SEASONAL CHARACTERIZATION OF DUST DAYS, MASS CONCENTRATION AND DRY DEPOSITION OF ATMOSPHERIC AEROSOLS OVER QINGDAO, CHINA

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Abstract The seasonal characterization of dust days, mass concentration and dry deposition of atmospheric aerosols were investigated using the historical data of dust days observed over Qingdao during the period from 1961 to 2001 and ground-based aerosol sampling data collected in the period from May 2001 to November 2002. In Qingdao, most of the dust days occurred in spring and in winter and no dust days existed in summer. The seasonal variation of the uplifting dust day over Qingdao was in phase with that analyzed over North China. The mean mass concentration of the total suspended particles (TSP) in spring, summer, autumn and winter was respectively 300, 110, 113 and 185 µg m⁻³. The values and phase of the seasonal oscillation for fine particles were very similar to those for coarse particles except for the month March, during which the concentration of the coarse particles was about 4 times as high as that of the fine particles. Comparison between seasonal variation of mass concentration of aerosols and dust days indicated that high frequency of uplifting dust day was accompanied by high TSP mass concentration. The TSP mass concentration measured by the low-volume instrument was about 30% lower than that measured by high-volume instrument, though the two data sets are highly correlated (correlation coefficient=0.89). The dry deposition flux during the observation period from May 2001 to November 2002 ranged from 0.06 to 0.2 g m⁻² d⁻¹ with a mean value of 0.13 g m⁻² d⁻¹, which was about 1/3 as that over Beijing.

Keywords aerosol, physical characteristics, TSP, dry deposition

1. Introduction

Aerosols play an important role in affecting the atmospheric quality, cloud formation and precipitation, influencing the energy balance of the earth-atmosphere system (Sokolik et al., 2001; Cao et al., 2003), although their concentration is very low. Recently, studies on atmospheric aerosols and their radiative forcing have been the interesting research area in global and/or regional environment and climate changes (Zhang et al., 2001; Menon et al., 2002). Among them, much attention has been given to investigating aerosols in Eastern Asia. Scientists have taken part in several international joint research projects, including the ACE-Asia (Aerosol Characterization Experiments in Asia) and the TRACE-P (Transport and Chemical Evolution over the Pacific), to conduct extensive observation and numerical model simulation on aerosols, especially dust aerosols in Eastern Asia in the spring of 2001 (Kanai et al., 2002; Zhang et al., 2003a; Gong et al., 2003).

A joint research project has been in operation since 2000 for Aeolian Dust Experiment on Climate Impact (ADEC) between Chinese Academy of Sciences and Japanese Science and Technology Bureau on yellow sand dust. Qingdao, a coastal city, located in south Shandong peninsula and facing the Yellow Sea on the southeast, has become a major observation station in the ADEC project. Under the impact of ocean current and the southeast monsoon, Qingdao has an ocean climate with high humidity and abundant precipitation. These characteristics play significant roles in affecting the origin, transport, transformation and deposition of atmospheric aerosols (Wang & Hu, 2001; Zhang et al., 2003b). The objective of the experimental program over Qingdao was to determine the seasonal variation of dust days, mass concentration and dry deposition of particles over Qingdao, which will be useful for further study on dust transport, input of dust from the continent into the sea and the cycle of ocean materials.

2. Experiment

The observation station, belonging to the Department of Meteorology, China Ocean University, is located at the shore of the Yellow Sea, and about 65 m above sea level, on the roof of a 3-storied building at the top of a small hill (120°19′E, 36°6′N).

A high-volume air sampler HV-1000F, manufactured by SIBATA Scientific Co., Ltd., is used to collect total suspended particles (TSP), with an air flow rate of 1 m³ min⁻¹ in operating. The filters are PF040 polyflon filter (25 cm×20 cm) manufactured by Advantec Co., Ltd. The low-volume size-segregated sampler (Andersen-200, AN-200), manufactured by SIBATA Scientific Co., Ltd., is employed, operating at 28.3 L min⁻¹ to achieve ideal size separation. This 8-stage AN-200 sampler with a backup filter is listed for particle size discrimination from stage 0 to 8 as follows: >11,
11–7.0, 7.0–4.7, 4.7–3.3, 3.3–2.1, 2.1–1.1, 1.1–0.65, 0.65–0.43 and <0.43 µm. The filters used for AN-200 are 80 mm-diameter PF050 polyflon filters manufactured by Advantec Co., Ltd., and for stage No. 0–6, and the 2500QAT-UP quartz filters manufactured by Tokyo Dylec Co., Ltd., for stage No. 7 and backup filtration. Before and after sampling, the filters must be stored under a constant temperature of 25 °C and at a relative humidity of 37% for over 24 hours, and weighed by a balance LAC214 with a resolution of 10⁻⁴g.

The history of the dust events over Qingdao from 1961 to 2001 was obtained from the meteorology data center, China Meteorological Administration. The dust weather days were divided into 3 levels on the basis of visibility (Zhou, 2001): floating dust day with visibility <10 km, uplifting dust day with 1 km ≤ visibility ≤ 10 km and dust storm with visibility <1 km.

