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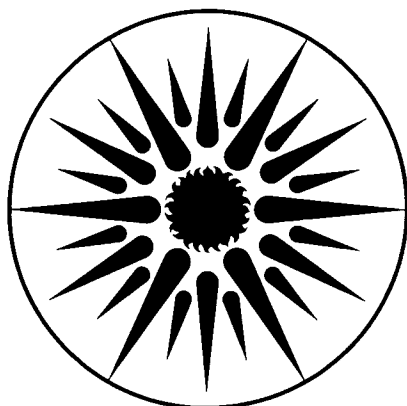
**Real-Time Measurement of the Size Fractionation of
Aerosol Black Carbon during the South Coast Air
Quality Study, June 13–September 4, 1987,
Claremont College, Claremont, California:
Preliminary Report**

A.D.A. Hansen and T. Novakov

May 1988

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REAL-TIME MEASUREMENT OF THE SIZE FRACTIONATION
OF AEROSOL BLACK CARBON DURING THE
SOUTH COAST AIR QUALITY STUDY, JUNE 13 - SEPTEMBER 4, 1987,
CLAREMONT COLLEGE, CLAREMONT, CALIFORNIA*

Preliminary Report, May 1988

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Abstract

During the periods June 13 to July 28 and August 17 to September 4, 1987, the Atmospheric Aerosol Group of Lawrence Berkeley Laboratory participated in the South Coast Air Quality Study conducted at Claremont College, Claremont, California. We used a multi-channel aethalometer preceded by size-selective inlets to determine the concentration of aerosol black carbon in two size ranges in real time. In this report we present our results from this study in the form of one-hour and periodic (typically 12-hour) averages of carbon concentrations for the total suspended aerosol and for the fraction having aerodynamic diameter smaller than approximately 0.3 μm . The total concentration results show daily mean values generally ranging from 1 to 4 $\mu\text{g}/\text{m}^3$, with a diurnal cycle showing little variation during nighttime hours and a pronounced peak between the hours of 8 am and 10 am. The results for the size fractionation show that the great majority of the aerosol black carbon was found in the size range smaller than 0.3 μm ; however, this fraction showed a systematic diurnal variation with a decline in the morning and the mid-day periods.

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Introduction

One of the components of combustion-derived aerosols is carbon with a microcrystalline graphitic structure (Wolff, 1981). Due to its large optical absorption cross section, this material is termed black carbon. It is produced only during incomplete high-temperature combustion; it cannot be formed or significantly transformed by secondary atmospheric processes. It is therefore a direct tracer for combustion emissions. Due to its long atmospheric lifetime, aerosol black carbon may be transported considerable distances from its source, leading to medium- and long-range impacts on both atmospheric physics (e.g., visibility degradation in distant regions downwind) and atmospheric chemistry (e.g., heterogeneous reactions leading to the oxidation of SO_2).

Both chemical and optical methods for determining the black carbon content of aerosol samples collected on filters have been developed and are in common use at many laboratories. However, these measurements require that a moderate loading of the aerosol be collected on the filter, and it is therefore not generally possible to obtain time resolutions of better than 1-2 hours in most urban locations. The aethalometer uses a continuous optical technique to measure aerosol black carbon in real time.

A single-channel aethalometer was used during the Carbonaceous Species Methods Comparison Study, conducted at Citrus College, Glendora, California from August 12 - 21, 1986 (Hansen and Novakov, 1987; work supported by the Coordinating Research Council). In that study, data was recorded with one-minute time resolution, resulting in 12252 data points for the nine-day period. The results showed that vehicular sources in the immediate vicinity could have pronounced influence on the concentration of aerosol black carbon on a short time scale. Plumes of duration 3 - 8 minutes were detected during which the instantaneous concentration of aerosol black carbon might increase by a factor of two or three relative to its value when the particular vehicle departed. However, this 1986 study did not give an indication as to the size distribution of the carbonaceous aerosol. One of the objectives of the 1987 SCAQS experiment was to study the size distribution of optically active aerosol species, with a view to investigating sources, size distribution transformations and the influence of humidity on the size distribution. Ambient atmospheric aerosol particles may contain both hygrophilic and hydrophobic materials. The proportions and the degree of mixing of these constituents will determine the response of the aerosol to humidity. The water associated with aerosols has a substantial influence on aerosol physical and chemical properties. The water layer will influence the optical properties of the aerosol: by both increasing the size and changing the refractive index of the aerosol (Sverdrup and Whitby, 1980; Covert et al., 1980), the adsorption of water will increase the scattering and absorption of light by the aerosol. The nucleation characteristics of the aerosol will determine its growth under high-humidity or condensing conditions and will

therefore strongly affect its rate of removal from the atmosphere by "wet" processes (Pueschel et al., 1981; Penner and Edwards, 1986). The presence of liquid water will allow aqueous-phase chemical reactions to occur. Very few species- and element-specific studies of aerosol response to changing humidity have been reported, and those reports deal principally with sulfate and nitrate (Pruppacher et al., 1983). Consequently, we constructed a multi-channel aethalometer: three channels were operated, one channel collecting the total aerosol, the next channel preceded by an impactor whose cut-off removed all particles of aerodynamic diameter greater than 1 μm , and the third channel preceded by an impactor of cut-off 0.3 μm . By comparing the results of these simultaneous measurements it is possible to determine in real time the aerosol black carbon concentration and attributes of its size distribution.

Experimental Details

The aethalometer operates by measuring the light transmission through a quartz fiber filter while air is being drawn through the filter (Hansen et al., 1982; Hansen et al., 1984). The absorption of light in the visible spectrum by ambient aerosols is primarily due to the presence of microcrystalline graphitic carbon. When suspended as a submicron aerosol and not surrounded by a droplet of water or other adsorbed optically-scattering material, the optical absorption cross-section of this material is approximately 8 m^2/g in the wavelength range 500 - 600 nm (Roessler and Faxvog, 1979). When collected on a fibrous filter, multiple internal reflections enhance the optical absorption approximately threefold and nullify the effects of scattering from the particles (Rosen and Novakov, 1983). Under these circumstances, the attenuation of light transmitted through the filter is due to the absorbing "elemental" or "black" carbon component of the aerosol and is not affected by light-scattering components such as organics, adsorbed water films, or sulfate and nitrate compounds. Solvent extraction followed by thermal analysis of the deposit on the quartz fiber filter can yield a quantitative chemical analysis of the amount of black carbon present (Gundel et al., 1984). Extensive work at LBL and elsewhere has shown that the optical measurement on a filter-collected sample can be calibrated to provide a quantitation of aerosol black carbon, with the relationship

$$-\Delta \ln I = \sigma \Delta S$$

The reduction of transmitted light intensity $\Delta \ln I$ is proportional to the incremental surface loading ΔS of black carbon on the filter, with the coefficient σ being the optical attenuation cross section. For quartz fiber filters, this coefficient has the value of 25.4 $\pm$ 1.7 m^2/gram measured at a wavelength of 632 nm.

In the aethalometer, the ambient air with black carbon concentration C g/m³ is drawn through the filter at velocity V m/s. The increment of black carbon collected in time ΔT results in a decrease in the light transmission of

$$-\Delta \ln I = \sigma * C * V * \Delta T .$$

A block diagram of the aethalometer measurement head is shown in Figure 1. The aerosol is collected only on a portion of the filter covering the detectors ("Channel 1", etc.). Another detector placed under a non-collecting portion of the filter gives a reference for the beam intensity. The transparent inlet head is diffusely illuminated; when pumping is applied to the filtering channels, the gradual accumulation of black carbon causes the "signal" intensities to slowly diminish relative to the "reference" intensity. The electronics and microcomputer convert the detectors' outputs into attenuation accumulation rates $\Delta \ln I / \Delta T$ from which the aerosol black carbon concentration in that channel's airstream can be calculated. The spectral convolution of the output of the incandescent lamp and the response of the detectors gives an effective measurement spectrum peaking in intensity between 500 nm and 700 nm. Previous work has shown that the absorption spectrum of ambient aerosols is essentially uniform and shows very little structure in the visible range. (Rosen et al., 1978).

The collecting spot areas of the filter were 0.71 cm², and the air flow rates were 4.5 liters per minute, controlled by critical orifices. Size separation of the aerosol was achieved by preceding two of the aethalometer channels by multi-orifice impactors (manufactured by Pollution Control Systems Corp.) operating at flowrates of 12 standard liters per minute. The remaining flow of 7.5 liters per minute was bypassed. Air flow rates were measured periodically with a standard gas test meter, but were not found to change significantly. The filter was changed usually every 12 hours, resulting in a flow through the active filter area of approximately 4.5 m³/cm². These filters were subsequently analyzed in the laboratory for total black carbon content, using the laser transmissometer whose measurements have been calibrated by the solvent extraction / quantitative thermal analysis method. The results were compared to the integral of the real-time output over the appropriate period to check the calibration. The aethalometer was set up at the east end of the SCAQS platform, with its inlet at 5 feet above ground level.

Results

The results are appended in two forms, with data divided for tabulation convenience into blocks representing sampling from between five to ten days:

(1) results from analyses of the filters, giving average black carbon concentrations for the total aerosol and for the sub - 0.3 μm aerosol channel for periods of usually 12 hours; and

(2) mean hourly concentrations of aerosol black carbon averaged over all the reporting hours in the data block, for both size ranges.

Filter analyses

One hundred and twenty three filters were collected by the aethalometer, mostly covering 12 - hour periods with changes in the morning and the evening. The total optical attenuation of the filter deposit was calculated both from the aethalometer data and from laboratory analysis of the filters. This gives the black carbon loading per square centimeter of the filter, and hence the mean ambient black carbon aerosol concentration sampled by that aethalometer channel during the sampling period. The results for the two channels, representing the total aerosol and the aerosol of aerodynamic diameter less than 0.3 μm , are presented as the rightmost two columns of the upper portion of each table. The units are micrograms per standard cubic meter. Concentrations ranged generally from 1 to 4 $\mu\text{g}/\text{m}^3$. These results are presented graphically in Figures 2, 3 and 4. Each of these figures shows the mean concentration of aerosol black carbon measured by the total aerosol channel of the aethalometer, covering ranges of dates representing about three weeks of sampling per figure. The horizontal axis tick marks on these figures indicate 3 - day intervals. The unusually high concentration displayed near the center of Figure 3 is seen from the data tabulation (Table 6, line 4) as being the analysis of a filter that was operated for only a short period of time one afternoon, spanning the afternoon local traffic maximum. With this exception, the data show lower concentrations that one might at first expect for this location: however, the meteorological conditions during the entire SCAQS timeframe were anomalous, leading to unusually high ventilations, occasional midsummer rain, weak or non-existent temperature inversions, and conditions generally quite unconducive to the typical summer stagnation smog expected at this inland receptor location.

Hourly averages

Within each data block, the measurements for each hour have been averaged together to form a mean diurnal cycle for the dates spanned by each data block grouping. The results are calculated both for the total aerosol black carbon concentrations, and also for the concentrations measured by the channel preceded by the impactor excluding particles of aerodynamic diameter greater than 0.3 μm . These results are shown in the lower portion of each table, with the 'Hour Start' column giving the hour number (local time) from the minutes zero to 59 of which the average is calculated. Figures 5 - 13 show this data in graphical form, one figure for each data block date range. It is clear that concentrations are generally stable from the mid-evening to the early morning hours, but show a decrease from 7 am to approximately 2 or 3 pm on which is superimposed a large increase in the morning and afternoon traffic hours. This behaviour is shown more directly by Figures 14 and 15 in which the hourly data are shown side by side for the various blocks. Figure 14 combines the data from June 13th to July 28th 1987, the first SCAQS summer session, represented by data blocks 1 - 6. Figure 15 combines data blocks 7 - 9, covering the dates 17th August to 4th September of the second session. Both of these figures show remarkable nighttime constancy of total aerosol black carbon concentration measurements over these multi-week periods from approximately 6 pm to 6 am, but considerable variability in the morning and daytime traffic -impacted hours.

Figures 16 - 24 show the average diurnal cycles of the fraction of the black carbon aerosol measured in the sub - 0.3 μm size range, expressed as percentages. Due to instrumental scaling, these results occasionally appear to exceed 100%, in which case they should be properly interpreted as equalling 100% to the resolution of the system. For some blocks, data recording problems caused loss of data at certain times leading to a few omissions. Generally, the results show that for most of the evening and the night, this fraction was steady and close to 100%. Particularly in the earlier portions of the study, this fraction gradually declined during the early morning hours. In all cases, a reduction was seen in the middle of the day. This could be due either to growth of the previously-small aerosol, or dilution of it by the addition of larger-particle carbonaceous aerosols, possibly from the same local sources that were responsible for the daytime increase in total aerosol black carbon concentration. Figures 25 and 26 show this data side by side for the block groupings in the two SCAQS sessions for the purposes of comparison. Again, results are consistent for the nighttime hours, but show more variability during the day. The gradual decline of the sub - 0.3 μm fraction percentage of the total is quite evident for the hours midnight to 7 am in the data shown in Figure 25 for the first SCAQS 1987 summer session. This drop of 12-15% in the value of the sub - 0.3 μm fraction reflects a change in the aerosol size distribution during this time period.

