P1.234 AEROSOL CONCENTRATIONS OBSERVED AT MT. HARUNA, JAPAN, IN RELATION TO LONG-RANGE TRANSPORT OF ASIAN MINERAL DUST AEROSOLS

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Abstract

As a part of the effort to understand the structure of long-range transported aerosol plumes and local pollution, aerosol observations monitored the mass concentrations and number-size distributions during the period August 2006 to July 2009 near the top of Mt. Haruna (1365 m), an isolated mountain in the Kanto Plain in Japan. The mass concentrations observed at Mt. Haruna and plain sites showed a seasonal variation with a maximum in spring and summer, respectively. The spring peaks in aerosols at Mt. Haruna were probably caused by long-range transport of mineral dust and anthropogenic particles from the Asian continent. The summer peaks at the plain sites was attributed to local pollution from the Tokyo metropolitan area. Three examples of 2007 Asian dust events were investigated to show that aerosols may be dispersed in a complicated three-dimensional structure and that delayed arrivals of the dust plumes at plain sites compared to Mt. Haruna were not a rare case. Because of the boundary layer being stable at night, the dust layer was advected eastward without the vertical mixing before sunrise. This study suggests that after thermal convection activated by sunlight during daytime Asian dust transported in the free troposphere may be brought down into the atmospheric boundary layer, increasing the dust concentration there.

1. Introduction

Many monitoring studies have been investigated Asian dust, anthropogenic aerosols, and their precursor gases from the Asian continent. The monitoring is performed mostly in the East China Sea or isolated islands to avoid local emission sources. Aerosols may be dispersed in a complicated three-dimensional structure. Iwasaka et al. (1983) detected a dust layer in the middle to lower troposphere using a lidar system. Tsunematsu et al. (2006) found a dust layer distributed at 1–5 km altitude above the boundary layer in the Kanto area in Japan. Because ground observations are usually limited to near sea level, it is difficult to map the three-dimensional structure and mechanism of aerosol transport. To better understand these multilayered structures of atmospheric aerosols originating from many sources, aerosol observations at several different altitudes would be useful.

Mountain observations are well suited for year-round in situ observations. However, orographic effects commonly cause moisture condensation so that orographic clouds and precipitation can scavenge aerosols. Diurnal wind circulation patterns also uplift air masses from lower altitudes during the day and mix them with air of the free troposphere. Some studies of mountain aerosols (e.g., Bigg, 1977; Kido et al., 2001; Naoe et al., 2003) have used only nocturnal data to avoid interference with the boundary layer aerosols. Fig. 1 shows the locations of observation sites at Mt. Haruna, Mt.

Happo, and Tsukuba. We chose Mt. Haruna for the following reasons. Because the Mt. Haruna observation site is in the transition region between the boundary layer and the free troposphere, it is well situated to detect aerosols from both of these layers. Also, it can observe both local and Asian aerosols, helping in evaluating the relative contribution of these two aerosol types.

Therefore, the aim of this study was to understand the three-dimensional structure of long-range transported aerosol plumes and local pollution based on mass concentrations and number-size distributions observed at Mt Haruna. In addition, we used PM_{10} data measured at Mt. Happo and SPM data from Kanto Plain sites and outside Kanto Plain sites in this study.

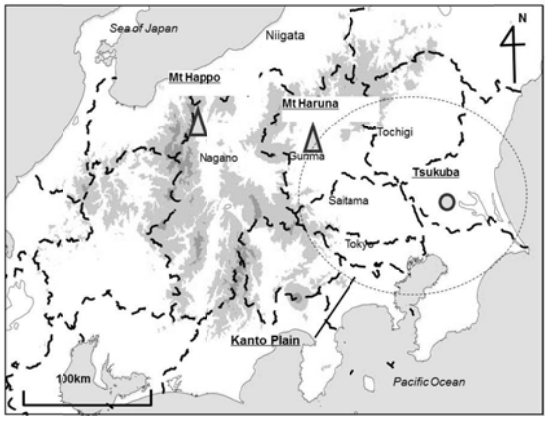

Fig 1. Map of central Japan, showing the locations of observation sites: Mt. Haruna (36.5°N, 138.9°E, 1365 m altitude), Mt. Happo (36.7°N, 137.8°E, 1850 m), and Tsukuba (36.0°N, 140.1°E, 31 m). Topography is shaded for >1000 and >2000 m; borders of prefectures (some named) are indicated by dashed lines.

