Wyoming PCASP Concentration, Sizing and Data File Formats

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The purpose of this document is three-fold; first, to present results of laboratory measurements made with the University of Wyoming Passive Cavity Aerosol Spectrometer Probe (PCASP; http://www.dropletmeasurement.com/), second, to describe how the processed PCASP data is archived in Network Common Data Format (NetCDF), and third, to described how data from a Scanning Mobility Particle Sizer (SMPS) is archived. The laboratory studies were conducted in the University of Wyoming Keck Aerosol Lab on 20051205, 20051230, 20060103 and 20060105. PCASP sample flow rate calibrations conducted after 20060105 are also documented here.

Four laboratory activities are documented: 1) the PCASP sample flow meter calibration (20051205), 2) PCASP and SMPS sampling of mobility-classified polystyrene latex (PSL) aerosol (20051230), 3) a check of the aerosol generation system (20060103), and 4) studies of the effect of changing the PCASP threshold from 20 to 5 (20060105). The last experiment was conducted because we are uncertain of the function of the PCASP threshold parameter. It was increased from 5 to 20 soon after we purchased the PCASP, but the effect of this change was never characterized.

PCASP Sample Flow Meter Calibration -

Results of a PCASP mass flow meter calibration are presented in Figure 1. For this work a Gilibrator flow meter was used to measure air flow into the inlet needle of the PCASP. Concurrently, measurements were made of the analog output signal corresponding to the PCASP mass flow meter. Flow rates were varied from 0.5 to 1.5 standard cubic centimeter per second (sccps) by adjusting the sample flow valve of the PCASP. The measured flow rate (Gilibrator) is converted to a volumetric flow rate at standard temperature and pressure (STP) and regressed versus the analog signal. A power fit was applied.

$$\dot{V}_{STP} = \alpha \cdot V_{out}^{\beta} \quad \text{(standard cubic centimeter per second)} \qquad (1)$$

Here V_{out} is the analog output voltage (V-dc) and the conversion from actual volume to standard-state volume is accomplished with P_{STP} =1013 mb, T_{STP} =293 K, local values of pressure and temperature (see below) and the ideal gas equation of state for dry air.

NetCDF Files -

Our data acquisition system records data ten times per second (10 Hz sampling). The resulting data file is processed and in this step the 10 Hz data is converted to a 1 Hz data file. The raw data files are distinguished from the processed files in the following way: The raw data files have the word “raw” in their name and the processed data files have the word “c1” in their name. For example, the processed data analyzed in this report has the name 20051230e.c1.nc, and this was derived from a raw file with the name 20051230e_raw.nc.

SMPS Files –

We also analyze data from a SMPS. Data from this instrument is archived in comma delineated ASCII format files; for the data shown in Figures 2 and 3 the filename is dec3005a.txt.

Particle Count, Concentration and Sizing -

The most current values α and β are often not applied when the raw NetCDF data file (generated by the Keck Lab acquisition system) is processed. Because of this, the flow rate should be updated as

$$\dot{V}_{STP} = \alpha \cdot \left(\left(\frac{\dot{V}}{\alpha_o} \right)^{\frac{1}{\beta_o}} \right)^{\beta} \quad \text{(standard cubic centimeter per second)} \qquad (2)$$

Here $\dot{V}$ (dimensions: standard cubic centimeter per second) is the sample flow value archived in the processed NetCDF file, α_o and β_o are the calibration coefficients (these are attributes of the flow rate variable archived in the processed NetCDF file), and α and β are the most current values of the calibration coefficients. Table 1 presents values of α and β derived between December 2005 and September 2006.

