.34
NH_4^+	μg/m³	335	1.31	1.07	0.05	0.90	0.81	0.15	4.70
Organics	μg/m³	316	4.50	3.38	0.16	2.82	7.97	0.86	21.64
OOA (1)	μg/m³	316	2.19	2.00	0.06	1.11	1.23	0.46	6.33
HOA (2)	μg/m³	316	2.31	1.39	0.19	3.35	11.24	0.31	27.68
Elemental Carbon	μg/m³	336	0.69	0.51	0.04	0.68	0.46	0.00	5.47
O_3	ppb	336	26.28	27.50	0.36	6.64	44.12	0.40	38.70
SO_2	ppb	330	9.82	8.60	0.31	5.61	31.45	0.50	32.90
NO	ppb	328	0.43	0.06	0.04	0.72	0.52	0.00	5.31
NO_2	ppb	326	5.21	4.07	0.25	4.49	20.17	0.59	26.99
NO_x	ppb	328	5.61	4.33	0.25	4.50	20.21	0.06	27.04
Isoprene	ppb	120	4.67	3.57	0.30	3.31	10.96	1.95	27.14
HCHO	ppb	323	0.90	0.82	0.03	0.47	0.22	0.18	3.16
Temperature	°C	336	-9.72	-10.10	0.27	4.89	23.94	-20.20	0.30
Relative Humidity	%	336	75.89	74.60	0.65	11.84	140.27	51.60	98.40

(1) Oxygenated-like organic aerosol
(2) Hydrocarbon-like organic aerosol

FIGURE 2

► Time series traces (black line < 22 nm; red line < 68 nm; and blue total) and box plots* for the hourly number concentration (1/cm³) measured by CPC and Nano SMPS deployed at the PSP site from July 12 through August 11 in 2004 and the QC site from January 15 through February 5 in 2004. (Date & Time; EST).

* - The bold line inside of the box - mean value; the boundary of the box closest to zero - the 25th percentile; a line within the box - the median; the boundary of the box farthest from zero - the 75th percentile; whiskers (error bars) above and below the box - the 90th and 10th percentiles.

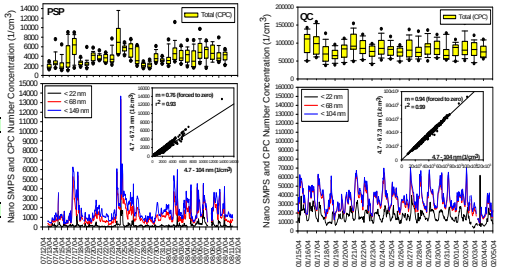


FIGURE 3

► Time-of-day average of CPC total number concentration at the PSP site from July 12 through August 11 in 2004; and the QC site from January 15 through February 5 in 2004.

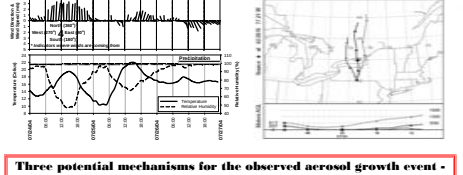


FIGURE 4

► Size distributions and number concentrations measured by Nano SMPS and LDMA SMPS at the PSP site from July 12 through August 11 in 2004.

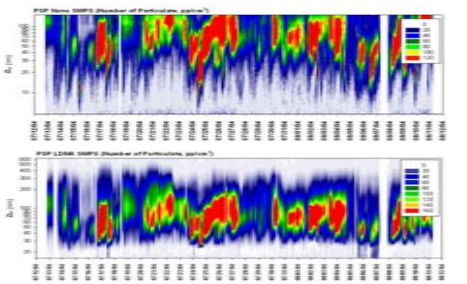
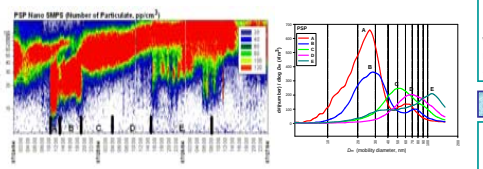


FIGURE 5

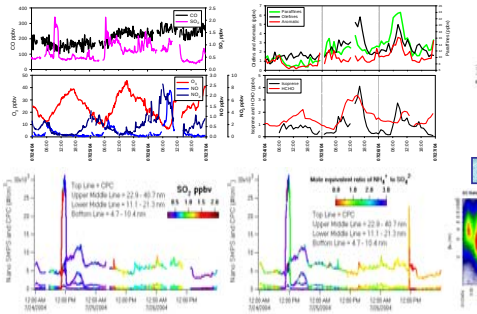
► Size distributions and number concentrations on July 24 and class averages of size distributions with dN/dlog*Dp*



► The event occurred on July 24 during morning hours with very high concentrations of particles with size < 10 nm measured by Nano SMPS

FIGURE 6

► Time series traces for the gases and size concentrations (colored by SO_2 concentration and the mole equivalent ratio of ammonium to sulfate from PILS).



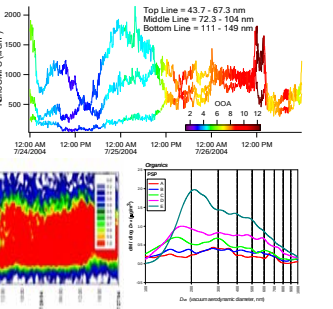
► Particle burst coincides in time with an increase in SO_2 and a transition from basic to acidic ion balance.

FIGURE 7

Three potential mechanisms for the observed aerosol growth event -
► Nucleation via the H_2SO_4-NH_3-H_2O or H_2SO_4-H_2O mechanism due to photochemical reactions oxidizing SO_2 to sulfuric acid
► Coupling between the morning surface layer and the mixed layer
► Transport from stationary sources

FIGURE 8

► Time series traces for the 'Organics' and number concentrations binned by size (colored by OOA).



► Condensation of organics and heterogeneous reactions may also enhance particle growth rates

FIGURE 9

► Growth rate calculated using

$$GR = \Delta D_m / \Delta t$$

where ΔD_m is the change in mode diameter over time Δt.

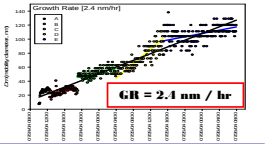


FIGURE 10

► Size distributions and number concentrations measured by Nano SMPS and LDMA SMPS at the QC site.

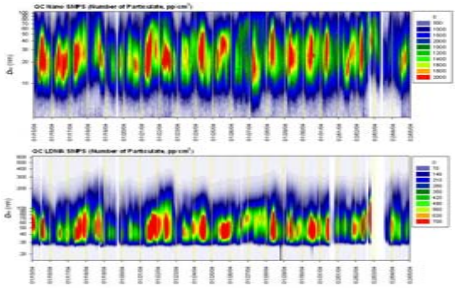
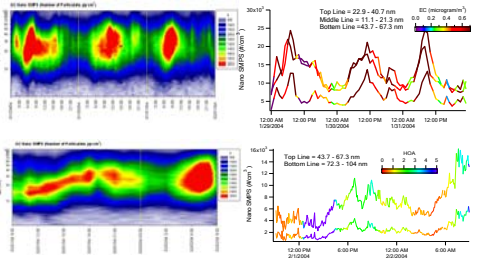


FIGURE 11



CONCLUSIONS AND SUGGESTIONS

► Strong growth of particles at the smallest measurable sizes is relatively infrequent at these sites.
► The strongest event at PSP could be due to one of three mechanisms.
► QC observations show almost daily bursts of small particles well-correlated to traffic patterns (i.e., EC and HOA).
► Condensation of organics (OOA) may also enhance particle growth rates.

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