3. Results and Discussion

3.1 Seasonal variation of sand dust weather over Qingdao

Fig. 1 shows the seasonal variation of the number of uplifting dust days per month averaged from 1961 to 2001 over Qingdao, illustrating a maximum in spring and no dust in the summer months of June, July and Aug. The mean value of the uplifting dust day was about 0.15 day per month. The months with uplifting dust day above the mean value were Nov., Dec., Jan., Feb., Mar., and Apr. Comparison indicated that the seasonal oscillation of the uplifting dust day over Qingdao was in phase with that analyzed over North China, which is closely related to changes of the climate background (Lang et al., 2003; Zhang et al., 2002; Fan & Wang, 2004).

3.2 Seasonal variation of TSP concentration over Qingdao

Fig. 2 presents the seasonal variation of the TSP mass concentration from Jan. 2001 to Oct. 2002 over Qingdao as measured by the high-volume instrument. The annual mean value of the TSP mass concentration was 177 µg·m⁻³. The months with TSP mass concentrations above this mean value were Dec., Jan., Feb., Mar., and Apr., similar to those of the uplifting dust days as shown in Fig. 1, with maximum and minimum values occurring in March (460 µg·m⁻³) and June (61 µg·m⁻³), respectively. The mean mass concentrations of the TSP in the spring, summer, autumn and winter were respectively 300 (the maximum), 110 (the minimum), 113 and 185 µg·m⁻³. Figs. 2 and 1, taken together, indicate that high uplifting dust days were accompanied by high TSP mass concentrations.

3.3 Seasonal variation of coarse and fine aerosol particle concentration

Fig. 3 shows the seasonal variation (from Nov., 2001 to Oct., 2002) of the aerosol concentrations for coarse (particle size >2 µm, the sum from level 0 to level 4) and fine (particle size <2 µm, the sum from level 5 to level 8) particles over Qingdao as measured by the low-volume (AN-200) instrument, indicating similar seasonal oscillations between the coarse and the fine particles, except for the month of March, when the concentration of the coarse particles was about 4 times as high as that of the fine particles. The annual mean values for fine and coarse particle concentrations were respectively 52 µg·m⁻³ and 71 µg·m⁻³,
indicating that the TSP mass concentrations measured by the AN-200 instrument, 123 µg·m⁻³, was about 30% lower than that measured by the high-volume instrument as shown in subsection 3.2. The correlation coefficient between the two data sets, as measured by the low- and the high-volume instruments, was, however, as high as 0.89. That the concentration for the high-volume sampler is higher than that from the low-volume sampler AN-200 sampler is considered to be due to the higher efficiency in collecting coarse particles for the former.

3.4 Seasonal variation of dry deposition flux over Qingdao

Dry deposition flux data of the aerosols were collected from May 2001 to Nov. 2002 over Qingdao. Because of the impact of precipitation (mostly for the months in summer and autumn), only 8 months of the effective dry deposition flux were displayed in Fig. 4, which illustrates that the recorded high values occurred in May 2001 and December 2002. The dry deposition flux ranged from 0.06 to 0.2 g·m⁻²·d⁻¹ with a mean value of 0.13 g·m⁻²·d⁻¹.

Since the data set of the deposition flux collected over Qingdao was not as complete as for Beijing because of heavier precipitation over Qingdao, only the dry period in Oct. and Nov. 2002 was chosen to compare these two cities: 0.1 and 0.16 g·m⁻²·d⁻¹ for Qingdao and 0.33 and 0.42 g·m⁻²·d⁻¹ for Beijing, showing that Qingdao measured up to only 1/3 of that for Beijing. Possible reasons are (a) Qingdao is far off the dust source, implying that some dust particles had already deposited before arrival in Qingdao, and (b) the soil over Qingdao was relatively wet, resulting in less dust injected from the wet surface into the boundary layer.

4. Conclusions

The current study has analyzed the historical data of dust weather observed over Qingdao during the period from 1961 to 2001 and surface aerosol observation data collected in the period from May 2001 to Nov. 2002. The major conclusions are as follows.

- From 1961 to 2001, Qingdao was mainly dominated by floating dust: the mean values of floating dust and uplifting dust were respectively 2.93 and 1.83 days per year; there was only one day of dust storm in these 41 years. The uplifting and floating dust days over Qingdao were respectively about 13% and 75% of those in Beijing during the same period.
- The mean value of the uplifting dust days was about 0.15 day per month. Most of the dust weather occurred in spring and in winter, and no dust weather existed in the summer. The seasonal oscillation of the uplifting dust days over Qingdao was in phase with those in North China.
- The annual mean value of TSP mass concentrations measured by high-volume instrument was 177 µg·m⁻³, with a maximum in March of 460 µg·m⁻³ and a minimum in June of 61 µg·m⁻³. The seasonal mean mass concentrations of TSP in spring, summer, autumn and winter were respectively 300, 110, 113 and 185 µg·m⁻³. The first two conclusions indicate that high frequency of uplifting dust day was accompanied by high TSP mass concentration.
- The seasonal oscillation of concentration for fine particles was mostly in phase with that for coarse particles except for the month of March, during which the concentration of coarse particles was about 4 times higher. The TSP mass concentration measured by the low-volume instrument was 123 µg·m⁻³, about 30% lower than that by the high-volume instrument, although the correlation coefficient of the two data sets was as high as 0.89.
- The dry deposition flux during the observation period from May 2001 to Nov. 2002 ranged from 0.06 to 0.2 g·m⁻²·d⁻¹ with a mean value of 0.13 g·m⁻²·d⁻¹. The deposition flux over Qingdao was about 1/3 as that over Beijing.

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