The sccps flow rate from Equation 2 is converted to an actual cubic centimeter per second (accps) via the following relationship

$$\dot{V}_{act} = \dot{V}_{STP} \cdot \frac{T_{pcasp}}{P_{pcasp}} \cdot \frac{P_{STP}}{T_{STP}} \quad \text{(actual cubic centimeter per second)} \qquad (3)$$

Here T_{pcasp} is the temperature of the aerosol sampled by the PCASP (294.15 K is assumed, the PCASP heaters are not operated during laboratory operation), P_{pcasp} is the corresponding pressure (in Laramie 780. mb is assumed if no measurement is made), and T_{STP} and P_{STP} define the standard state.

The array of PCASP concentrations is evaluated as

$$n[*,1:31] = \frac{A[*,1:31]}{\dot{V}_{act}[*]} \quad \text{(concentration, count per actual cm}^3\text{)} \qquad (4)$$

Here $A[*,1:31]$ is the processed NetCDF array containing the particle count and $\dot{V}_{act}$ is the volumetric flow rate (Equation 3). We note that all count values in the subset array $A[*,0]$ are zero and should be ignored. The spectral density for channel "i" is derived as

$$\left(\frac{dn}{d\log_{10} D}\right)_i = \frac{n_i}{\log_{10}(D_i / D_{i-1})} \quad \text{(concentration per decimal log size interval)} \qquad (5)$$

where D_{i-1} and D_i are the particle diameters (thresholds) defining the upper and lower limits of the channel. For this analysis we use size thresholds reported by Peter Liu in April 2005. Results are shown in Table 2 and are based on the method described in Liu et al. (1992). Note that there are 31 size thresholds and that these correspond to the 30 PCASP channels described in the previous section (i.e., $A[*,1:31]$).

Laboratory Issues –

The setup used for the preparation and sampling of mobility-classified PSL aerosol is documented our laboratory notebook. SMPS-A is the scanning DMA and SMPS-B is the selection DMA. An Aerosol Dynamics Inc. (ADI, ^{210}Po) neutralizer is used to charge equilibrate the aerosol subsequent to selection and prior to sampling. Since the polydisperse flow measurements reported by either SMPS-A or SMPS-B are unreliable, these flow values were set with TSI 4100 flow meters. Flow measurements with the 4100 meters were made during nebulization of distilled deionized water, not during nebulization of the PSL aerosols. Flow measurements reported by the TSI 4100 flow meters are intercompared with the BIOS flow meter. The TSI4100 flow value agrees within 2% of the BIOS value.

Water suspensions of Polystyrene latex spheres were prepared in the following ways: 30 drops of concentrated PSL solution (Duke Scientific) into 150 ml of distilled deionized water (491 nm PSL

Catalog Number 3495A), 6 drops of concentrated PSL solution into 150 ml of distilled deionized water (199 nm PSL Catalog Number 3200A) and 5 drops of concentrated PSL solution into 150 ml of distilled deionized water (125 nm PSL Catalog Number 3125A). When atomized these solutions produced 100 to 400 particles per cubic centimeter.

Results of Laboratory Studies -

Size spectra are presented in Figure 2a for 125 nm PSL, in Figure 2b for 199 nm PSL and in Figure 2c for 491 nm PSL. Plotted on the y-axis is spectral density; concentration per decimal logarithmic size interval. The 1 Hz PCASP data was averaged over the 316 second SMPS-A scan intervals. Concentrations reported by the SMPS-A, PCASP and CPC-3 are written on the graphs.

Overall there is reasonable agreement among the SMPS-A and PCASP concentration values, but the PCASP underestimates the SMPS-A concentration by ~10% at 491 nm (Figure 2c). Comparisons between the CPC-3 and PCASP concentration values reveal a 10% discrepancy for all particles sizes with the CPC-3 values consistently larger than the PCASP values.

Mode sizes were evaluated as the midpoint diameter of the channel with the largest spectral density. The derived mode sizes are written on the graphs. The SMPS-A and PCASP mode diameters are in reasonable agreement. There is also reasonable agreement between the PSL size and the mode size values from the SMPS-A and the PCASP. A summary of the size spectra from 20051230 is shown in Figure 3. Here we apply size thresholds shown in Table 2 and compare the resulting spectra to those generated using the factory bin thresholds. Clearly, the former agree better with the SMPS size spectra.

