PERGAMON

Atmospheric Environment 35 (2001) 2715–2721

ATMOSPHERIC ENVIRONMENT

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Characteristic number size distribution of aerosol during Asian dust period in Korea

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Received 30 November 1999; received in revised form 24 July 2000; accepted 27 July 2000

Abstract

The size-separated number concentrations of aerosols ranging from 0.3 to 25 μm were observed in Seoul and Anmyon Island in the west coast of Korea during Asian dust period in Spring 1998. During the heavy dust period, the number size distributions of aerosols observed in both places were characterized by decreases in small size < 0.5 μm and increase in large size between 1.35 and 10 μm. For particles in this range, there was a good correlation between number concentrations observed in both two places. The number of coarse particles > 10 μm showed a distinct diurnal variation without a significant change in amplitude, which was more pronounced in Seoul. It suggests that coarse particles were more affected by local sources. Trajectories back in time showed that the air collected in Korea during dust period originated from desert regions in the central part of China. From these results, it was evident that increased particles in the range of 1.35–10 μm during dust source period represented mineral components, which originated possibly from the dust source regions. © 2001 Elsevier Science Ltd. All rights reserved.

Keywords: Aerosol; Mineral dust; Number concentration; Yellow sand; Long-range transport

1. Introduction

Arid and semi-arid regions of the world, covering about one-third of the Earth's land surface are the major source for mineral dust. If meteorological conditions are favorable, the mobilization of the dust and its further emission into the atmosphere occur throughout the year. However, the physico-optical properties of mineral particles have not been well known and very few studies have been done before the early 1970s. Schutz and Jaenicke (1974) were among the first scientists who observed size distributions of mineral dust and reported the measurement results in the source regions of the Libyan Desert. Due to the limitation in measurement instrument, their study was restricted to particle radii larger than 1 μm. Later, a more comprehensive study was done by Jaenicke and Schutz (1978) to understand the transport process of dust-laden material from Sahara to the west. In Asian regions, Iwasaka et al. (1983) conducted a similar research near the source areas of Asia's arid regions.

Several observations of aerosol concentrations were made during Asian dust period in the eastern part of China (Zhou et al., 1981; Wang et al., 1982), Japan (Mizohata and Mamuro, 1978), the North pacific ocean (Duce et al., 1980; Uematsu et al., 1983), and source regions (Ren et al., 1993; Zaizen et al., 1995). However, there have been very few studies done in Korea. Cho (1980) and Kim et al. (1986) showed that the number concentration of particles were relatively higher in spring than other seasons in Korea. The maximum density was

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PII: S1352-2310(00)00404-0

Fig. 1. Map of research area showing Seoul and Anmyon Island in Korea.

found to be near the particle sizes 0.06 and 6.8 μm in spring (Cho, 1980). There is still no data available about number-size distribution of aerosol during Asian dust period in Korea.

The purpose of this study is to determine the characteristic aerosol size distribution in Korea during dust period by examining the size-separated number concentrations simultaneously measured in Seoul and Anmyon Island (Fig. 1). Seoul is a metropolitan with local sources of anthropogenic pollutants. On the other hand, Anmyon Island represents clean background air as a Background Air Pollution Monitoring (BAPMoN) station of World Meteorological Organization. In spring, aerosols in urban areas are mainly composed of anthropogenic particles from local sources and Asian dust transported from the continent. In coastal zones, sea salts, water vapor, and Asian dust are dominant aerosol particles with much less local pollutants.

2. Experiment

The number concentrations of aerosols were measured using optical particle counters (HIAC/ROYCO 5230). This instrument was set on the roof of building. Air was sampled from air intake at 12 m height to a cylindrical chamber outside the building and then led to the instrument. Inside the chamber, flow rate was lowered and very large particles were excluded to protect the instrument. The light source was a semiconductor laser and the optical system was set 90° scattered. The optical particle counters were operated in the dynamic range of 0.3–25 μm with 7 cutoff diameters of 0.5, 0.82, 1.35, 2.23, 3.67, 6.06 and 10 μm. These eight ranges were equivalently divided at log-decimal scale except the last one. Three-minute-averaged data were obtained every hour during spring 1998.