2. Methods

A tapered element oscillating microbalance (TEOM) (TEOM-1400a, Thermo Scientific, formally R&P Co. Inc.) was used to measure PM_{10} mass concentration, and an OPC (RION Co. Inc., Model KC01-E) was used to measure the number concentrations of aerosol particles with five diameter ranges : >0.3 μm, >0.5 μm, >1 μm, >2 μm, and >5 μm. To avoid the hygroscopic growth of aerosol particles, aerosols were measured by the TEOM at relative humidities of less than 30% by warming the TEOM sensor to 30 °C.

Year-round PM_{10} observation were carried out at Mt. Happo (36.7°N, 137.8°E, 1850 m), on the eastern slope of the North Japan Alps approximately 100 km WNW of Mt. Haruna, by the Acid Deposition and Oxidant Research Center (ADORC) as a part of Acid Rain Monitoring Survey conducted by the Ministry of Environment. Number-size distributions of aerosols were monitored in Tsukuba (110 km ESE of Mt. Haruna, 36.0°N, 140.1°E, 31 m altitude) by an OPC of the same model as that used at Mt. Haruna. The instrument was installed in a room with controlled temperature on the top (sixth) floor of the Meteorological Research Institute (MRI).

As part of local pollution monitoring efforts in Japan, SPM mass concentrations were monitored at more than 1000 observation sites by local governments and by the Ministry of the Environment. For comparison with PM_{10} data at Mt. Haruna, we classified the SPM data into two groups: sites in the Kanto Plain (105 stations in Tochigi, Gunma, and Saitama Prefectures), and sites outside the Kanto Plain (44 stations in Nagano and Niigata Prefectures).

A Mie scattering lidar installed by the National Institute for Environmental Studies (NIES) in Tsukuba was used to measure the aerosol backscatter coefficient and depolarization ratio, which were then converted into vertical distributions of spherical and nonspherical aerosols by the retrieval processes (Shimizu et al., 2004). The time-height distributions of the backscattering coefficient and depolarization ratio were used for distinguishing the dust plume from other aerosols.

3. Results

Three examples of 2007 Asian dust events are shown in Fig 2, by graphs of the temporal variation in the number concentration of coarse aerosols (>5 μm) at Mt. Haruna and Tsukuba (Meteorological Research Institute site). In the first event, on 25–26 March, the number concentration of coarse particles at Mt. Haruna increased, followed 11 hours later by an increase at the Tsukuba site (Fig. 2a). In the second event, on 31 March–1 April, the number concentration at Mt. Haruna increased 9 hours before increasing at Tsukuba (Fig. 2b). In the third event, on 25–26 May 2007, the number concentration at Tsukuba increased 6 to 9 hours later than at Mt. Haruna (Fig. 2c). As we discuss later, the controlling factor of the dust arrival at the plain sites seemed to be vertical mixing initiated in the morning by solar radiation.

From 31 March to 1 April 2007 (Fig. 2b), an Asian dust event was observed in most of Japan in routine surface meteorological observations of the Japan Meteorological Agency. At Mt. Haruna, the number concentration of coarse particles (>5 μm) increased rapidly during the night of 31 March to 1 April. The dust transport route in this case was simulated by the NOAA hybrid single-particle Lagrangian integrated trajectory (HYSPLIT) model. The backward trajectory analysis (not shown) that started at 0900 JST on 1 April 2007 at a height of 1500 m indicated that the dust plume was advected toward the east-southeast at a speed of 30 m s^{-1}. This speed was high enough to transport the air mass from Mt. Haruna to Tsukuba in 2 hours, but the observed time difference was 9 hours.