It is likely that the nighttime aerosol typically consisted of a mixture of local, fresh source material (mostly traffic), and well-aged aerosols from the previous day. In the early morning hours, air temperatures were often 20°C lower than afternoon high temperatures. This temperature drop coupled with the extensive use of landscape misters and sprinklers in the small hours resulted in visible watery haze and high relative humidity in the morning. The liquid water content of such a haze is low and we would therefore not expect the data to show a significant growth of the aerosol into the size fraction greater than 1 μm . This result was observed: the data for the channel preceded by the impactor of 1 μm cutpoint are essentially identical to those for the total aerosol channel. However, as discussed above, we did observe a relative decrease of 10-15% for the concentration of aerosol black carbon measured by the channel preceded by the 0.3 μm cutpoint impactor. Thus, a certain fraction of the sub - 0.3 μm aerosol grew in size but did not grow larger than 1 μm . This growth may have been humidity related and caused by the accretion of water by a fraction of the carbonaceous particles' population.

Conclusions

During the summer session of the 1987 South Coast Air Quality Study conducted in the inland region of the California South Coast Air Basin, we performed measurements of black carbon in real time in both the total aerosol and the aerosol of aerodynamic diameter smaller than 0.3 μm . The results from the analysis of 12 - hour filters show average concentrations generally ranging from 1 $\mu\text{g}/\text{m}^3$ to 4 $\mu\text{g}/\text{m}^3$. Collecting the real-time data into hourly averages shows concentrations typically stable overnight, but showing peaks between 8 am and 10 am every morning. The percentage fraction of the 'elemental' carbonaceous aerosol in the size range smaller than 0.3 μm was generally very close to 100% overnight, gradually decreasing in the early morning hours (especially during the first summer SCAQS session), and showing a minimum of around 70% during midmorning hours when the influence of local sources may have been most pronounced. A measurement of aerosol black carbon is a tracer for the impact of combustion emissions at a site at any time scale. Over periods of hours, the measurements reflect fuel use patterns, local meteorology, and local to regional transport. On a shorter time scale, these scales are correspondingly reduced to those of individual source (e.g., vehicle) activity in the immediate neighborhood. The aethalometer, with its capacity of temporal resolution, therefore makes a valuable contribution to the study of primary combustion emissions. When coupled with size selection to study the size distribution of this primary emission tracer, we may obtain insights into the capacity of these aerosols for growth either by coagulation or by the nucleation and accretion of water.

Acknowledgments

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References

- Covert, D. S., et al. (1980), in The Character and Origins of Smog Aerosols, (G. M. Hidy et al., eds.), Wiley, New York, p. 559.
- Gundel, L. A., R. L. Dod, H. Rosen, and T. Novakov (1984), "The relationship between optical attenuation and black carbon concentration for ambient and source particles," Sci. Total Environ., 36, 197-202.
- Hansen, A. D. A., H. Rosen, and T. Novakov (1982), "Real-time measurement of the absorption coefficient of aerosol particles," Appl. Opt., 21, 3060-3062.
- Hansen, A. D. A., H. Rosen, and T. Novakov (1984), "The aethalometer - an instrument for the real-time measurement of optical absorption by aerosol particles," Sci. Total Environ., 36, 191-196.
- Hansen, A. D. A., and T. Novakov (1987), "Real-time measurement of aerosol black carbon during the Carbonaceous Species Methods Comparison Study August 12 - 21, 1986, Citrus College, Glendora, California", Final Report to the Coordinating Research Council, November, 1987, Lawrence Berkeley Laboratory Report LBL-24582, University of California, Berkeley, CA
- Penner, J. E., and L. L. Edwards (1986), in Proceedings, 23rd Conference on Radar Meteorology and Conference on Cloud Physics, Snowmass, Colorado, September 22-26, 1986, American Meteorological Society, Vol. 2, p. 83.
- Pruppacher, H. R., Semonin, R. G., and Slinn, W. G. N., eds. (1983), Precipitation Scavenging, Dry Deposition and Resuspension, Elsevier, New York.
- Pueschel, R. F. et al. (1981), Geophys. Res. Lett., 8, 221-224.

Roessler, D. M., and F. R. Faxvog (1979), "Optoacoustic measurement of optical absorption in acetylene smoke," J. Opt. Soc. Amer., 69, 1699-1703.

Rosen, H., A. D. A. Hansen, L. A. Gundel and T. Novakov (1978), "Identification of the optically absorbing component in urban aerosols," Appl. Opt., 17, 3859-3861.

Rosen, H., and T. Novakov (1983), "Optical transmission through aerosol deposits on diffusely reflective filters: a method for measuring the absorbing component of aerosol particles," Appl. Opt., 22, 1265-1267.

Sverdrup, G. M., and Whitby, K. T. (1980), in The Character and Origins of Smog Aerosols, (G. M. Hidy et al., eds.), Wiley, New York, p. 527.

Wolff, G. T. (1981), "Particulate elemental carbon in the atmosphere," JAPCA, 31, 935-938, which summarizes the 1980 symposium "Particulate Carbon: Atmospheric Life Cycle."

Data Tabulation Summary1987 South Coast Air Quality StudyLawrence Berkeley Laboratory Aerosol Black Carbon Data

Data are reported in nine grouping blocks:

Block 1: 6/13/87 - 6/18/87
Block 2: 6/18/87 - 6/26/87
Block 3: 6/26/87 - 7/03/87
Block 4: 7/03/87 - 7/11/87
Block 5: 7/11/87 - 7/18/87
Block 6: 7/18/87 - 7/28/87
Block 7: 8/17/87 - 8/22/87
Block 8: 8/22/87 - 8/30/87
Block 9: 8/30/87 - 9/04/87

Data are reported for total aerosol black carbon, and for aerosol black carbon in the size fraction of aerodynamic diameter 0.3 μm and smaller. Reporting units are micrograms per cubic meter. The first portion of each summary table lists the operating dates and times for each filter period, and the mean aerosol black carbon concentrations in each size range calculated for those periods. The second portion lists the concentrations averaged by starting hour over the dates covered in the block, to calculate a mean diurnal cycle for the days in the block.

Table 1

Summary from data block 1

Start Day	Start Month	Start Time	End Day	End Month	End Time	Mean Total	B.C. <.3um
13	6	2018	14	6	919	2.41	1.99
14	6	952	14	6	1830	1.45	1.33
14	6	1837	15	6	839	1.16	1.19
15	6	849	15	6	1146	2.24	2.32
15	6	1748	15	6	2055	0.68	1.27
15	6	2104	16	6	834	1.75	1.87
16	6	857	16	6	1617	3.26	3.14
16	6	1631	17	6	839	1.91	2.03
17	6	850	17	6	1707	2.56	2.66
17	6	1719	18	6	838	2.13	1.87
18	6	852	18	6	1653	2.84	3.14

Hour Start	B.C. Total	BC < .3 um	Hour Start	B.C. Total	BC < .3 um	Hour Start	B.C. Total	BC < .3 um
0	2.19	2.21	8	2.33	----	16	1.63	1.47
1	1.71	1.61	9	6.06	6.24	17	1.64	1.71
2	1.94	1.90	10	3.55	2.87	18	2.22	2.13
3	1.75	1.66	11	1.53	0.96	19	3.00	2.88
4	1.54	1.48	12	2.40	1.94	20	2.30	2.25
5	1.81	1.68	13	2.54	1.98	21	1.88	1.84
6	2.43	2.12	14	2.72	2.26	22	1.58	1.50
7	1.22	----	15	3.18	2.68	23	1.81	1.72

Table 2

Summary from data block 2

Start Day	Start Month	Start Time	End Day	End Month	End Time	Mean Total	B.C. <.3um
18	6	1705	19	6	807	2.10	2.16
19	6	836	19	6	1750	2.92	3.36
19	6	1815	20	6	919	1.54	1.58
20	6	941	20	6	1946	1.64	1.56
20	6	2006	21	6	1115	1.22	1.08
21	6	1132	21	6	2102	0.94	1.06
21	6	2128	22	6	840	1.61	1.61
22	6	851	22	6	1708	3.33	3.28
22	6	1720	23	6	915	1.94	1.96
23	6	927	23	6	1755	3.39	2.77
23	6	1807	24	6	812	1.70	1.63
24	6	827	24	6	1727	3.99	3.39
24	6	1741	25	6	826	2.67	2.74
25	6	839	25	6	1804	4.02	3.39
25	6	1815	26	6	840	2.49	2.43

Hour Start	B.C. Total	BC < .3 um	Hour Start	B.C. Total	BC < .3 um	Hour Start	B.C. Total	BC < .3 um
0	1.75	1.75	8	5.35	5.19	16	2.86	2.69
1	1.93	1.89	9	2.67	2.54	17	3.33	3.03
2	1.77	1.66	10	1.82	1.47	18	2.30	2.09
3	1.78	1.62	11	2.16	1.62	19	2.11	2.04
4	1.71	1.56	12	2.89	2.25	20	1.80	1.84
5	1.55	1.41	13	1.93	1.60	21	1.72	1.77
6	1.37	1.26	14	1.07	0.95	22	1.40	1.43
7	0.98	0.84	15	2.04	1.85	23	1.85	1.81

Table 3

Summary from data block 3

Start Day	Start Month	Start Time	End Day	End Month	End Time	Mean Total	B.C. <.3um
26	6	851	26	6	1733	4.08	3.58
26	6	1748	27	6	915	2.05	2.12
27	6	943	27	6	1855	2.57	2.51
27	6	1914	28	6	1415	1.44	1.44
28	6	1431	28	6	2112	1.25	1.44
28	6	2129	29	6	901	1.58	1.74
29	6	915	29	6	1937	2.50	2.56
29	6	2003	30	6	839	1.74	1.82
30	6	859	30	6	1744	2.70	2.70
30	6	1800	1	7	842	2.06	2.13
1	7	853	1	7	1857	2.79	2.87
1	7	1907	2	7	822	2.02	2.19
2	7	834	2	7	1651	3.64	3.65
2	7	1707	3	7	946	2.14	2.29
3	7	955	3	7	2023	2.26	2.21

Hour Start	B.C. Total	BC < .3 um	Hour Start	B.C. Total	BC < .3 um	Hour Start	B.C. Total	BC < .3 um
0	2.13	2.13	8	2.60	2.31	16	2.72	2.72
1	1.98	1.94	9	4.87	4.33	17	3.55	3.37
2	1.85	1.76	10	2.62	1.89	18	2.88	2.74
3	1.86	1.73	11	2.22	1.66	19	3.11	2.98
4	1.73	1.57	12	1.93	1.66	20	2.23	2.23
5	1.81	1.65	13	1.22	1.08	21	1.79	1.79
6	1.76	1.68	14	1.40	1.37	22	1.64	1.64
7	1.30	1.23	15	2.14	2.14	23	1.46	1.46

Table 4

Summary from data block 4

Start Day	Start Month	Start Time	End Day	End Month	End Time	Mean Total	B.C. <.3um
3	7	2033	4	7	1029	1.63	1.80
4	7	1051	4	7	2225	1.27	1.17
4	7	2235	5	7	1129	1.57	1.36
5	7	1143	5	7	2247	0.97	0.90
5	7	2258	6	7	826	1.22	1.47
6	7	1757	7	7	840	2.24	2.24
7	7	854	7	7	1728	3.03	2.97
7	7	1739	8	7	859	2.00	2.11
8	7	911	8	7	1731	3.13	3.04
8	7	1742	9	7	838	1.43	1.39
9	7	849	9	7	2026	2.12	1.91
9	7	2036	10	7	911	0.99	0.94
10	7	921	10	7	1846	2.16	2.08
10	7	921	11	7	1846	1.36	1.41

Hour Start	B.C. Total	BC < .3 um	Hour Start	B.C. Total	BC < .3 um	Hour Start	B.C. Total	BC < .3 um
0	1.46	1.43	8	0.88	0.75	16	1.98	2.02
1	1.42	1.26	9	3.84	2.99	17	2.78	2.84
2	1.36	1.18	10	2.55	1.55	18	2.48	2.48
3	1.27	1.08	11	2.62	1.60	19	2.54	2.64
4	1.29	1.07	12	2.08	1.54	20	1.79	1.79
5	1.33	1.07	13	1.00	0.67	21	1.62	1.56
6	1.29	1.01	14	1.05	0.75	22	1.54	1.54
7	1.17	0.89	15	1.22	1.20	23	1.54	1.47

Table 5

Summary from data block 5

Start Day	Start Month	Start Time	End Day	End Month	End Time	Mean Total	B.C. <.3um
11	7	1239	11	7	2034	2.63	2.80
11	7	2040	12	7	1133	0.89	0.89
12	7	1148	12	7	2057	1.49	1.57
12	7	2110	13	7	848	2.33	2.65
13	7	902	13	7	1708	3.73	3.70
13	7	1720	14	7	841	2.00	2.17
14	7	853	14	7	1707	3.92	3.78
14	7	1718	15	7	849	1.84	2.03
15	7	905	15	7	1856	3.05	2.71
15	7	1908	16	7	834	1.78	1.79
16	7	848	16	7	1831	2.39	1.87
16	7	1841	17	7	841	0.74	0.67
17	7	852	17	7	1935	1.22	1.20
17	7	1949	18	7	950	0.59	0.71
18	7	1004	18	7	1856	0.84	0.75

Hour Start	B.C. Total	BC < .3 um	Hour Start	B.C. Total	BC < .3 um	Hour Start	B.C. Total	BC < .3 um
0	1.35	1.31	8	0.64	0.54	16	2.59	3.32
1	1.20	1.17	9	4.05	2.39	17	2.82	3.19
2	1.10	0.97	10	2.68	1.58	18	2.51	2.83
3	1.20	1.12	11	2.36	1.84	19	2.78	2.86
4	1.23	1.19	12	1.25	0.83	20	2.34	2.20
5	1.44	1.39	13	1.42	1.15	21	1.70	1.65
6	1.86	1.80	14	1.60	1.15	22	1.73	1.63
7	1.15	1.05	15	2.38	2.91	23	1.45	1.40

