NOTES AND CORRESPONDENCE

On the Kosa (Asian Dust) Event in November 2002: Aerosol Number Concentrations and Precipitation Chemistry in Toyama, Japan

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Abstract

The Kosa event was observed widely in Japan on 12 November 2002. Measurements of size-separated aerosol number concentrations and precipitation chemistry were performed in Toyama during the autumn and early winter of 2002. The number of aerosol particles larger than 3.0 μm in diameter dramatically increased during the Kosa event, whereas the number concentrations of finer particles hardly changed. The concentration of non-sea-salt calcium and pH were high in the precipitation sampled during the Kosa event.

1. Introduction

Kosa (Asian dust) particles are transported from the Asian continent over Japan, mainly during the spring seasons (Iwasaka et al. 1983), and not only affect radiation intensity in the atmosphere, but also contribute to the neutralization of acids in water droplets (Tsuruta 1991; Watanabe et al. 1999). On 12 November 2002, Kosa was widely seen in Japan (http://www.jma.go.jp/JMA_HP/jma/index.html). Kosa events have been rarely observed in the autumn seasons. The total number of days when Kosa events were observed at the 123 weather stations in Japan during October and Novem-

ber is shown in Fig. 1. In autumn, Kosa had sometimes been seen in the early 1970s, but hardly observed after 1975. Kosa also was detected at some weather stations (6 points) in November 1996. In the case of November 2002, a total of 76 Japanese routine meteorological observatories reported Kosa events.

Observational studies on aerosol optical characteristics or number concentrations of aerosol particles during Kosa events have been performed in the spring seasons (Tanaka et al. 1989; Chun et al. 2001). Precipitation chemistry affected by Kosa particles has been examined (Dokiya et al. 1995; Minoura et al. 1998). Kosa or mineral particles also were studied by electron microscopy (Okada et al. 1987; Nii-mura et al. 1998). However, investigations on both aerosol number concentrations and precipitation chemistry during particular Kosa events rarely have been made. Moreover, there

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Fig. 1. Total number of days when Kosa events were observed at the weather stations in Japan (123 points) during October and November.

are no case studies on Kosa events during the autumn seasons in literature.

In this paper, characteristics of size-separated aerosol number concentrations and the chemical composition of precipitation in Toyama, Hokuriku district, located near the coastal region of the Japan Sea, during the Kosa event in the autumn 2002, are examined, and the effect of Kosa particles on the atmospheric environment, especially acidic precipitation is discussed.

2. Methods

Surface weather charts at 09H JST from 10 to 13 November 2002 are displayed in Fig. 2. A low pressure system over the continent on 10 November might have caused the dust storm, and developed after 11 November. Then, the low pressure passed through Japan, and the Kosa event was observed on 12 November.

The number concentrations of aerosol particles in the five diameter ranges of $d > 0.3$, 0.5, 1.0, 3.0 and 5.0 μm were measured using a laser particle counter (Kanomax, Model 3886) with a 10 mm ID Tygon tube (100 cm length). The counter was set on the roof of the building of the college of Technology, Toyama Prefectural University at Kosugi-machi in Toyama. One-minute-averaged data were obtained every hour.

Bulk sampling of precipitation was performed at the Toyama Astronomical Observatory every 3–10 days. Figure 3 presents the map of Japan showing the locations of Toyama Prefectural University and Toyama Astronomical Observatory. After the sampling, the pH of the precipitation samples was measured by an electrode

Fig. 2. Surface weather charts at 09H JST from 10 to 13 in November 2002.

Fig. 3. Map of Japan showing the locations of Toyama Prefectural University and Toyama Astronomical Observatory.

using a pH meter (Horiba, Model D-14). The accuracy was ± 0.01 pH. The analysis of dissolved ionic species was performed using an ion chromatograph (Shimadzu, non-suppressor type), equipped with an IC-A3 column to quantify Cl^- , NO_3^- , SO_4^{2-} and an IC-C3 column to quantify Na^+ , NH_4^+ , K^+ , Mg^{2+} and Ca^{2+} . The eluent used was 8.0 mM *p*-hydroxybenzoic acid/3.2 mM tris (hydroxymethyl) aminomethane/50 mM boric acid for the anions, and 2.5 mM oxalic acid for the cations. The analytical meth-

ods were described in detail by Honoki et al. (2001). The mean analytical error was within 5%.