On 20060103 experiments were conducted using a Kr^{80} neutralizer (TSI 774-0043) in front of the scanning SMPS (SMPS-A). This did not significantly alter the amplitude of peaks occurring at sizes smaller than the primary SMPS mode (cf., Figures 2b and 2c). This result indicates that these peaks are not the result of incomplete charge equilibration when only using the ADI neutralizer.

On 20060105 the PCASP threshold was reduced from 20 to 5; results are shown in Table 3. The comparison (threshold 20 versus threshold 5) indicates that a decrease in the PCASP threshold does not increase the average concentration of particles classified in the first channel of the PCASP; nor does the threshold decrease result in an increase in the first-channel standard deviation. From this it is concluded, tentatively, that the “noise” in the first PCASP channel during operation on the King Air is not intrinsic to the PCASP. However, Table 3 also shows that the number of non-zero particle events decreased from ~150 to ~130 in response to a 20 to 5 decrease in the PCASP threshold. This result was not expected.

Bibliography –

Liu, P.S.K, W.R.Leaitch, J.W.Strapp and M.A.Wasey, Response of Particle Measurement Systems airborne ASASP and PCASP to NaCl and latex particles, Aerosol Sci. Technol., 83-95, 1992

		0.1692	780	78000	101300
		1.8828	22.00	295.15	293.00
Sample	Gilibrator	Gilibrator	Gilibrator	Fit Departures	VDP
VDC	accpm	accps	sccps	%	accps
0.99	0.00	0.00	0.00	-16.51	0.00
2.64	81.10	1.35	1.03	-1.72	1.22
2.63	81.72	1.36	1.04	-0.48	1.22
2.63	81.69	1.36	1.04	-0.44	1.22
1.82	40.48	0.67	0.52	-0.47	0.49
1.82	40.81	0.68	0.52	-0.05	0.50
1.82	41.24	0.69	0.53	0.34	0.50
2.23	60.64	1.01	0.77	0.90	0.85
2.22	60.20	1.00	0.77	0.47	0.85
2.22	60.17	1.00	0.77	0.43	0.85
2.93	100.80	1.68	1.28	0.16	1.49
2.93	100.90	1.68	1.29	0.21	1.49
2.93	100.70	1.68	1.28	0.04	1.49
3.25	122.90	2.05	1.57	1.06	1.76
3.25	123.50	2.06	1.57	1.46	1.77
3.25	121.70	2.03	1.55	-0.83	1.77
2.63	82.09	1.37	1.05	-0.08	1.22
2.63	81.19	1.35	1.03	-1.01	1.22
2.63	82.13	1.37	1.05	0.19	1.22