Table 6

Summary from data block 6

Start Day	Start Month	Start Time	End Day	End Month	End Time	Mean Total	B.C. <.3um
18	7	1914	19	7	946	1.49	1.35
19	7	1002	19	7	1953	0.94	0.47
19	7	2006	20	7	836	1.46	1.21
20	7	1509	20	7	1733	9.14	8.97
20	7	1744	20	7	841	1.51	1.67
21	7	853	21	7	1924	1.28	1.19
21	7	1942	22	7	839	1.57	1.57
22	7	851	22	7	2041	2.18	2.14
22	7	2052	23	7	834	2.47	2.35
23	7	847	23	7	1752	2.77	1.66
23	7	1805	24	7	843	2.11	1.77
24	7	857	24	7	1720	2.77	1.65
24	7	1728	25	7	913	2.21	1.58
25	7	925	25	7	1935	2.13	0.61
25	7	1948	26	7	2058	1.40	0.85
26	7	2114	27	7	836	2.60	1.63
27	7	847	27	7	1707	3.90	1.25
27	7	1718	28	7	836	1.86	0.68
28	7	852	28	7	1822	3.83	1.94

Hour Start	B.C. Total	BC < .3 um	Hour Start	B.C. Total	BC < .3 um	Hour Start	B.C. Total	BC < .3 um
0	1.95	1.93	8	3.56	----	16	2.94	3.73
1	1.79	1.61	9	3.85	----	17	3.59	4.49
2	1.68	1.46	10	1.71	----	18	2.54	2.97
3	1.40	1.23	11	0.83	----	19	2.46	2.93
4	1.58	1.39	12	0.73	----	20	1.84	1.75
5	1.57	1.35	13	0.89	----	21	1.73	1.59
6	1.95	1.81	14	0.58	0.50	22	1.88	1.61
7	0.81	0.60	15	1.44	1.36	23	2.07	1.84

Table 7

Summary from data block 7

Start Day	Start Month	Start Time	End Day	End Month	End Time	Mean Total	B.C. <.3um
17	8	1440	18	8	826	2.08	2.24
18	8	842	18	8	1728	3.37	3.35
18	8	1739	19	8	813	2.60	2.68
19	8	824	19	8	1812	3.68	3.27
19	8	1821	20	8	753	2.61	2.42
20	8	805	20	8	1726	3.02	2.62
20	8	1735	21	8	731	2.28	2.18
21	8	741	21	8	1652	4.05	2.94
21	8	1659	22	8	819	1.92	1.67
22	8	832	22	8	1801	2.04	4.09

Hour Start	B.C. Total	BC < .3 um	Hour Start	B.C. Total	BC < .3 um	Hour Start	B.C. Total	BC < .3 um
0	2.27		8	6.61		16	2.88	
1	2.03	1.93	9	4.73	4.16	17	3.72	3.60
2	1.90	1.80	10	2.68	2.19	18	3.73	3.54
3	1.85	1.79	11	1.77	1.61	19	3.61	3.51
4	1.83	1.72	12	1.15	1.15	20	2.88	2.79
5	2.03	1.90	13	1.20	1.41	21	2.32	2.25
6	1.99	1.99	14	1.37	1.69	22	1.94	1.88
7	1.34	1.46	15	2.04	2.20	23	2.21	2.17

Table 8

Summary from data block 8

Start Day	Start Month	Start Time	End Day	End Month	End Time	Mean Total	B.C. <.3um
22	8	1814	23	8	840	1.20	1.15
23	8	850	23	8	1637	1.44	1.27
23	8	1649	24	8	654	1.57	1.43
24	8	705	24	8	1741	2.32	1.95
24	8	1750	25	8	726	1.27	1.09
25	8	736	25	8	1742	2.81	2.19
25	8	1849	26	8	743	2.43	2.76
26	8	756	26	8	1838	3.33	3.29
26	8	1848	27	8	740	2.54	2.34
27	8	750	27	8	1745	4.28	4.14
27	8	1753	28	8	719	2.84	2.71
28	8	733	28	8	1914	3.89	3.56
28	8	1925	29	8	909	3.06	2.89
29	8	918	29	8	1804	3.84	2.81
29	8	1813	30	8	811	2.25	1.77

Hour Start	B.C. Total	BC < .3 um	Hour Start	B.C. Total	BC < .3 um	Hour Start	B.C. Total	BC < .3 um
0	2.00	1.94	8	3.14	2.98	16	3.40	3.47
1	2.24	2.04	9	3.04	2.94	17	4.09	4.09
2	2.13	2.03	10	3.01	2.80	18	3.06	3.06
3	1.53	1.45	11	1.41	1.27	19	2.73	2.75
4	1.61	1.50	12	1.07	1.04	20	2.35	2.35
5	2.01	1.95	13	----	----	21	2.15	2.15
6	2.45	2.57	14	1.48	1.50	22	2.18	2.18
7	1.39	1.44	15	1.76	1.97	23	2.05	2.05

Table 9

Summary from data block 9

Start Day	Start Month	Start Time	End Day	End Month	End Time	Mean Total	B.C. <.3um
30	8	822	30	8	1728	2.58	2.00
30	8	1820	31	8	744	2.38	1.95
31	8	753	31	8	1812	3.95	2.97
31	8	1820	1	9	758	3.43	2.65
1	9	807	1	9	1228	4.29	2.89
1	9	1714	2	9	658	1.51	1.68
2	9	1949	3	9	843	3.01	2.98
3	9	851	3	9	1710	4.13	3.46
3	9	1718	4	9	908	2.12	1.90

Hour Start	B.C. Total	BC < .3 um	Hour Start	B.C. Total	BC < .3 um	Hour Start	B.C. Total	BC < .3 um
0	2.10	1.91	8	3.17	2.28	16	2.86	2.86
1	1.88	1.71	9	4.76	2.62	17	2.95	2.95
2	1.79	1.55	10	3.62	2.10	18	2.28	2.19
3	2.23	1.99	11	0.80	----	19	3.33	3.19
4	1.92	1.77	12	1.78	1.64	20	3.42	3.28
5	1.33	1.33	13	0.74	0.75	21	3.39	3.26
6	3.51	3.83	14	3.49	3.80	22	2.46	2.27
7	2.46	2.78	15	2.13	2.30	23	2.20	2.02

Figure Captions

Figure 1 : Schematic cross-section of aethalometer measurement head, showing two sampling channels and the reference detector. The upper body is machined from translucent material: the lower body from metal. Thus, the light transmitted from the lamp to the photodetectors passes through the quartz fiber filter. Aerosols drawn through the sampling channels are collected by the filter, and the rate at which the transmission of light is progressively attenuated (relative to the reference beam) is proportional to the rate at which aerosol black carbon is collected on the filter.

Figure 2 : Total aerosol black carbon concentration calculated as averages for the periods of operation of filters from 13th June to 3rd July 1987. Each filter period was approximately 12 hours: refer to Tables 1 - 9 for the exact dates and times. The tick marks on the horizontal axis indicate 3 - day intervals.

Figure 3 : Mean total aerosol black carbon concentration for the range of dates 3rd July to 28th July 1987, as per presentation of Figure 2.

Figure 4 : Mean total aerosol black carbon concentration for the range of dates 17th August to 9th September 1987, as per presentation of Figure 2.

Figure 5 : Mean diurnal cycle of total aerosol black carbon concentrations for block 1 of data spanning dates 13th June to 18th June 1987, averaged for each starting hour.

Figure 6 : Mean diurnal cycle of total aerosol black carbon concentrations for block 2 of data spanning dates 18th June to 26th June 1987, averaged for each starting hour.

Figure 7 : Mean diurnal cycle of total aerosol black carbon concentrations for block 3 of data spanning dates 26th June to 3rd July 1987, averaged for each starting hour.

Figure 8 : Mean diurnal cycle of total aerosol black carbon concentrations for block 4 of data spanning dates 3rd July to 11th July 1987, averaged for each starting hour.

Figure 9 : Mean diurnal cycle of total aerosol black carbon concentrations for block 5 of data spanning dates 11th July to 18th July 1987, averaged for each starting hour.

Figure 10 : Mean diurnal cycle of total aerosol black carbon concentrations for block 6 of data spanning dates 18th July to 26th July 1987, averaged for each starting hour.

Figure 11 : Mean diurnal cycle of total aerosol black carbon concentrations for block 7 of data spanning dates 17th August to 22nd August 1987, averaged for each starting hour.

Figure 12 : Mean diurnal cycle of total aerosol black carbon concentrations for block 8 of data spanning dates 22nd August to 30th August 1987, averaged for each starting hour.

Figure 13 : Mean diurnal cycle of total aerosol black carbon concentrations for block 9 of data spanning dates 30th August to 4th September 1987, averaged for each starting hour.

Figure 14 : Comparison of mean diurnal cycles of total aerosol black carbon concentration for blocks 1 - 6 of data, covering the first session of the summer 1987 SCAQS experiment from 13th June to 28th July 1987. Data for each block are represented by columns of different shading.

Figure 15 : Comparison of mean diurnal cycles of total aerosol black carbon concentration for blocks 7 - 9 of data, covering the second session of the summer 1987 SCAQS experiment from 17th August to 4th September 1987. Data presentation scheme as for Figure 14.

Figure 16 : Mean diurnal cycle of percentage fraction of aerosol black carbon collected by channel preceded by impactor of cutpoint 0.3 μm aerodynamic diameter, relative to total aerosol channel. Data averaged for each starting hour over days within block 1, from 13th June to 18th June 1987.

Figure 17 : Mean diurnal cycle of percentage fraction of aerosol black carbon collected by channel preceded by impactor of cutpoint 0.3 μm aerodynamic diameter, relative to total aerosol channel. Data averaged for each starting hour over days within block 2, from 18th June to 26th June 1987.

Figure 18 : Mean diurnal cycle of percentage fraction of aerosol black carbon collected by channel preceded by impactor of cutpoint 0.3 μm aerodynamic diameter, relative to total aerosol channel. Data averaged for each starting hour over days within block 3, from 26th June to 3rd July 1987.

Figure 19 : Mean diurnal cycle of percentage fraction of aerosol black carbon collected by channel preceded by impactor of cutpoint 0.3 μm aerodynamic diameter, relative to total aerosol channel. Data averaged for each starting hour over days within block 4, from 3rd July to 11th July 1987.

Figure 20 : Mean diurnal cycle of percentage fraction of aerosol black carbon collected by channel preceded by impactor of cutpoint 0.3 μm aerodynamic diameter, relative to total aerosol channel. Data averaged for each starting hour over days within block 5, from 11th July to 18th July 1987.

Figure 21 : Mean diurnal cycle of percentage fraction of aerosol black carbon collected by channel preceded by impactor of cutpoint 0.3 μm aerodynamic diameter, relative to total aerosol channel. Data averaged for each starting hour over days within block 6, from 18th July to 28th July 1987.

Figure 22 : Mean diurnal cycle of percentage fraction of aerosol black carbon collected by channel preceded by impactor of cutpoint 0.3 μm aerodynamic diameter, relative to total aerosol channel. Data averaged for each starting hour over days within block 7, from 17th August to 22nd August 1987.

Figure 23 : Mean diurnal cycle of percentage fraction of aerosol black carbon collected by channel preceded by impactor of cutpoint 0.3 μm aerodynamic diameter, relative to total aerosol channel. Data averaged for each starting hour over days within block 8, from 22nd August to 30th August 1987.

Figure 24 : Mean diurnal cycle of percentage fraction of aerosol black carbon collected by channel preceded by impactor of cutpoint 0.3 μm aerodynamic diameter, relative to total aerosol channel. Data averaged for each starting hour over days within block 9, from 30th August to 4th September 1987.

Figure 25 : Comparison of mean diurnal cycles of percentage fraction of aerosol black carbon in sub - 0.3 μm aerodynamic diameter size range for blocks 1-6 of data, covering the first session of the summer 1987 SCAQS experiment from 13th June to 28th July 1987. Data for each block are represented by columns of different shading.

Figure 26 : Comparison of mean diurnal cycles of percentage fraction of aerosol black carbon in sub - 0.3 μm aerodynamic diameter size range for blocks 7-9 of data, covering the second session of the summer 1987 SCAQS experiment from 17th August to 4th September 1987. Data presentation scheme as for Figure 25.