3. Results and discussion

3.1. Case selection

In 1998, Asian dust was observed all over Korea including Seoul Anmyon Island from 14 to 22 April. In source regions, dust phenomena were consistently observed during that period (Fig. 2). Husar et al. (2000) reported that in April 1998, several usually intense dust storms occurred over the Gobi Desert in Western China and Mongolia. In particular, the storm on 19 April 1998 produced a dust cloud that crossed the Pacific and caused aerosol concentration near the health standard ($PM_{10} > 150\,\mu m\,m^{-3}$) over much of the west coast of North America. It is, however, dust storm on 15 April that is transported for long distance and hit Korean peninsula on 19 and 20 April. The backward-trajectory analysis also showed that the air sampled in Korea on 19 April originated from the desert region in Mongolia plateau (Fig. 3). In this study, 14–22 April was considered as Asian dust period, of which heavy dust incident was only observed in Seoul in the afternoon on the 19th and 20th.

3.2. Size-separated number concentration or aerosols

Fig. 4 displays the size-separated number concentrations of aerosol observed in Seoul during the Asian dust period, 14–22 April 1998. For smallest particles in the range of 0.3–0.82 μm, number concentration was slightly decreased during the heavy dust period of 19 and 20 April. The number of particles in the range of 0.82–2.23 μm showed large fluctuation until 19 April and then remained high. However, it was particles between 2.23 and 10 μm that markedly changed during the dust period. Their concentrations stayed low until 18 April and then increased substantially. Number concentrations reached to the maximum value on the 19th and decreased slowly afterwards. The largest particles of 1025 μm size showed a distinct diurnal variation with a maximum during the day and minimum at night, and its amplitude did not change during the course of dust episode.

Fig. 5 exhibits time-series variation of aerosol number concentrations in Anmyon Island during April 1998. The number concentration of the smallest size showed little variation during this period. However, aerosol concentrations in the range of 0.5–2.23 μm reached to several maximum values on 16, 17 and 19 April. Large particles in the range of 2.23–10 μm considerably increased in numbers on 19 April, when the most severe dust event occurred in Korea. This high concentration remained for 2 days. Large particles greater than 10 μm showed daily fluctuation but without any distinct trend.

During the dust event, the total concentrations of aerosols greater than 2.23 μm were substantially increased by approximately one order of magnitude in both places compared with those in previous time period.