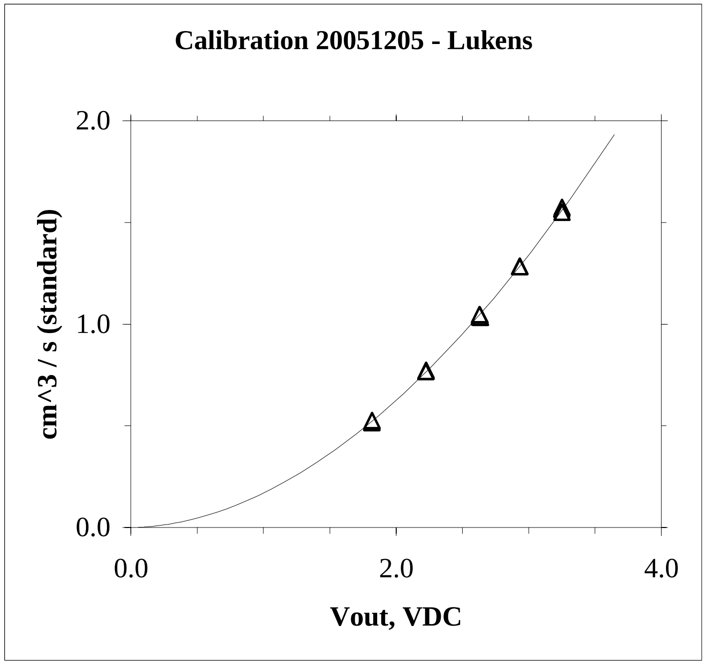

Figure 1 – Flow calibration of the PCASP mass flow meter from C:\jeff\keck\keck_pcasp\flow_calibration.xls