Aethalometer measurement head

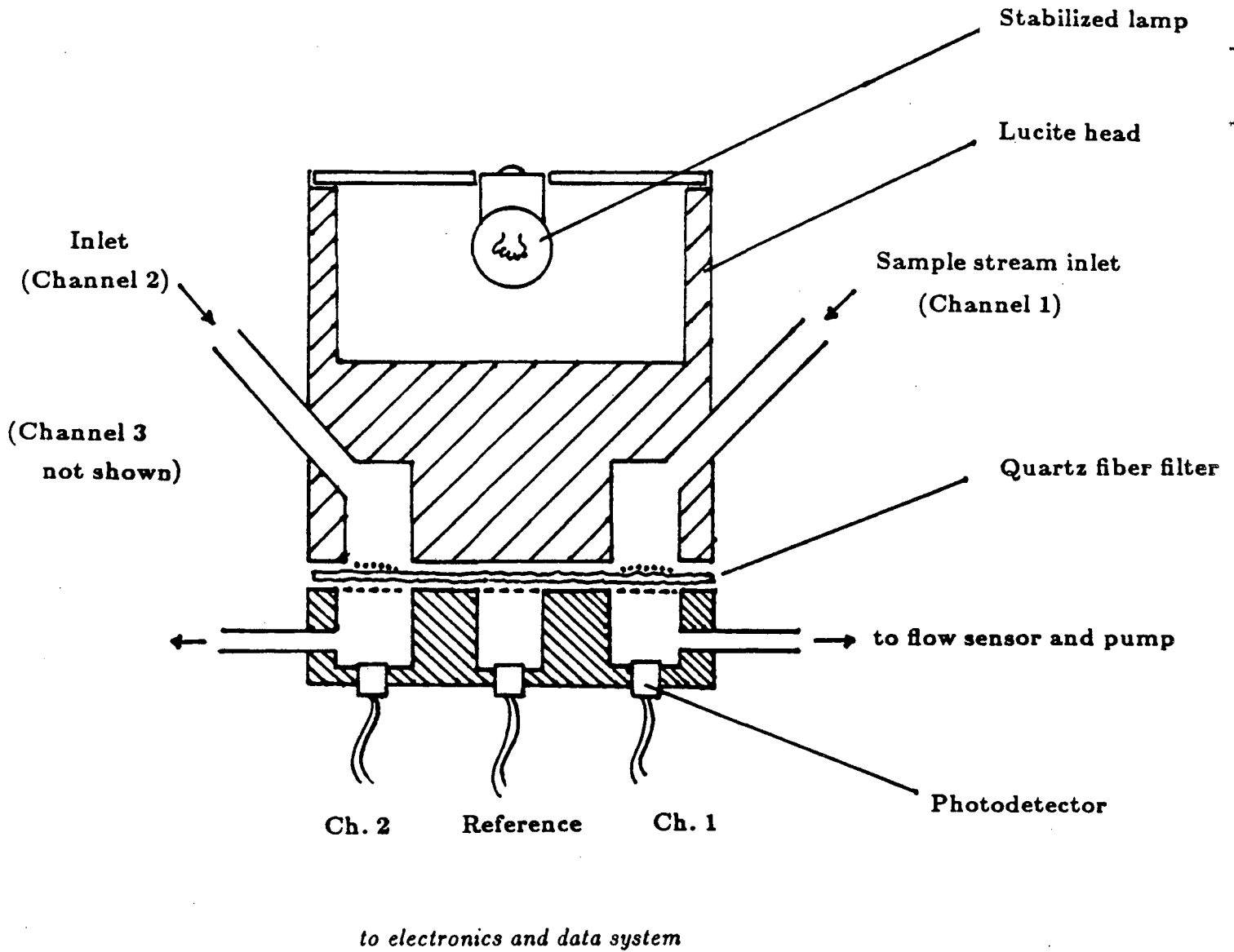


Figure 1

SCAQS 87 Aerosol Black Carbon
Period means 6/13/87 - 7/3/87

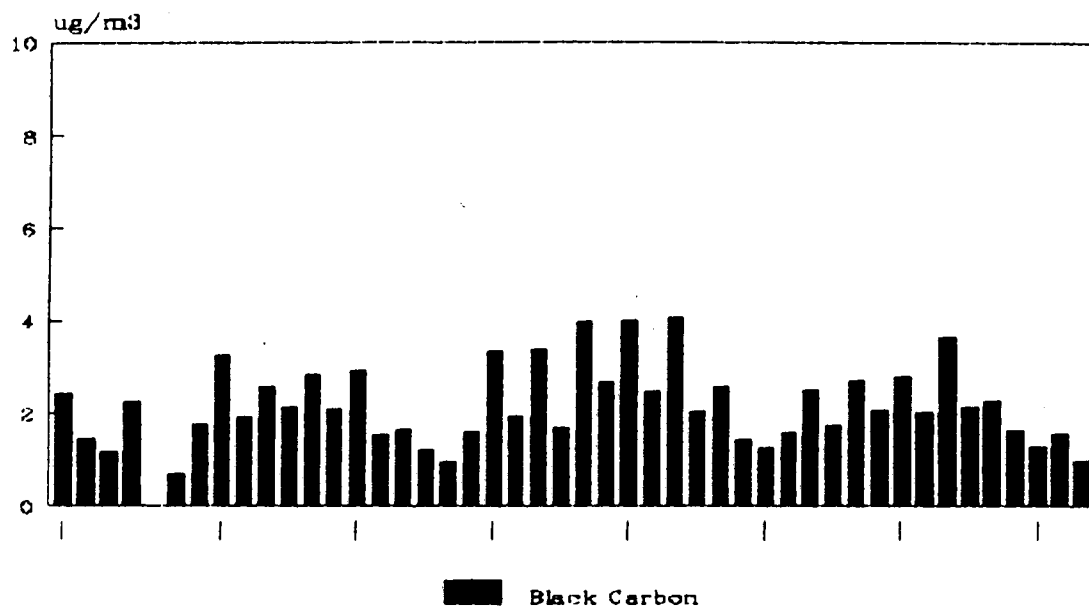


Figure 2

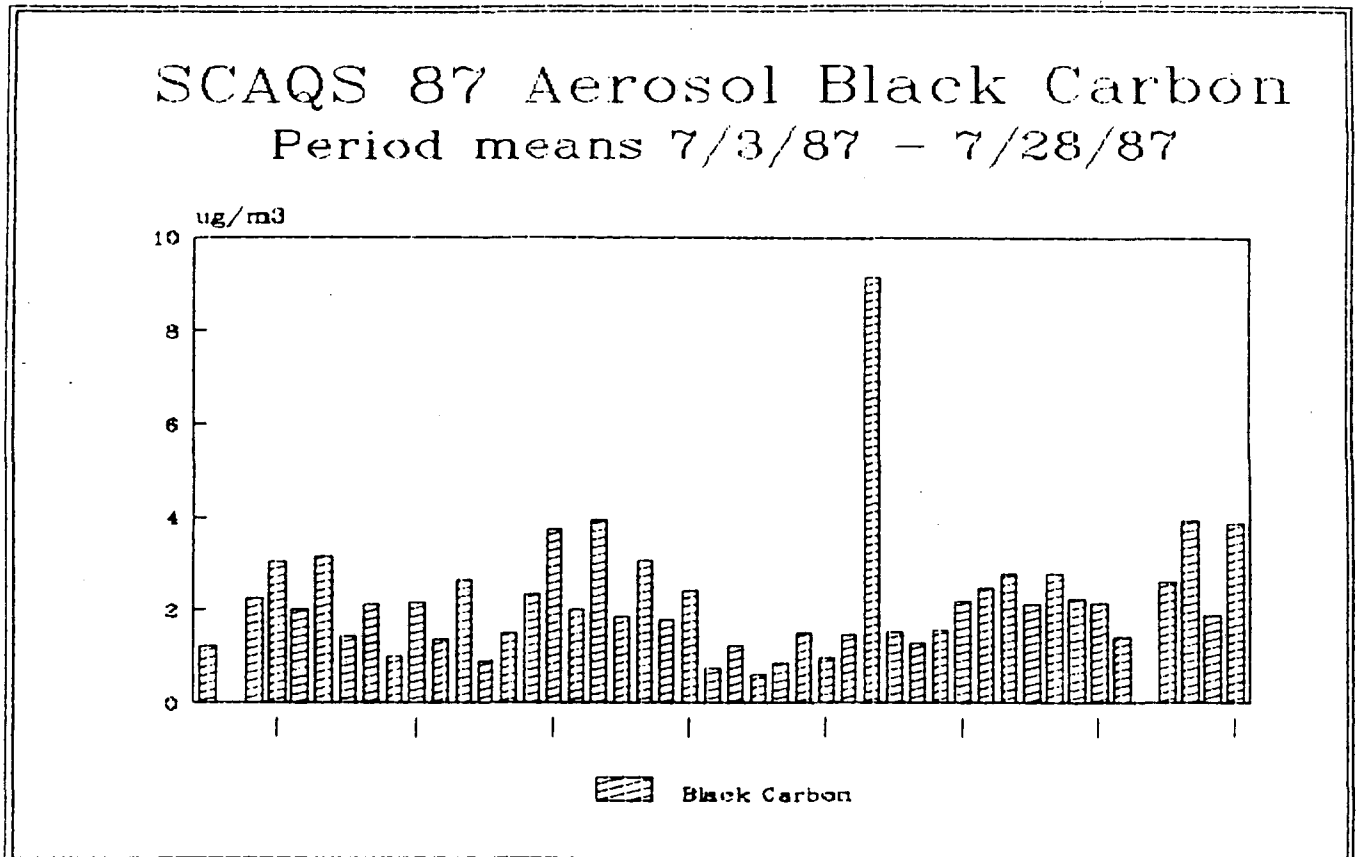


Figure 3

SCAQS 87 Aerosol Black Carbon

Period means 8/17/87 - 9/4/87

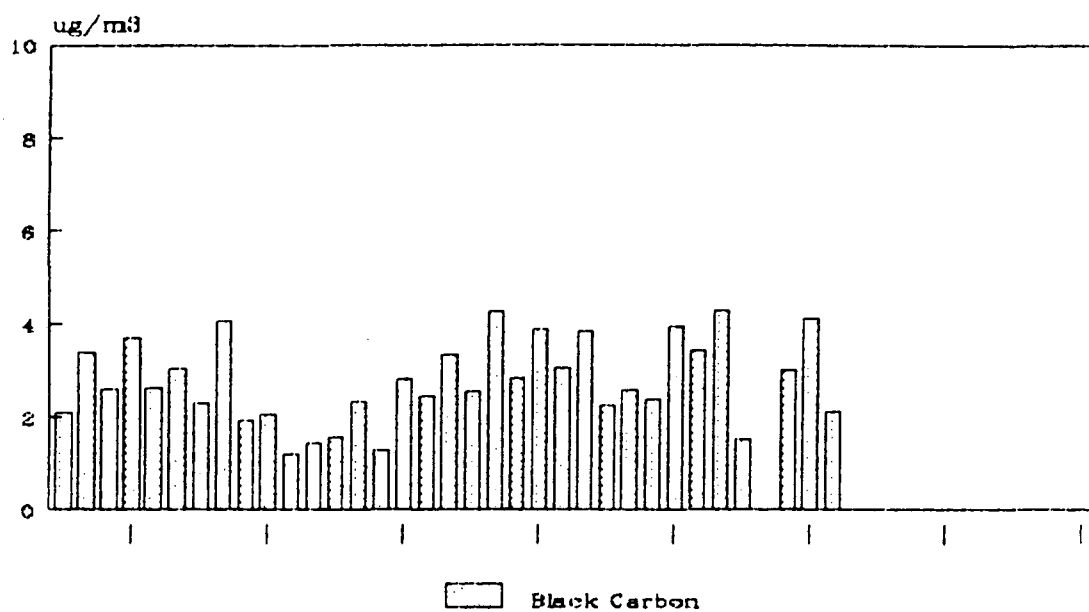


Figure 4

SCAQS 87 Aerosol Black Carbon
Hourly means: 6/13/87 - 6/18/87

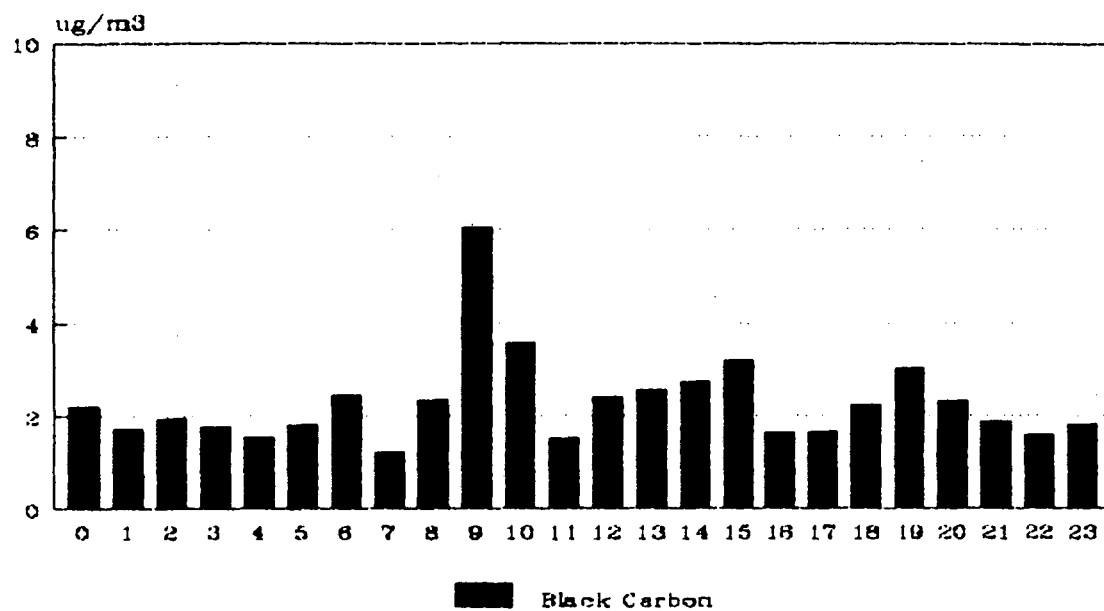


Figure 5

SCAQS 87 Aerosol Black Carbon
Hourly means: 6/18/87 - 6/26/87

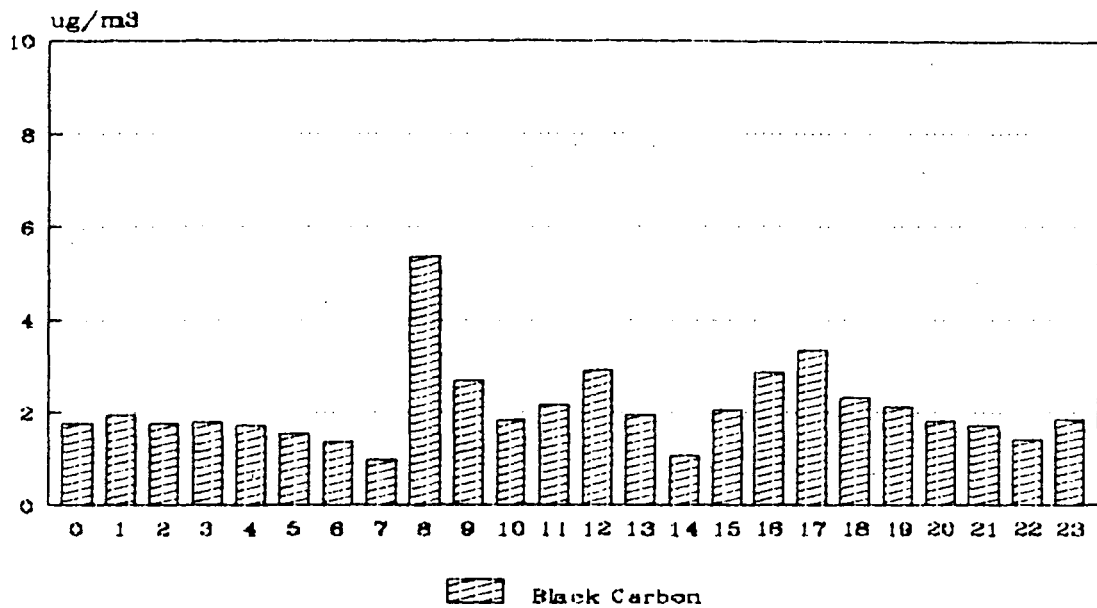


Figure 6

SCAQS 87 Aerosol Black Carbon
Hourly means: 6/26/87 - 7/3/87

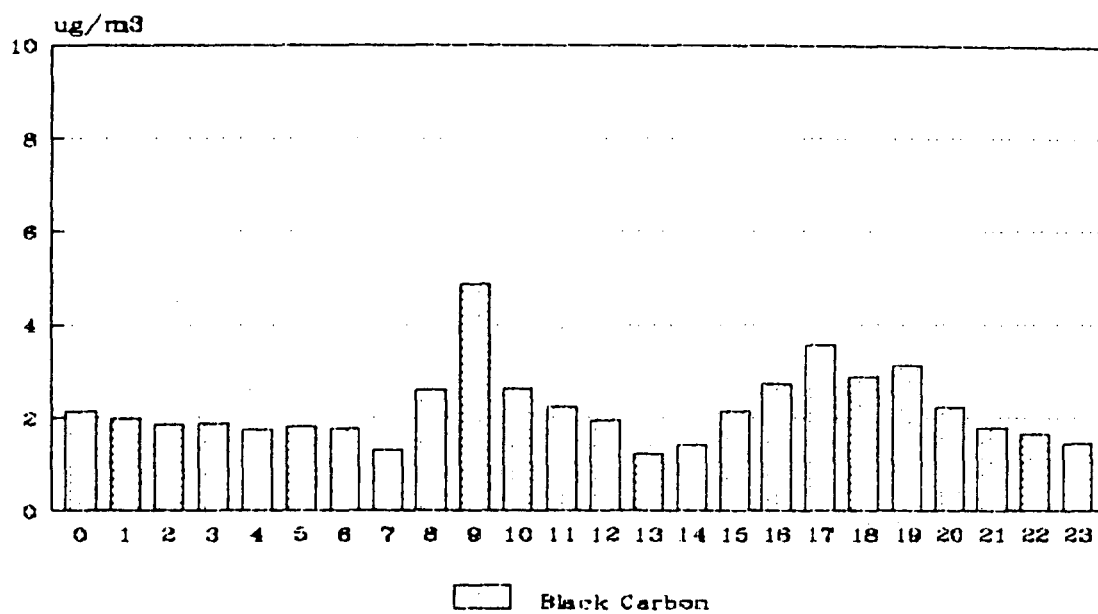