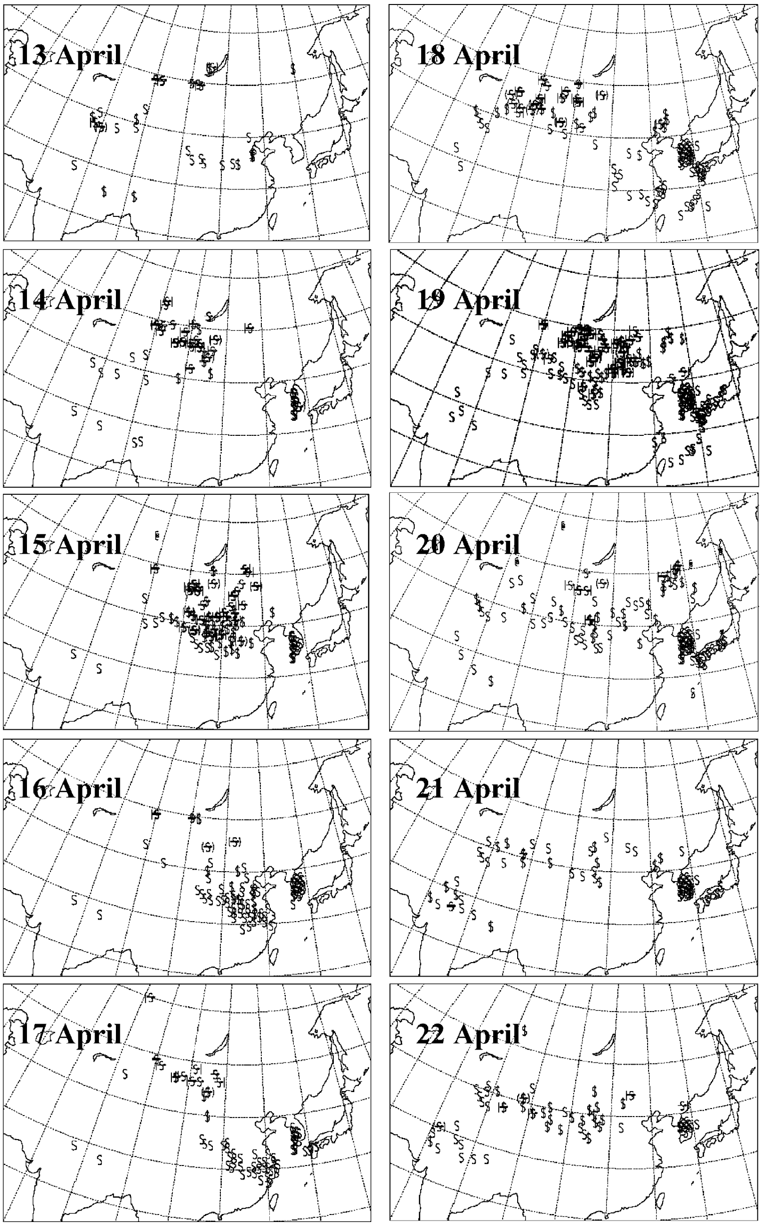

Fig. 2. The daily dust phenomenon during the period from 13 to 22 April 1998.

It is clearly shown in Fig. 6, where number concentrations observed in Seoul were compared for three different cases: dust period (14–22 April), heavy dust period (19 and 20 April), and non-dust period (March–May). During non-dust period, number concentrations in the size range were even lower. These observations are in good agreement with the result of early study by Shin and Kim (1992) that the mineral components collected in Korea had the size spectrum between 1 and 10 μm. However, number concentrations for particles smaller than 1 μm was reduced during a heavy dust period, which was more noticeable in Seoul. In Seoul, the number of fine particles was the greatest during non-dust period (Fig. 6). The shift in number concentrations of fine particles (< 1 μm) from non-dust to heavy dust period was opposite to that of coarse ones (1–10 μm), which implied that mineral dust is the major component of aerosol over Korea during dust period.

The fine particles contain primary particles from combustion sources and secondary materials such as sulfate,

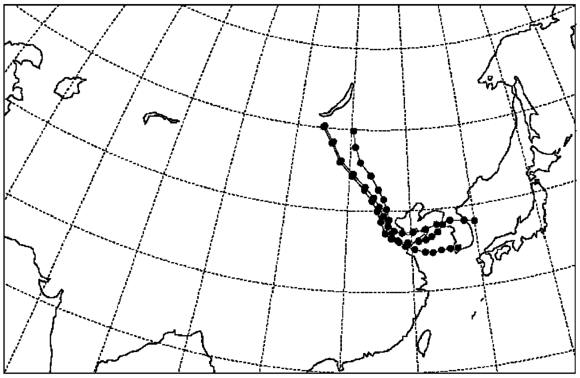

Fig. 3. 96 h backward trajectories on 295 K of air collected in Korea on 06 UTC 19 April 1998.

nitrate, and ammonium formed by gas-to-particle conversion. If the air masses collected in both places originated from the same source regions, then the difference was probably due to the local influences. While Anmyon Island locates right in the west coast of Korean peninsula, Seoul locates further inland, the east of big industrial complexes along the coast. Thus, air collected in Seoul could pick up more anthropogenic pollutants than that in Anmyon Island. It usually takes about a couple of days of SO_2 to be oxidized to SO_4 (Seinfeld and Pandis, 1998). Asian dust events is usually followed by the passage of strong frontal system and it is highly possible that the movement of air was faster during the heavy dust incident. Hence, there would be less time available for sulfur oxidation and thus the number of fine particles smaller than 1 μm was possibly more decreased during heavy dust episode. The effect of