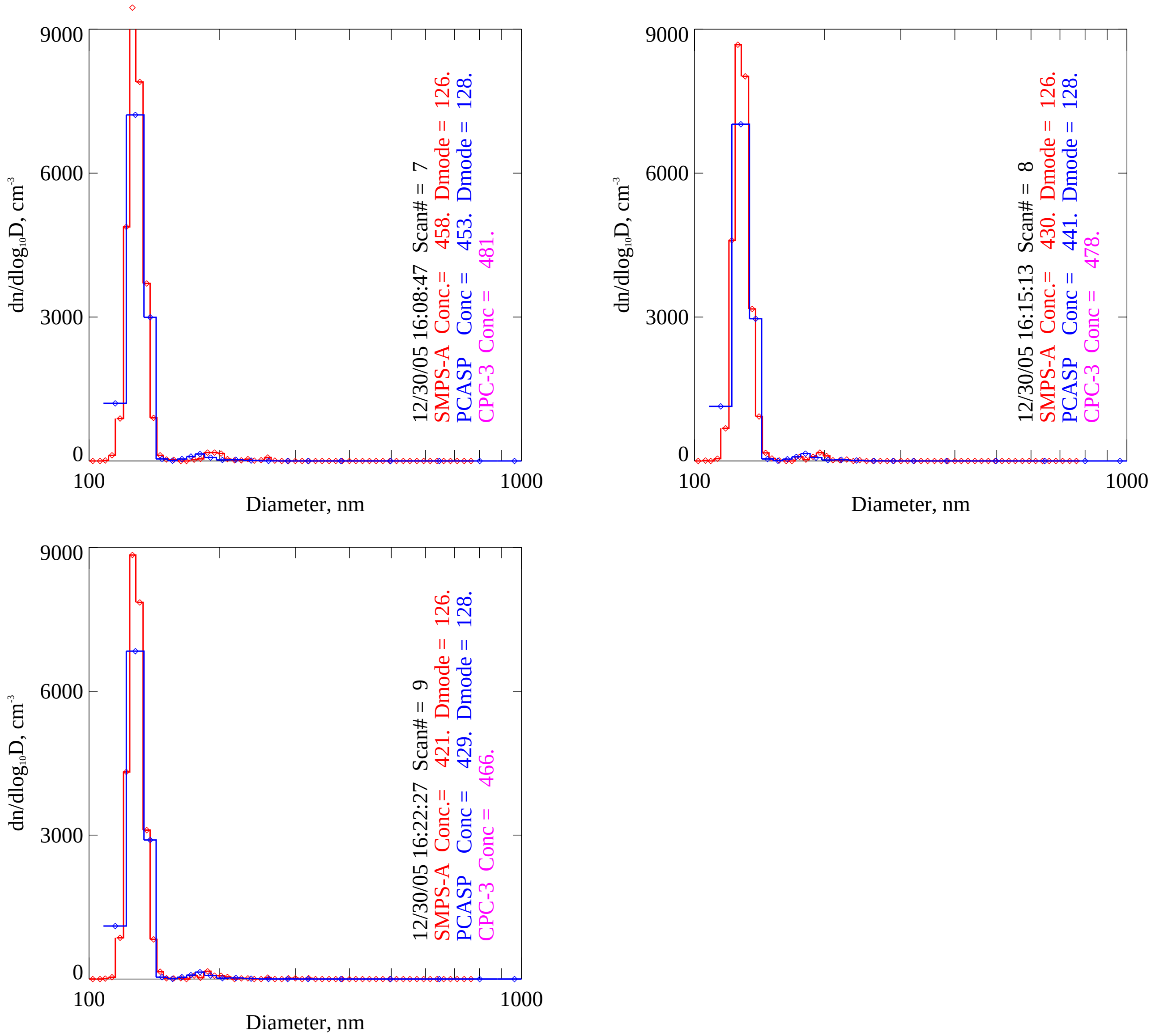

Figure 2a – 125 nm PSL. The histograms are based on lower- and upper-bound bin thresholds (Table 2). Symbols indicate the channel mid-point diameters.