Figure 7

SCAQS 87 Aerosol Black Carbon

Hourly means: 7/3/87 - 7/11/87

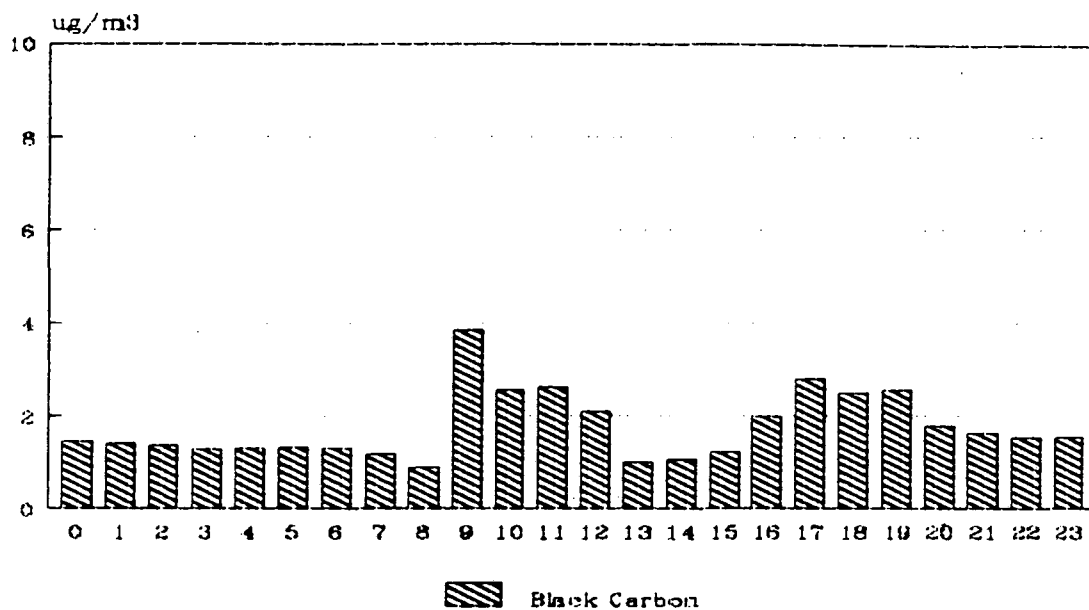


Figure 8

SCAQS 87 Aerosol Black Carbon

Hourly means: 7/11/87 - 7/18/87

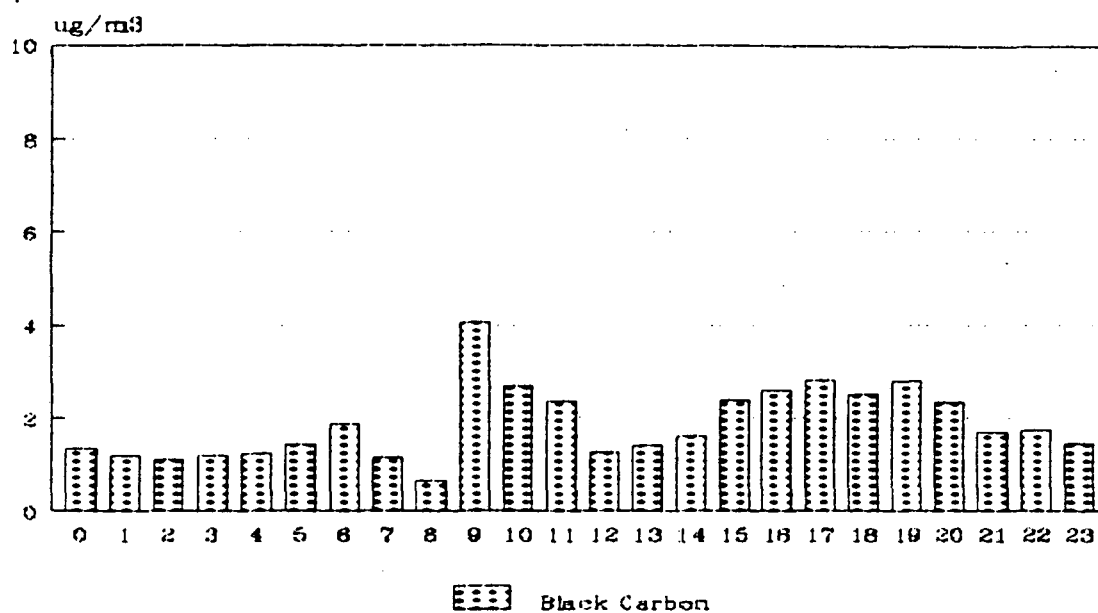


Figure 9

SCAQS 87 Aerosol Black Carbon

Hourly means: 7/18/87 - 7/26/87

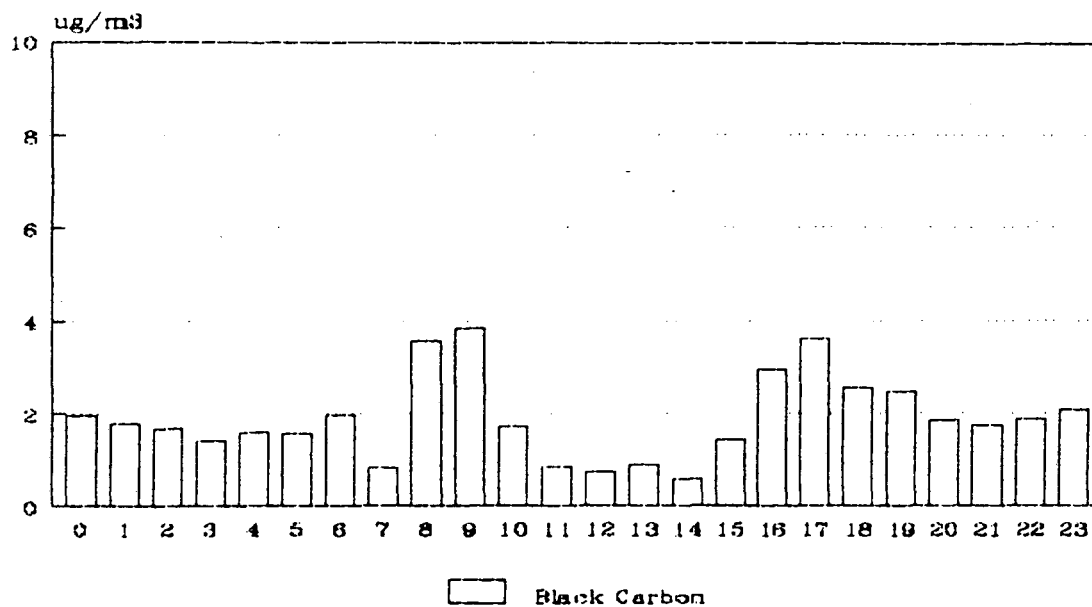


Figure 10

SCAQs 87 Aerosol Black Carbon
Hourly means: 8/17/87 - 8/22/87

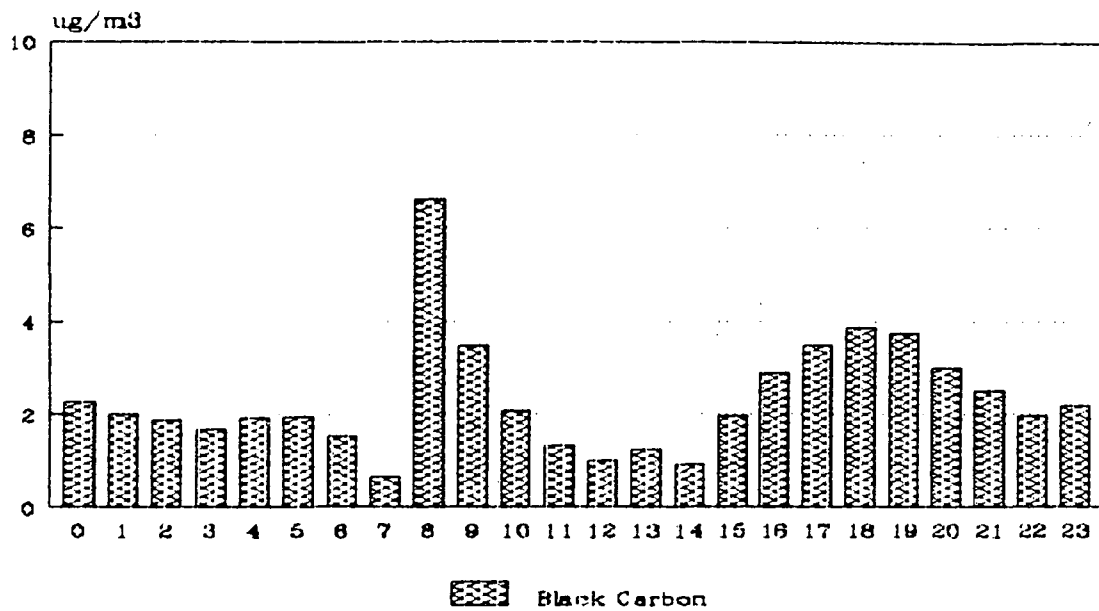


Figure 11

SCAQS 87 Aerosol Black Carbon
Hourly means: 8/22/87 - 8/30/87

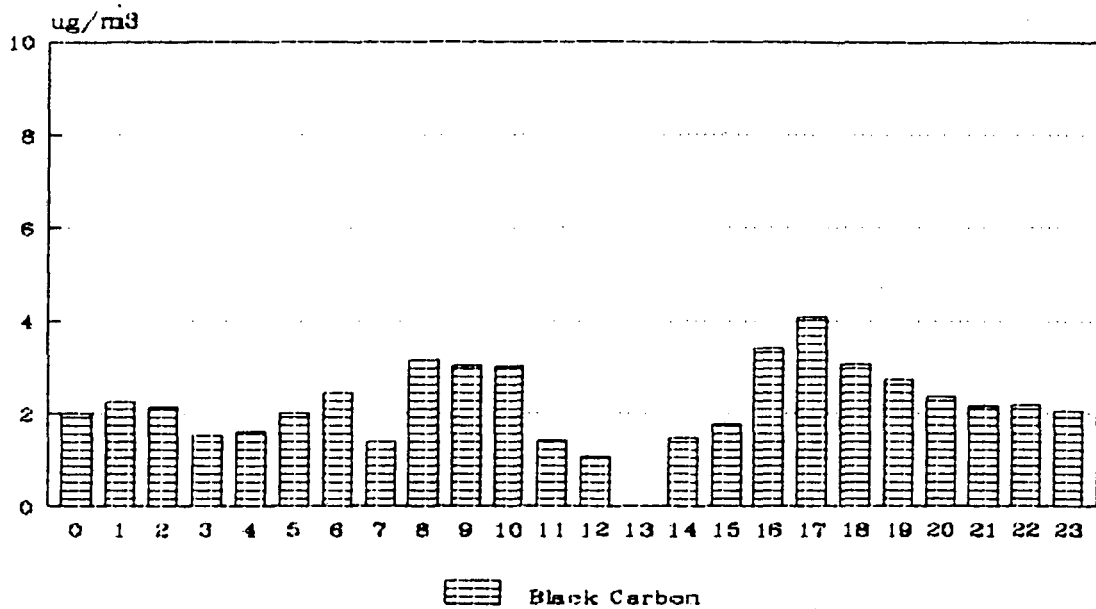


Figure 12

SCAQS 87 Aerosol Black Carbon
Hourly means: 8/30/87 - 9/4/87