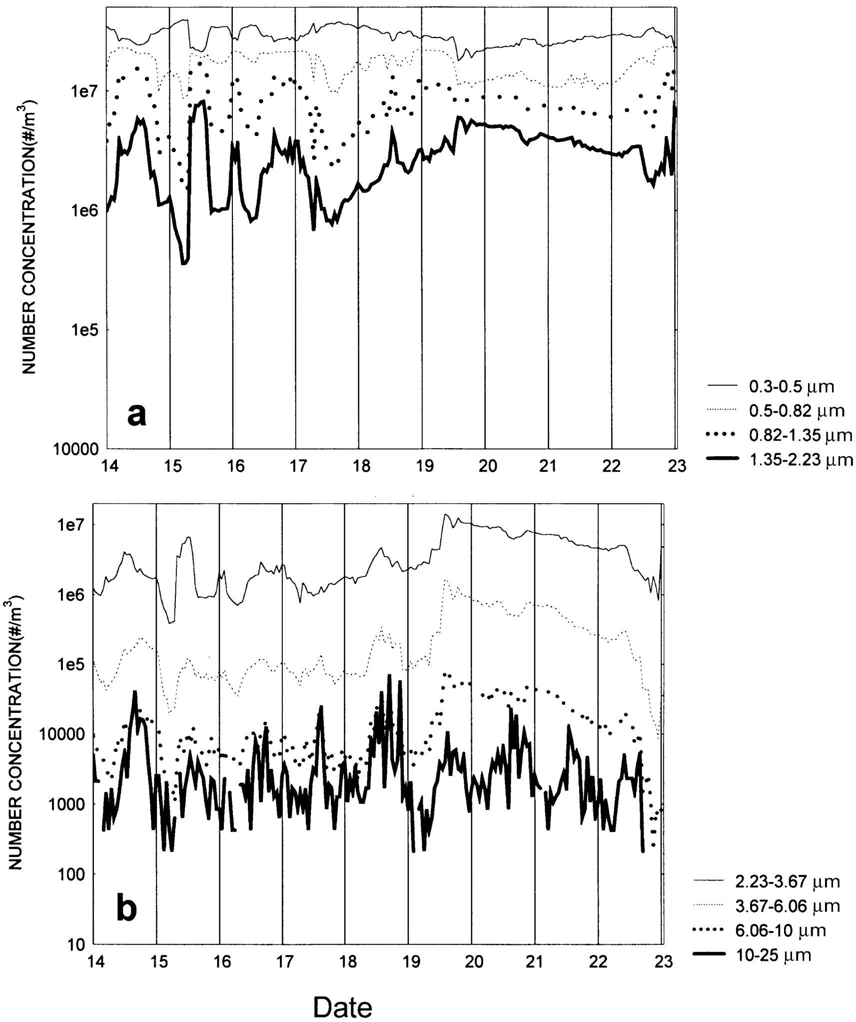

Fig. 4. Time series variation of aerosol number concentrations (ea m^{-3}) in Seoul during Asian Dust period in April 1998. The upper panel (a) is for the size range from 0.3 to 2.23 μm and lower one (b) from 2.23 to 25 μm.