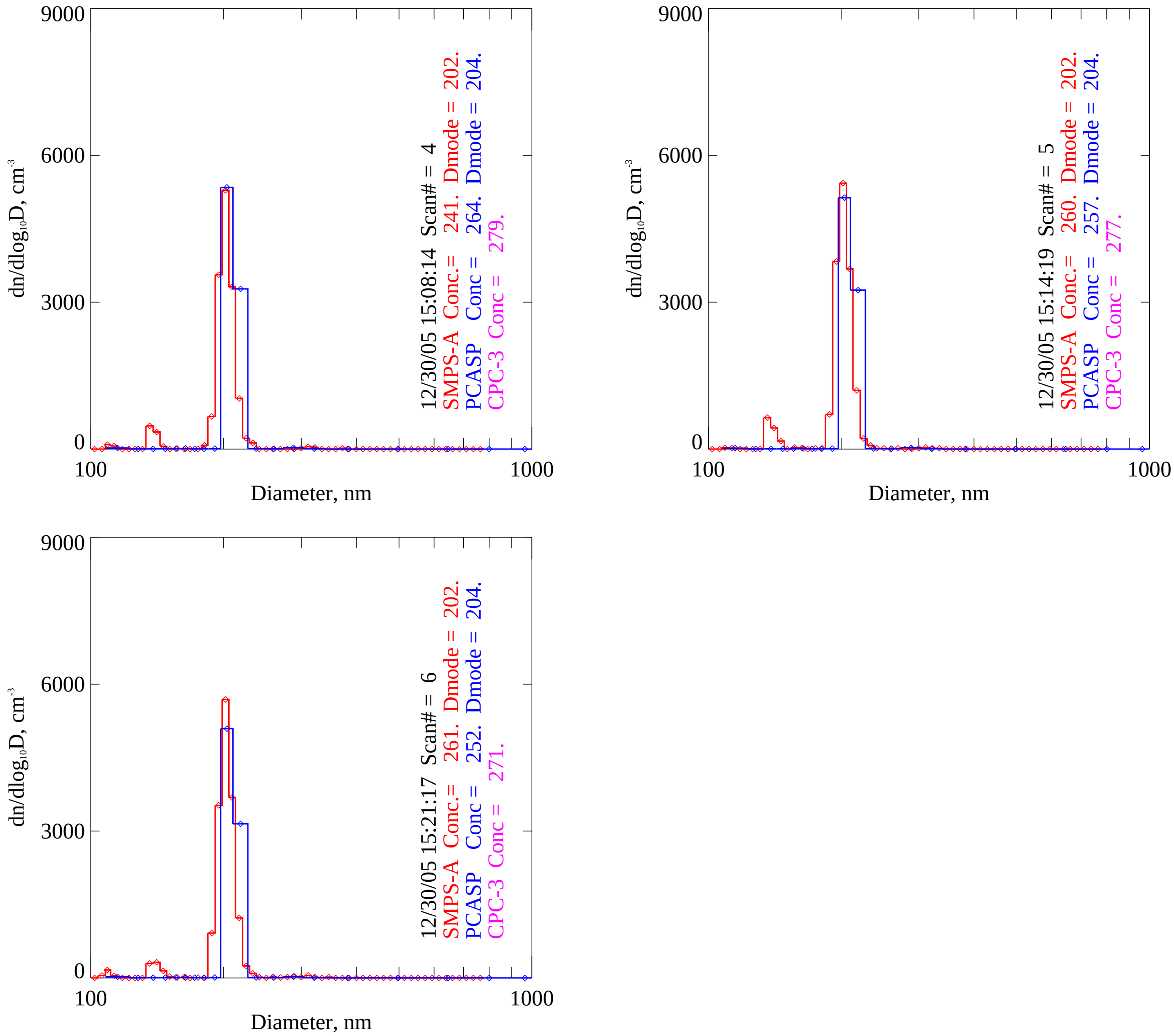

Figure 2b – 199 nm PSL. The histograms are based on lower- and upper-bound bin thresholds (Table 2). Symbols indicate the channel mid-point diameters.

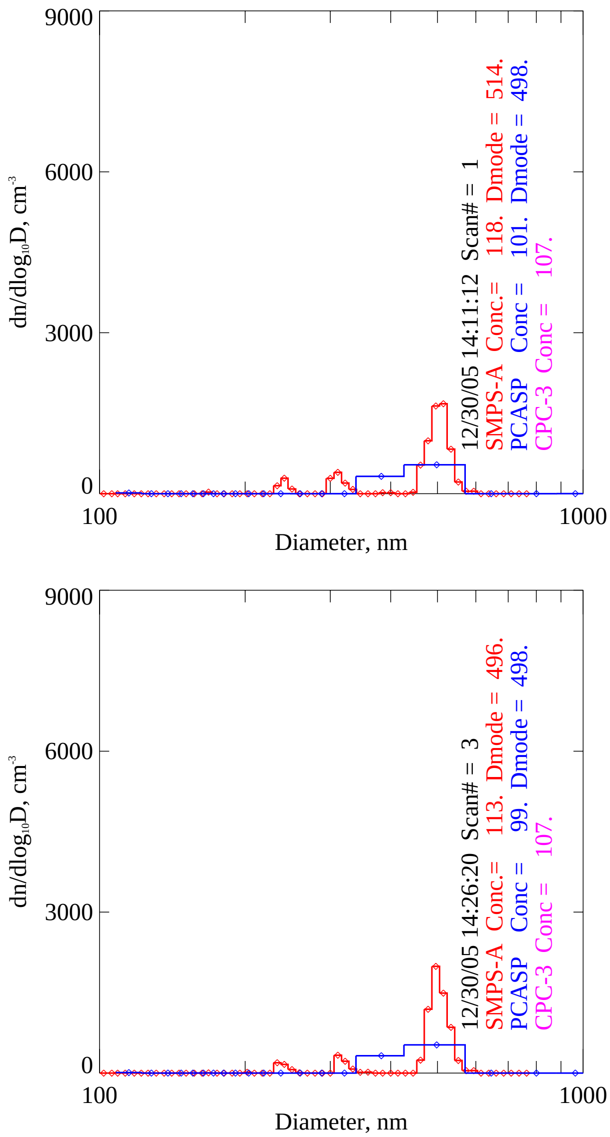

Figure 2c – 491 nm PSL. The histograms are based on lower- and upper-bound bin thresholds (Table 2). Symbols indicate the channel mid-point diameters.