3. Results and discussion

3.1 Aerosol number concentrations

Time series of the size-separated aerosol number concentrations at Kosugi-machi during November and December 2002 are shown in Fig. 4. Unfortunately, the number concentrations were not measured from the morning of

Fig. 4. Time series of the size-separated aerosol number concentrations at Kosugi-machi in Toyama during November and December 2002.

Fig. 5. Aerosol number concentrations for three different cases: on 11 November (before the Kosa event), 12 November (during the Kosa event) and 14 November (after the Kosa event).

23 to the morning of 24 in November due to electric trouble. The number of aerosol particles in the range of 3.0–5.0 μm was usually around $10 \ell^{-1}$. During the Kosa event, the number was near $1000 \ell^{-1}$. In the daytime of 12 November, the number concentrations of aerosol particles larger than 3.0 μm abruptly increased whereas the aerosol number concentration in the range of 0.3–0.5 μm hardly changed. The high concentrations of the larger particles continued until the morning of 13 November. After the daytime of 13 November, the number of concentrations decreased due to rain fall. The larger particles concentrations also rose abruptly on 5 December (Fig. 4). The relatively high concentrations continued until 6 December. Perhaps, the Kosa event might have occurred also.

The mean aerosol number concentrations for three different cases: on 11 November (before the Kosa event), 12 November (during the Kosa event) and 14 November (after the Kosa event), are presented in Fig. 5. The number concentrations of the fine particles (0.3–0.5 μm) did not increased during the Kosa event. The coarse particles larger than 1.0 μm dramatically increased. The particles in the range of 0.5–1.0 μm also increased. After the Kosa event, the number concentrations were reduced. Chun et al. (2001) reported that during the dust period in Seoul, coarse particles (1–10 μm) also in-

creased, which implied that mineral dust is the major component, however, number concentrations for particles smaller than 1 μm were reduced. The fine particles contain primary particles from combustion sources and secondary materials such as sulfate, nitrate and ammonium formed by gas-to-particle conversion (Seinfeld and Pandis 1998). Observation in Seoul is greatly affected by anthropogenic pollutants. Asian dust (Kosa) events are usually followed by the passage of strong frontal systems and the movement of air is fast (Chun et al. 2001). Therefore, the number of fine particles decreased during the dust episode in Seoul. Air quality in the city of Seoul seems to be more polluted than that at Kosugi-machi located in a rural (or semi-urban) area. The decrease in fine particles seems to be small considering the passage of the frontal system at Kosugi-machi, differing from the case in Seoul. Perhaps air pollution, including fine particles, might also have been transported with Kosa particles from the continent. As a result, the fine particle concentrations hardly changed. However, much more detailed research is required to understand the phenomenon.

3.2 Precipitation chemistry

A summary of the chemistry of the precipitation (mainly rain water) bulk sampled at Toyama Astronomical Observatory is shown

Table 1. Summary of the chemistry of the bulk precipitation samples at Toyama Astronomical Observatory from October to December 2002. Units of the concentrations of ionic constituents are microequivalents per liter.

Date	pH	Cl ⁻	NO ₃ ⁻	SO ₄ ²⁻	_{nss} SO ₄ ²⁻	Na ⁺	NH ₄ ⁺	K ⁺	Mg ²⁺	Ca ²⁺	_{nss} Ca ²⁺
6–12 Oct	4.77	43.6	10.8	30.2	27.0	27.0	13.9	17.7	6.7	22.0	20.8
12–23 Oct	4.53	187.5	16.8	58.1	37.4	172.8	3.1	3.6	39.9	24.0	16.4
23–26 Oct	4.36	394.0	16.1	88.4	46.4	350.2	0.0	5.1	76.1	37.1	21.7
26 Oct–3 Nov	4.55	275.7	10.5	57.3	26.4	257.9	0.0	5.3	58.3	26.6	15.2
3–10 Nov	4.50	214.6	12.5	67.5	43.3	201.5	4.1	5.5	43.1	26.5	17.7
10–17 Nov	5.13	400.5	20.2	99.5	55.6	366.7	1.2	9.8	87.4	81.8	65.6
17–24 Nov	4.17	235.7	17.2	97.1	69.3	232.1	5.5	9.3	50.5	29.9	19.7
24–27 Nov	4.68	143.8	4.7	45.1	28.8	135.4	0.6	2.0	31.6	22.2	16.2
27 Nov–1 Dec	4.20	75.5	23.3	88.9	81.0	65.6	15.8	5.0	27.4	26.9	24.0
1–8 Dec	4.48	191.4	12.4	69.7	48.4	177.0	1.2	2.6	38.8	39.0	31.2
8–15 Dec	5.12	146.6	7.8	41.3	25.1	135.1	1.6	3.6	30.3	36.5	30.5
15–22 Dec	—	107.3	13.2	81.3	70.4	91.6	13.0	3.8	24.4	20.5	16.5