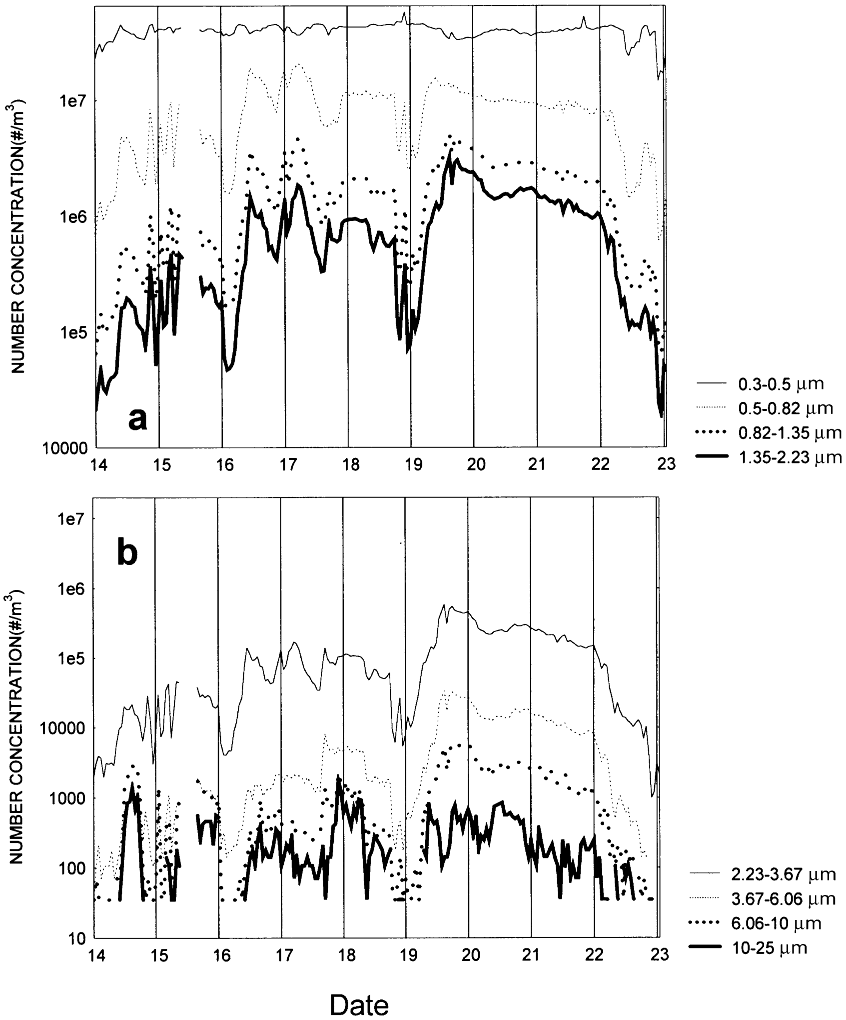

Fig. 5. Time series variation of aerosol number concentrations (ea m^{-3}) in Anmyon Island during Asian Dust period in April 1998. The upper panel (a) is for the size range from 0.3 to 2.23 μm and lower one (b) from 2.23 to 25 μm.

humidity can be also considered. The monthly average of April 1998 was higher in Anmyon Island (74.7%) than in Seoul (64.4%). Humidity was especially lower in Seoul on 19 April, which suggest that the hygroscopic growth of fine particles was less efficient. As a result, reduction in the number of fine particles smaller than 1 μm was more pronounced in Seoul during heavy dust period.

Number concentrations of large particles from 10 to 25 μm showed daily variation without any noticeable difference during the course of the dust period. The variation was more distinct in Seoul with bigger amplitude than in Anmyon Island. It indicates that large particles were likely more affected by local sources such as construction or free ways.

3.3. Correlation between size-separated number concentrations

The correlation matrix of size-separated number concentrations observed in Seoul and Anmyon Island during 14–22 April is given in Table 1. The correlation was significant (coefficient >0.8) for particles in the range of 2.23–10 μm. On the other hand, correlation was insignificant between particles >10 μm and those in other size bins, and between particles <0.82 μm. While fine particles <0.82 μm from Anmyon Island were not correlated with particles from Seoul, there was weak but negative correlation found between particles <0.82 μm from Seoul and those of 1.35–10 μm from Anmyon Island. These results are strong evidence for aerosols of

1.35–10 μm collected both in urban and coastal region in Korea during Asian dust period to originate from the same source. The correlation of number concentrations for each size bin from the two places was further improved when Asian dust was intense. Except for large particles over 10 μm in Seoul, there was positive or negative correlation between each size bin. It indicates that particles larger than 10 μm were from local sources. A significant correlation between the smallest aerosols from both places also suggests that during heavy event, processes generating secondary fine particles were not fully activated and thus local influence was pronounced.