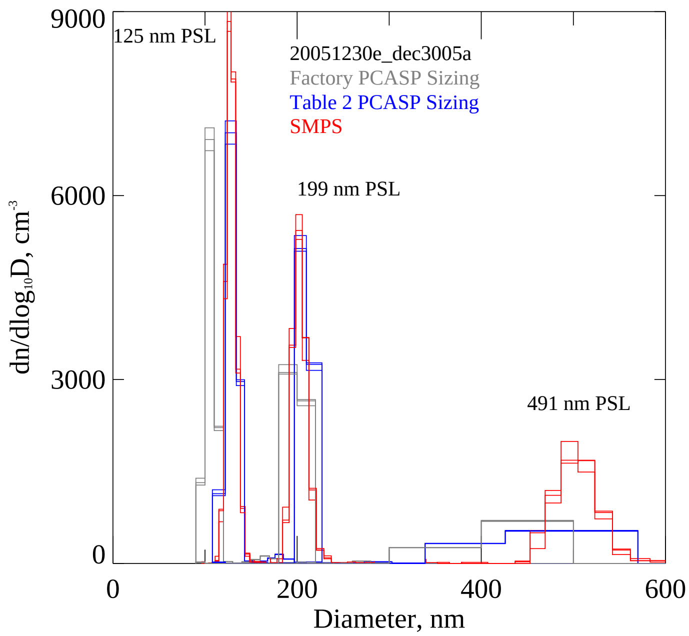

Figure 3 – Size spectra corresponding to mobility-selected PSL test aerosols. Measurements made at each of the indicated PSL sizes were repeated three times and all 27 spectra are shown; however, for clarity the modes recorded by the SMPS at sizes smaller than the primary mode were removed. The PCASP mode sizes corresponding to the factory size thresholds are smaller than PCASP modes based on size thresholds shown in Table 2. Furthermore, the PCASP mode sizes corresponding to Table 2, the SMPS mode sizes and the PSL size particles all agree.

Date	α	β	sccps @ V=2.85 V-dc	Departure in sccps from 9-Dec-05 in %
9-Dec-05	0.1698	1.8828	1.22	0
5-May-06	0.1196	2.1374	1.12	-8
7-Jul-06	0.1248	2.0659	1.09	-11
19-Sep-06	0.1293	2.0989	1.16	-5
10/20/2006	0.1265	2.0663	1.10	-10

Table 1 – PCASP sample mass flow meter calibration coefficients

Table 2, Refractive Index = 1.59 Sizing (April 2005)

Chan #	Diameter Threshold, μm	Chan #	Diameter Threshold, μm	Chan #	Diameter Threshold, μm
1	0.108	11	0.210	21	1.047
2	0.122	12	0.227	22	1.222
3	0.134	13	0.247	23	1.405
4	0.143	14	0.273	24	1.596
5	0.152	15	0.303	25	1.794
6	0.160	16	0.339	26	2.001
7	0.168	17	0.426	27	2.215
8	0.176	18	0.570	28	2.437
9	0.185	19	0.721	29	2.667
10	0.197	20	0.880	30	2.905
					3.151

Table 2 – Channel-to-size assignments derived in April 2005 by P.S.K.Liu (Liu et al., 1992)