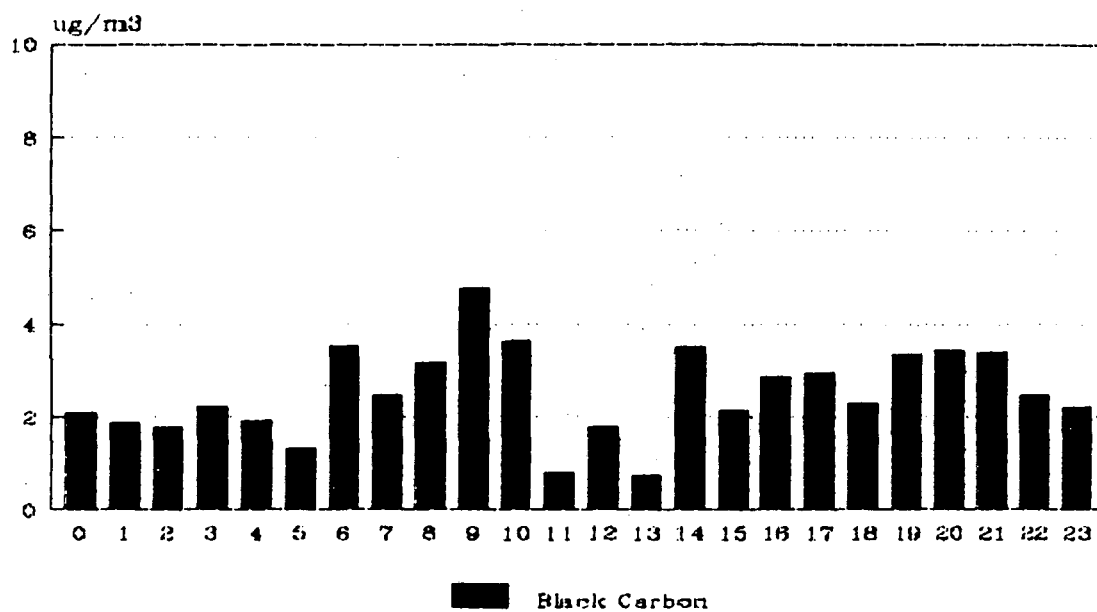


Figure 13

SCAQS 87 Aerosol Black Carbon

Hourly means: 6/13/87 - 7/28/87

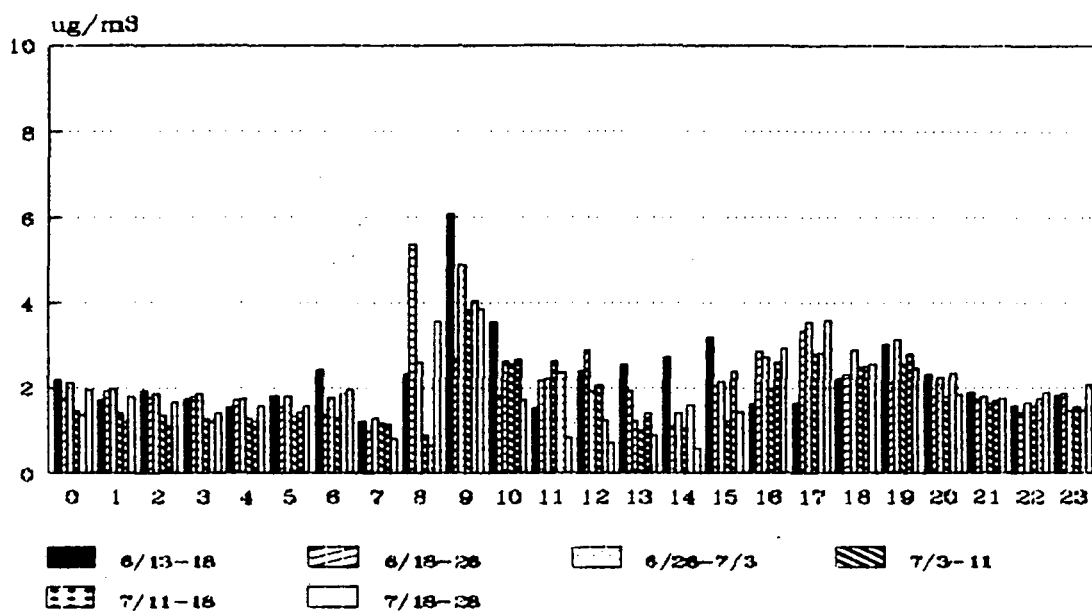


Figure 14

SCAQS 87 Aerosol Black Carbon
Hourly means: 8/17/87 - 9/4/87

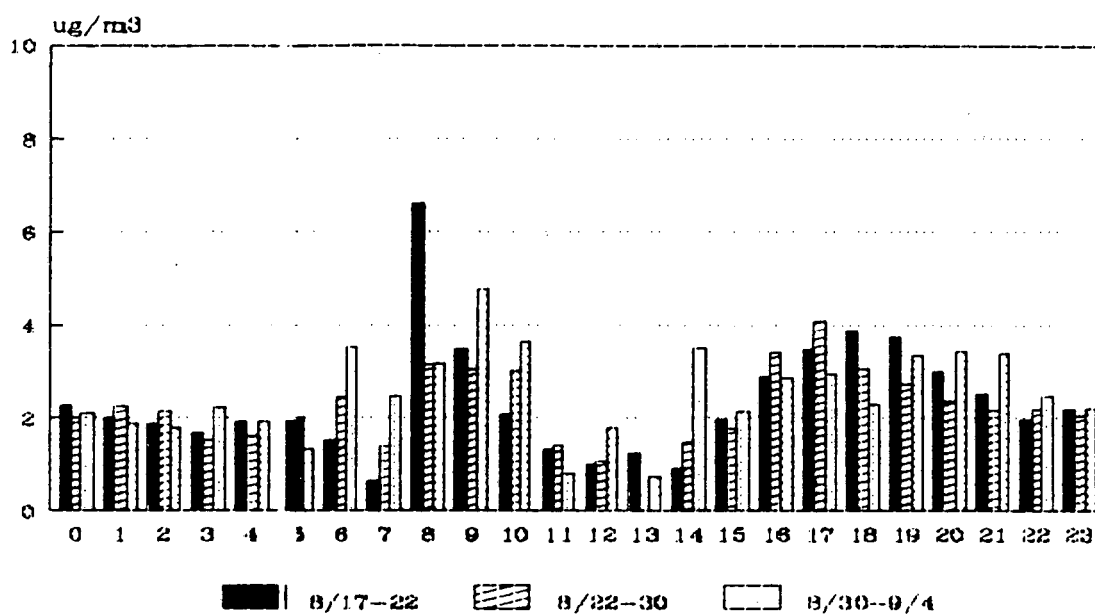


Figure 15

SCAQS 87 Aerosol Black Carbon
Fraction $< 0.3 \mu\text{m}$ 6/13/87 - 6/18/87

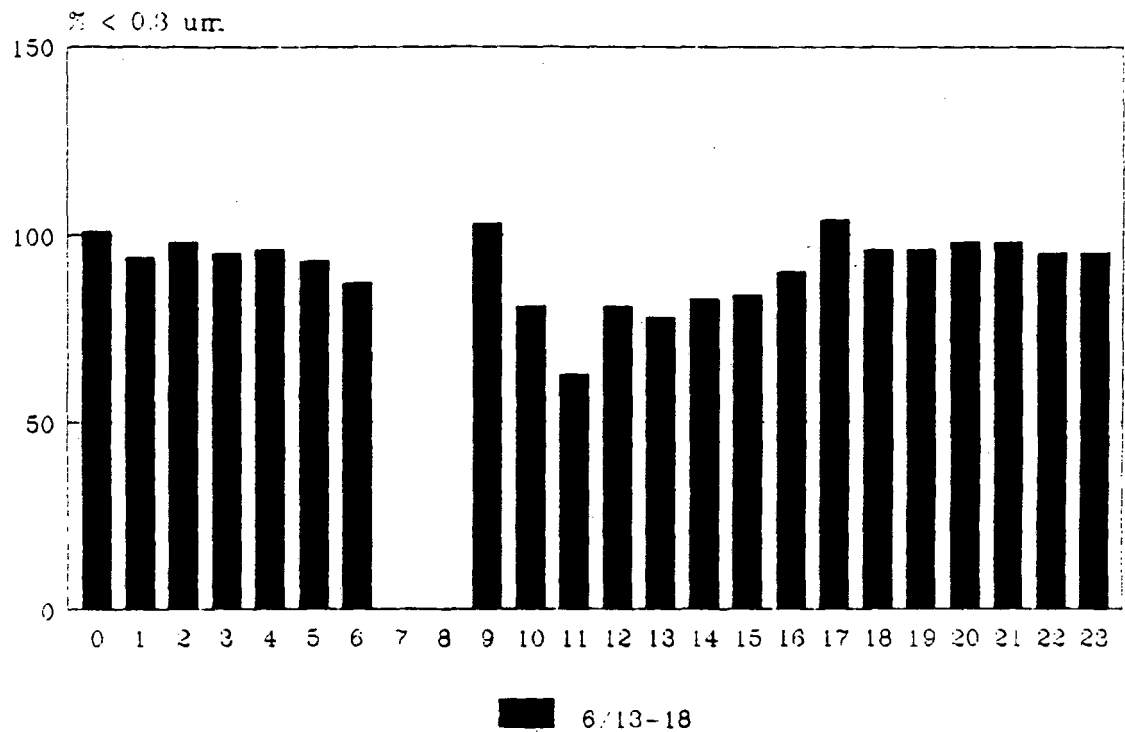


Figure 16

SCAQS 87 Aerosol Black Carbon
Fraction $< 0.3 \mu\text{m}$ 6/18/87 - 6/26/87

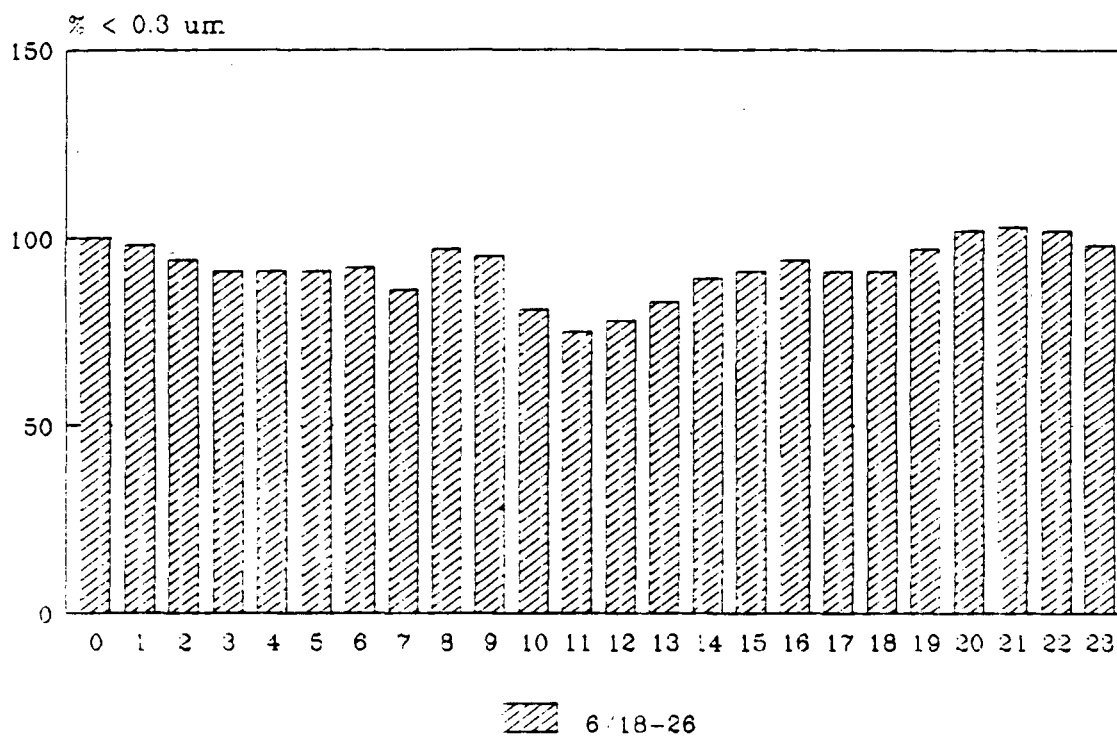


Figure 17

SCAQS 87 Aerosol Black Carbon
Fraction < 3um 6/26/87 - 7/3/87

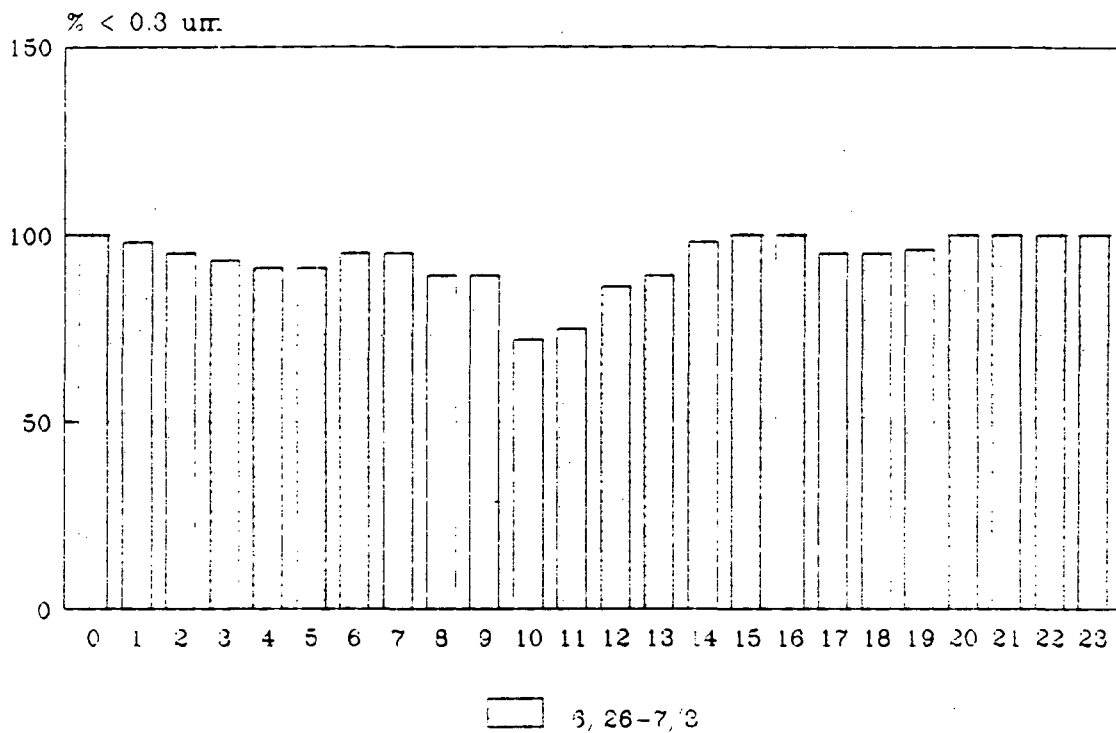


Figure 18

SCAQS 87 Aeros.