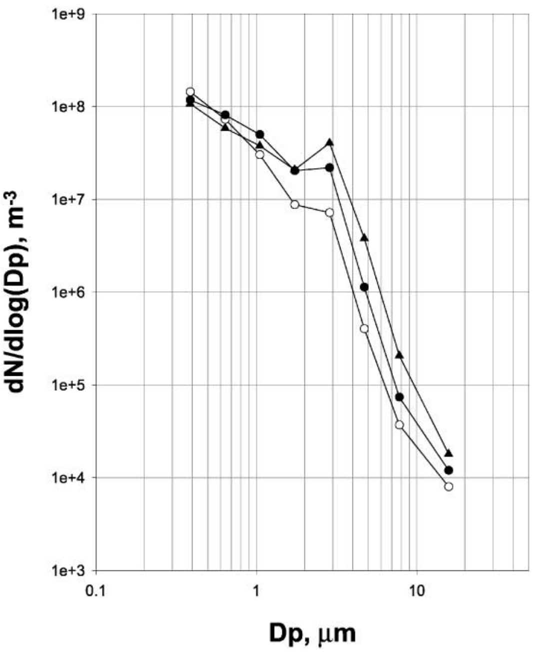

Fig. 6. Aerosol number concentrations for three different cases observed in Seoul in 1998: non-dust period (open circle) during March–April, regular dust period (black circle) during 14–22 April and heavy dust period (triangle) during 19–22 April 1998.

4. Conclusions

During Asian dust period in April 1998, size-separated number concentrations of aerosols in Seoul and Anmyon Island showed characteristic increase in the size range of 1.35–10 μm from non-dust to heavy period. The correlation between number concentrations observed in two places was good for this size range. These suggest that the component from Asian dust was in the size range between 1.35 and 10 μm. It could be narrowed down to 2.23 and 6.06 μm. The number concentration of aerosol > 10 μm observed in Seoul showed strong diurnal variation and its amplitude remained constant through Asian dust period. In Anmyon Island, concentrations of large particles > 10 μm fluctuated without a consistent trend. It was also found that there was no correlation between number concentration of particles > 10 μm from Seoul and Anmyon Island. Therefore, the upper size limit of Asian dust is nominally suggested as 10 μm in this study. The results of trajectory analysis also imply that the major component of aerosols collected in Korea during Asian dust period originated possibly from the Asian desert regions.

Acknowledgements

Authors are deeply grateful to Prof. S.-U. Park, Dr. P. Manins, Dr. G. Ross, Dr. M. Houper, Mr. H.M. Cho and Mr. D.S. Shin for their help and encouragement. This research is supported by the research project of METRI/National Research Laboratory (NRL) which is concerned with the research for "The development of Climate Change Monitoring Techniques in Korean Peninsula".

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Table 1
The correlation coefficient of aerosol number concentrations observed in Seoul and Anmyon Island during 14–22 April, 1998

Anmyon Is. Seoul (μm)	0.3–0.5 μm	0.5–0.82 μm	0.82–1.35 μm	1.35–2.23 μm	2.23–3.67 μm	3.67–6.06 μm	6.06–10 μm	10–25 μm
0.3–0.5	0.20	− 0.24	− 0.47	− 0.55	− 0.60	− 0.60	− 0.58	− 0.19
0.5–0.82	− 0.14	− 0.17	− 0.41	− 0.51	− 0.57	− 0.60	− 0.52	− 0.13
0.82–1.35	− 0.22	0.02	0.02	0.01	0.02	0.00	0.06	0.05
1.35–2.23	− 0.18	0.20	0.44	0.52	0.57	0.59	0.59	0.23
2.23–3.67	− 0.07	0.33	0.68	0.81	0.88	0.90	0.84	0.28
3.67–6.06	− 0.04	0.33	0.70	0.83	0.90	0.93	0.86	0.26
6.06–10	− 0.01	0.32	0.66	0.78	0.85	0.87	0.82	0.28
10–25	0.12	0.04	0.01	0.00	0.00	0.00	0.06	0.11

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