in Table 1. Units of the concentrations of ionic constituents are microequivalents per liter ($\mu\text{eq}/\ell$). Unfortunately, the pH of the precipitation sampled from 15–22 December could not be measured. The pH of the precipitation water ranged from 4.17 to 5.13. Most of the samples were acidified. The levels of non-sea-salt sulfate (SO_4^{2-}) and non-sea-salt calcium (Ca^{2+}) were estimated using the following equations:

$$\begin{aligned}\text{SO}_4^{2-} &= \text{SO}_4^{2-} - (\text{SO}_4^{2-}/\text{Na}^+)_{\text{seawater}} \cdot \text{Na}^+, \\ \text{Ca}^{2+} &= \text{Ca}^{2+} - (\text{Ca}^{2+}/\text{Na}^+)_{\text{seawater}} \cdot \text{Na}^+, \end{aligned}$$

where $(\text{SO}_4^{2-}/\text{Na}^+)_{\text{seawater}}$ and $(\text{Ca}^{2+}/\text{Na}^+)_{\text{seawater}}$ are the concentration ratio of SO_4^{2-} to Na^+ and that of Ca^{2+} to Na^+ in seawater, which are 0.12 and 0.044 (equivalent ratio), respectively (Wilson 1975; Keene et al. 1986). The major components in the precipitation samples were Cl^- and Na^+ derived from sea-salt particles, with a similar equivalent ratio of seawater. The concentration ratio of Mg^{2+} to Na^+ also was similar to that of seawater. The SO_4^{2-} and NO_3^- contributed to the acidification of the precipitation samples. The concentration of SO_4^{2-} was much higher than that of NO_3^- . Higher concentrations of SO_4^{2-} in precipitation have been

seen in the Hokuriku district especially during winter seasons (Honoki and Hayakawa 2001; Honoki et al. 2001). A similar result also was reported on cloud water chemistry over the Japan Sea (Watanabe et al. 2001a), whereas a higher NO_3^- concentration in cloud water was seen near the industrial region in Japan (Watanabe et al. 2001b). According to Honoki and Hayakawa (2001), the contribution rate of SO_4^{2-} originating from the Asian continent was about 0.5 in the coast of the Hokuriku district.

Kosa particles are rich in CaCO_3 (Tsuruta 1991) and suppress acidification of rain and cloud water (Minoura et al. 1998; Watanabe et al. 1999 and 2001a). High concentrations of Ca^{2+} are detected in cloud and rain water that contain Kosa particles (Dokiya et al. 1995; Watanabe et al. 1999 and 2001a). The Ca^{2+} in the precipitation samples might have contributed to the neutralization of acids. Variations of the concentration of Ca^{2+} and acidity (pH) in the precipitation are presented in Fig. 6. The concentration of Ca^{2+} and pH were significantly high in the precipitation water sampled during 10–17 November when the Kosa event was observed. The acidic species in

Fig. 6. Variations of the concentration of $_{\text{nss}}\text{Ca}^{2+}$ (bar graph) and pH (line graph) in the precipitation sampled at the Toyama Astronomical Observatory in Toyama.

the precipitation were neutralized by the Kosa particles. As mentioned above, Kosa particles also might have been detected on 5 December. The $_{\text{nss}}\text{Ca}^{2+}$ concentration was slightly high in the precipitation sampled on 1–8 December (Table 1). If Kosa events increase not only in the spring seasons but also in the autumn, then acidification of cloud and rain water would be suppressed, especially in the coastal regions of the Japan Sea.

4. Summary

Size-separated aerosol number concentrations and chemical composition of bulk sampled precipitation were measured in Toyama, Hokuriku district, located near the coastal region of the Japan Sea, during the autumn and early winter in 2002. The number concentrations of aerosol particles larger than $3.0\ \mu\text{m}$ in diameter significantly increased on 12 November when Kosa events were reported at the weather stations in Japan, and on 5 December. The high concentrations of large particles continued for the next few days. The fine particles smaller than $0.5\ \mu\text{m}$ hardly changed.

The precipitation water was usually acidified. However, the concentration of $_{\text{nss}}\text{Ca}^{2+}$ and pH were high in the precipitation sampled during the Kosa event. If Kosa particles are

transported frequently even in the autumn seasons, acidification of precipitation would be suppressed.

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