Carbon

Fraction < 3um 7/13/87 7/11/87

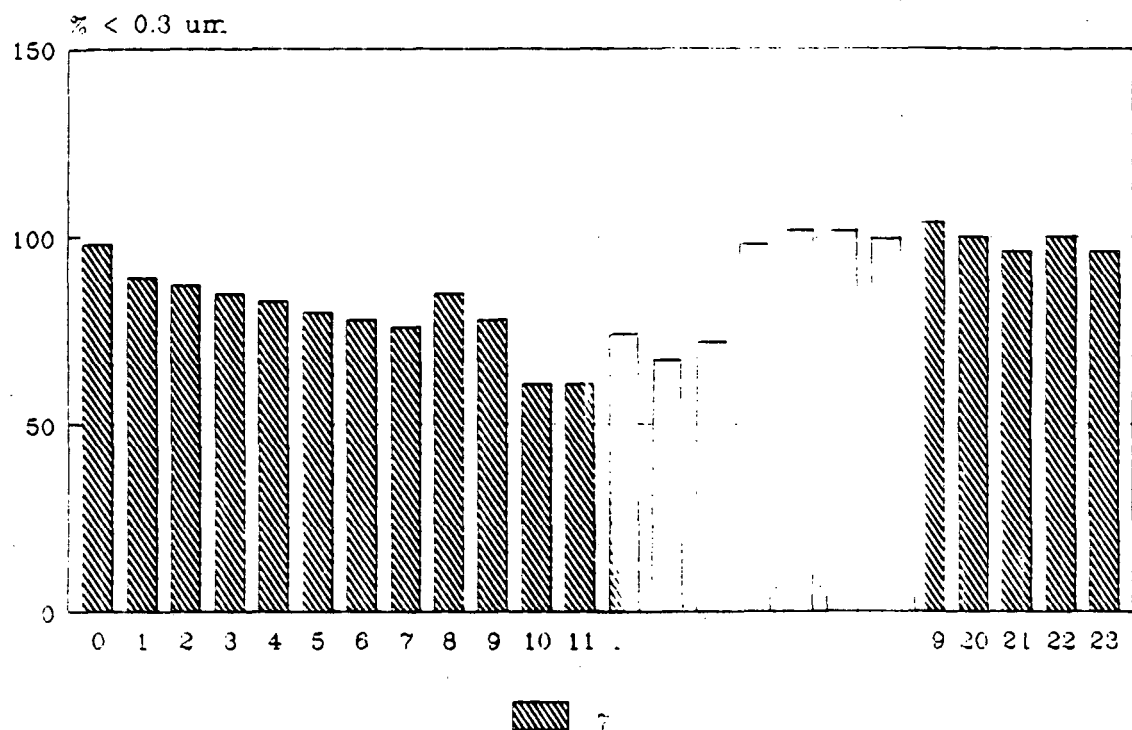


Figure 19

SCAQS 87 Aerosol Black Carbon Fraction $< 0.3 \mu\text{m}$ 7/11/87 - 7/18/87

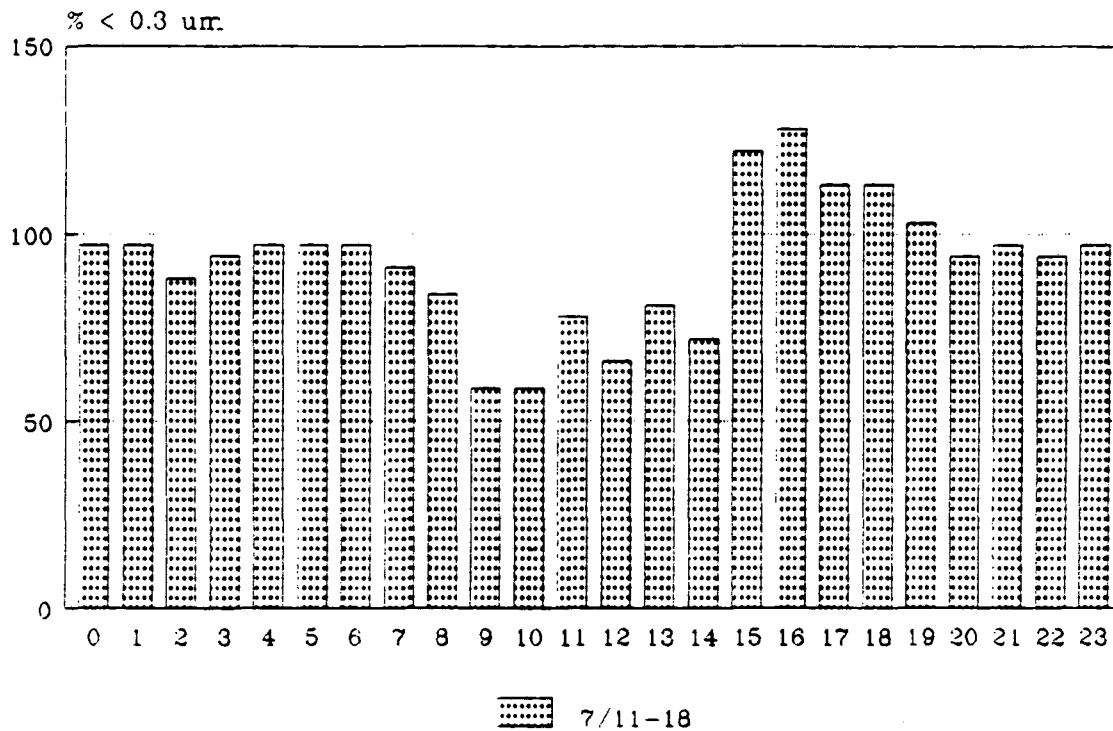


Figure 20

SCAQS 87 Aerosol Black Carbon Fraction < .3um 7/18/87 - 7/28/87

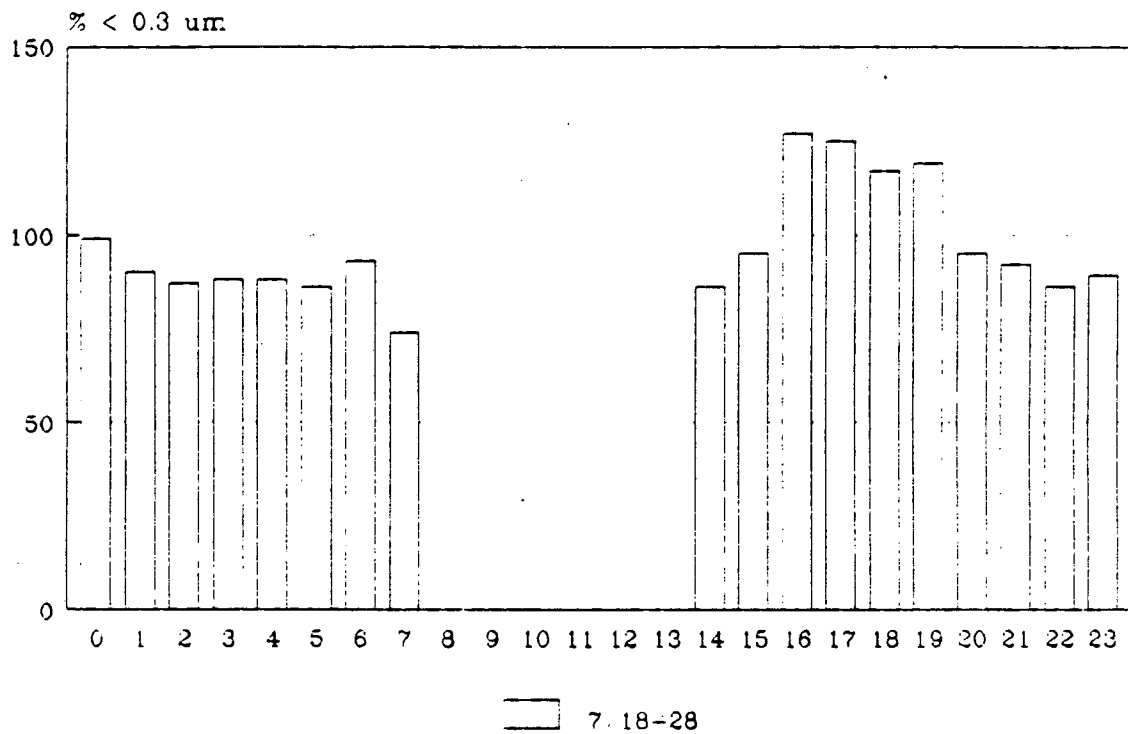


Figure 21

SCAQS 87 Aerosol Black Carbon
Fraction $< 0.3 \mu\text{m}$ 8/17/87 - 8/22/87

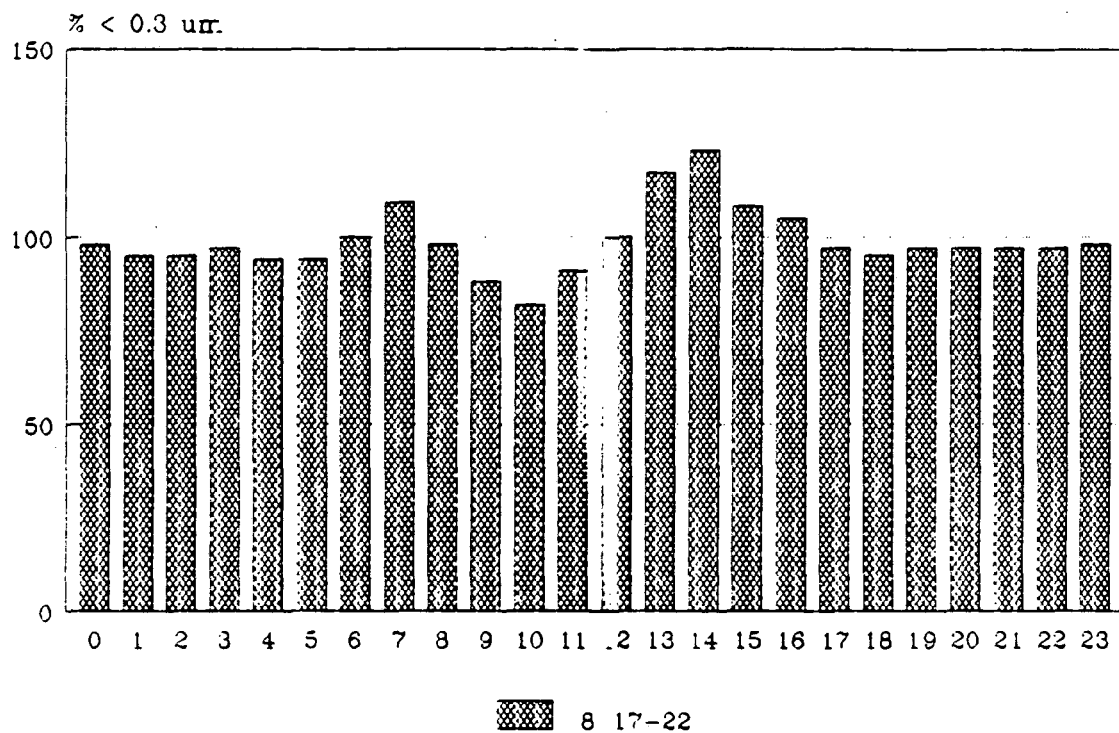


Figure 22

SCAQS 87 Aerosol Black Carbon