	PCASP lower-bound size threshold (um) (according to factory)												
	0.09	0.10	0.11	0.12	0.13	0.14	0.15	0.16	0.17	0.18	0.20	0.22	0.24
0.20 um PSL, threshold = 20, December 30, 2005													
Start time of 316 s sampling interval (LT)	150814												
Mode PCASP diameter (um)	0.20												
Average of 1 Hz PCASP samples in 316 s sampling interval (including zeros)	1.6	0.2	0.2	0.2	0.3	0.4	0.1	0.2	0.3	206.2	153.8	0.5	0.3
Standard Deviation of 1 Hz PCASP samples in 316 s sampling interval (including zeros)	3.0	0.4	0.4	0.4	0.5	0.6	0.4	0.4	0.6	14.8	12.7	0.7	0.6
Number of non-zero 1 Hz PCASP samples in the 316 s sampling interval	153	51	51	54	73	99	42	45	96	316	316	114	93
Start time of 316 s sampling interval (LT)	151419												
Mode PCASP diameter (um)	0.20												
Average of 1 Hz PCASP samples in 316 s sampling interval (including zeros)	1.4	0.2	0.2	0.2	0.2	0.4	0.1	0.1	0.3	198.1	152.6	0.5	0.4
Standard Deviation of 1 Hz PCASP samples in 316 s sampling interval (including zeros)	2.8	0.4	0.5	0.5	0.5	0.6	0.3	0.3	0.6	14.9	13.0	0.8	0.7
Number of non-zero 1 Hz PCASP samples in the 316 s sampling interval	149	61	48	64	68	96	36	36	89	316	316	128	112
Start time of 316 s sampling interval (LT)	152117												
Mode PCASP diameter (um)	0.20												
Average of 1 Hz PCASP samples in 316 s sampling interval (including zeros)	1.6	0.2	0.2	0.2	0.3	0.3	0.1	0.1	0.3	196.5	148.0	0.4	0.4
Standard Deviation of 1 Hz PCASP samples in 316 s sampling interval (including zeros)	2.8	0.4	0.5	0.5	0.6	0.6	0.3	0.4	0.6	14.1	12.9	0.6	0.6
Number of non-zero 1 Hz PCASP samples in the 316 s sampling interval	161	52	63	72	81	86	41	38	94	316	316	118	104
0.20 um PSL, threshold = 5, January 5, 2006													
Start time of 316 s sampling interval (LT)	143913												
Mode PCASP diameter (um)	0.20												
Average of 1 Hz PCASP samples in 316 s sampling interval (including zeros)	1.4	0.2	0.2	0.2	0.2	0.3	0.1	0.1	0.3	230.2	137.2	0.5	0.5
Standard Deviation of 1 Hz PCASP samples in 316 s sampling interval (including zeros)	3.0	0.4	0.4	0.5	0.4	0.5	0.3	0.3	0.5	15.8	12.1	0.7	0.7
Number of non-zero 1 Hz PCASP samples in the 316 s sampling interval	128	51	51	54	59	88	22	29	85	316	316	133	116
Start time of 316 s sampling interval (LT)	144612												
Mode PCASP diameter (um)	0.20												
Average of 1 Hz PCASP samples in 316 s sampling interval (including zeros)	1.1	0.2	0.2	0.1	0.2	0.3	0.1	0.1	0.3	224.8	136.1	0.4	0.4
Standard Deviation of 1 Hz PCASP samples in 316 s sampling interval (including zeros)	2.5	0.4	0.4	0.4	0.4	0.5	0.3	0.4	0.6	14.9	12.4	0.6	0.7
Number of non-zero 1 Hz PCASP samples in the 316 s sampling interval	126	47	42	43	58	83	36	29	88	316	316	110	113
Start time of 316 s sampling interval (LT)	145222												
Mode PCASP diameter (um)	0.20												
Average of 1 Hz PCASP samples in 316 s sampling interval (including zeros)	1.3	0.2	0.2	0.2	0.2	0.3	0.1	0.1	0.3	228.0	129.9	0.5	0.5
Standard Deviation of 1 Hz PCASP samples in 316 s sampling interval (including zeros)	2.6	0.4	0.4	0.4	0.4	0.6	0.4	0.3	0.6	14.8	12.3	0.7	0.7
Number of non-zero 1 Hz PCASP samples in the 316 s sampling interval	129	49	47	49	52	77	38	23	75	316	316	120	113

Table 3 – Summary for the lowest 13 channels of the PCASP during laboratory studies conducted on 30 December 2005 (top block of data) and 5 January 2006 (bottom block of data). The test aerosol is 0.199 um PSL (mobility classified). The comparison (threshold 20 versus threshold 5) indicates that a decrease in the PCASP threshold does not increase the average concentration of particles classified in the first channel of the PCASP; nor does the threshold decrease result in an increase in the first-channel standard deviation.