Fraction $< .3\mu\text{m}$ 8/22/87 - 8/30/87

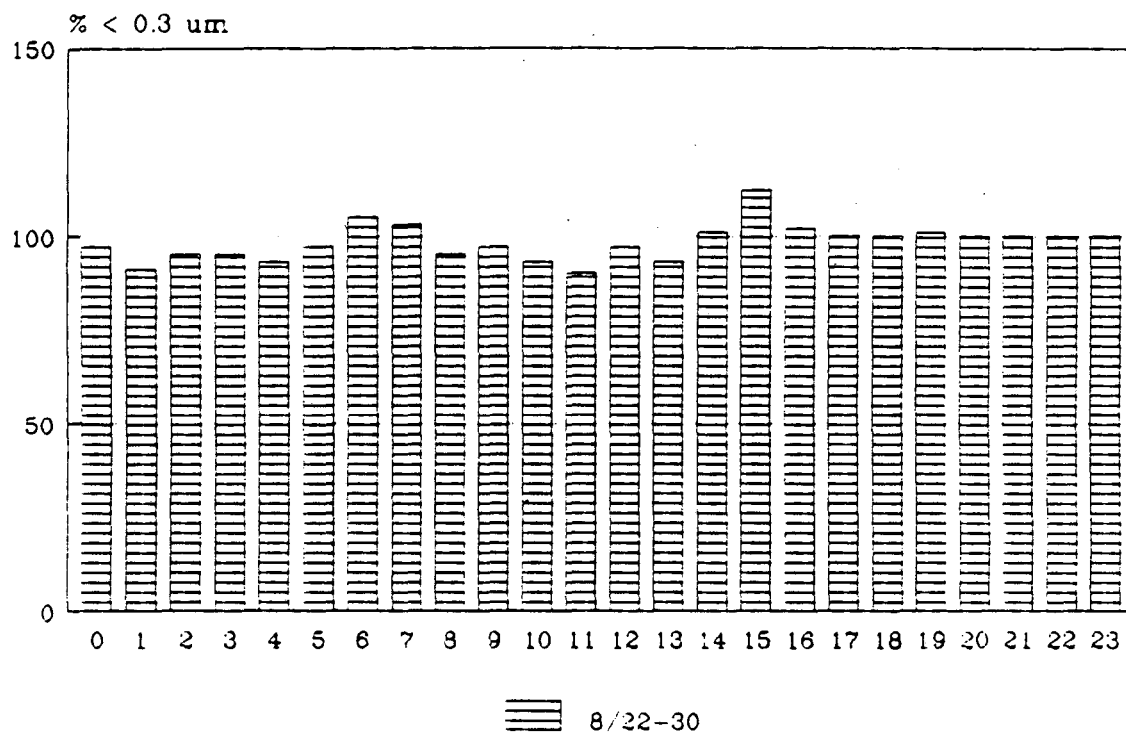


Figure 23

SCAQS 87 Aerosol Black Carbon
Fraction $< .3\mu\text{m}$ 8/30/87 - 9/4/87

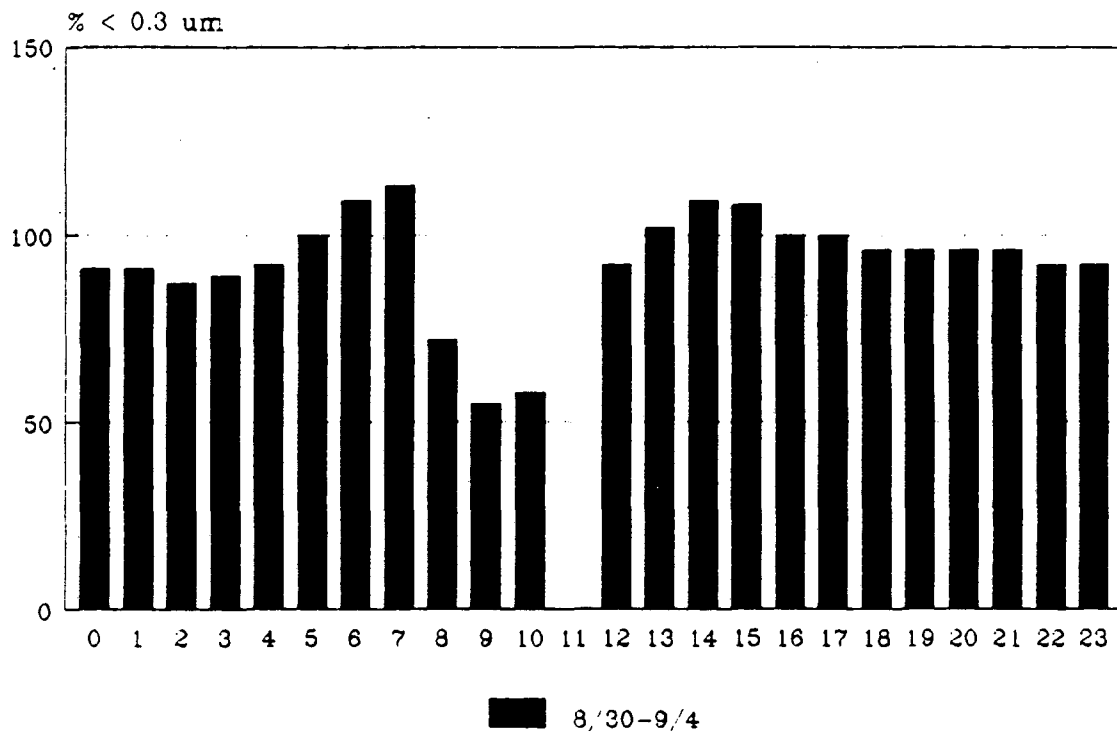


Figure 24

SCAQS 87 Aerosol Black Carbon Fraction <.3um 6/13/87 - 7/28/87

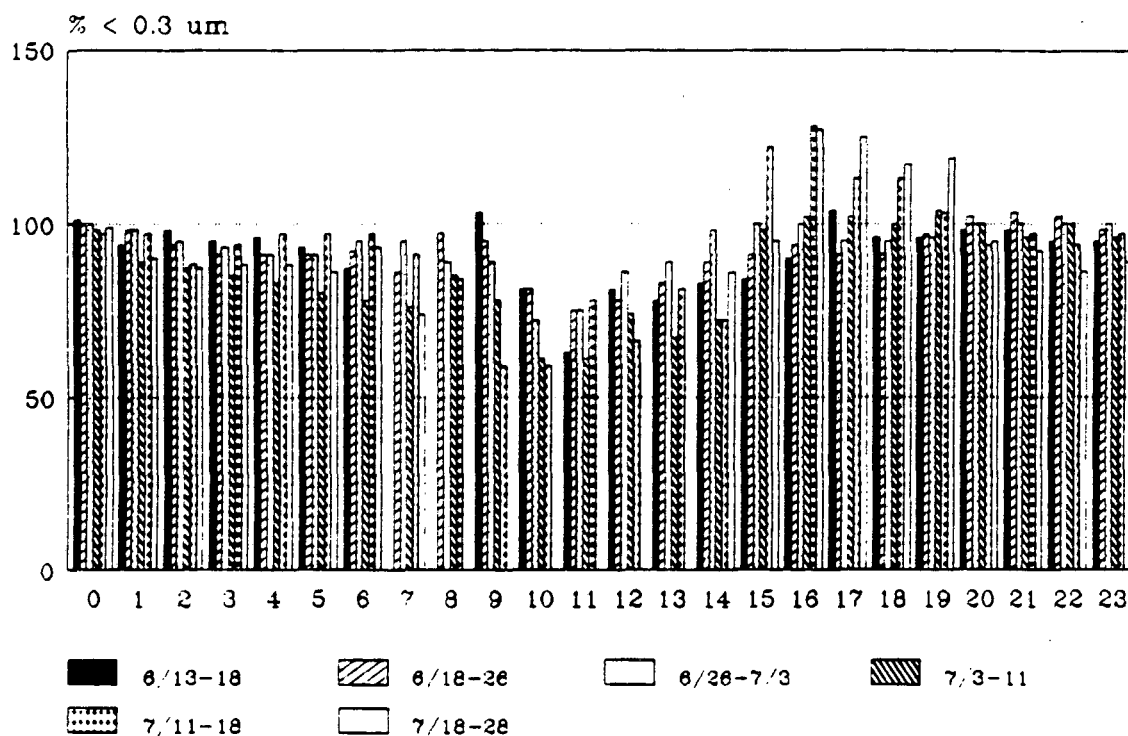


Figure 25

SCAQS 87 Aerosol Black Carbon Fraction $< 0.3 \mu\text{m}$ 8/17/87 - 9/4/87

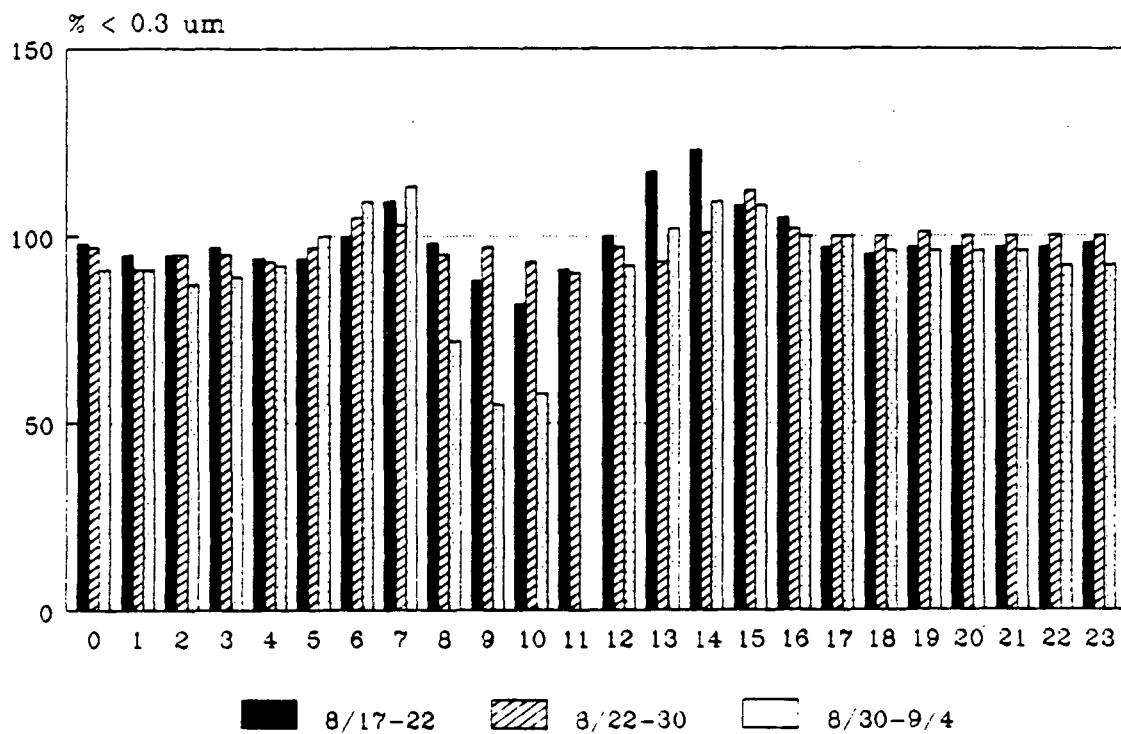


Figure 26

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