Fig. 3 shows the depolarization ratios observed by lidar at the NIES in Tsukuba during this dust event. Before 0600 JST on 1 April, the dust layer could not be observed owing to interference from low clouds. Once the cloud layer disappeared, the dust plume was apparent in high depolarization ratios in an aerosol layer between 3 and 4 km altitude. During the period 0700–0800 JST, the layer expanded downward, suggesting that the dust plume was being injected into the boundary layer. The vertical mixing appeared to be more active at 0800 JST. At 0900 JST, a rapid increase in coarse particle concentration was observed by the ground-based OPC at Tsukuba. Because the boundary layer is stable at night, before sunrise the dust layer was advected eastward without the vertical mixing. As vertical mixing began after sunrise and proceeded, the dust layer reached the surface level. This dust injection into the boundary layer was faster than would be due to the gravity settling.

In this connection, Tsunematsu et al. (2006) described a typical event in which a dust layer lying over the boundary layer absorbed infrared radiation from the surface at night, which enhanced the stability at the bottom of the dust layer while resulting in a high concentration of pollutants within the boundary layer. The increase in stability in such cases may prevent dust aerosols from being injected into the boundary layer by convection. Once thermal convection is activated by sunlight during daytime, vertical exchange between the free troposphere and the boundary layer could bring the dust down into the boundary layer, increasing the dust concentration there. The delayed arrival of Asian dust in Tsukuba is not a rare case, and is consistent with this explanation. The mechanism controlling the three-dimensional distribution of aerosol plumes in the free troposphere and boundary layer should be investigated in more detail.

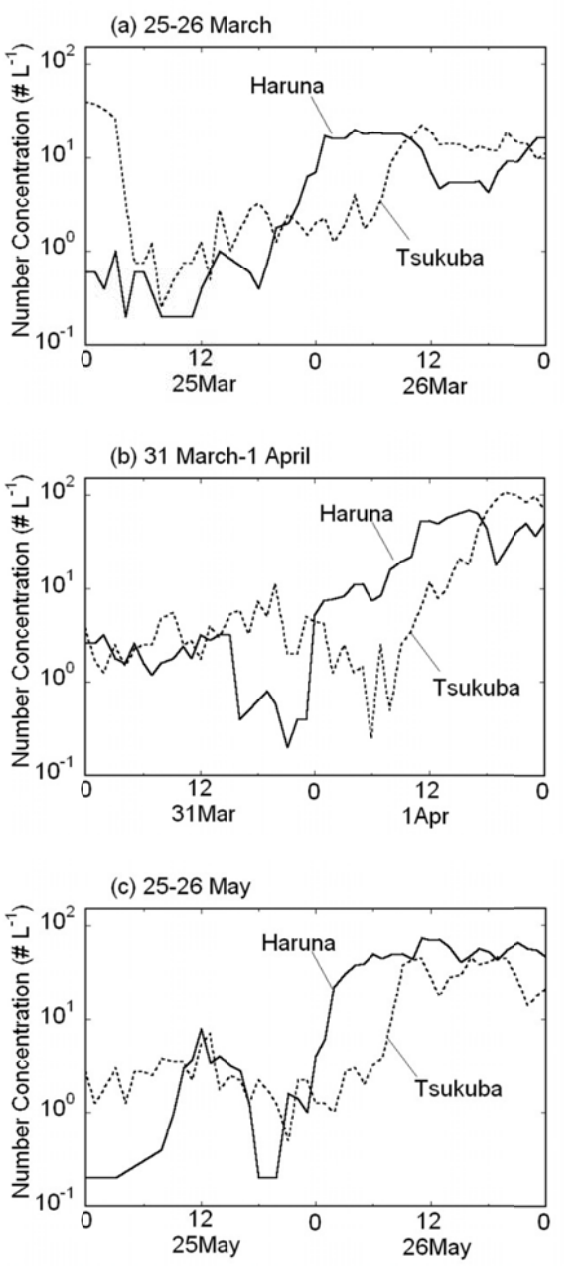

Fig 2. Temporal variation in the number concentration of coarse (>5 μm) aerosols at Mt. Haruna and Tsukuba during Asian dust events (a) on 25–26 March, (b) on 31 March–1 April, and (c) on 25–26 May 2007.

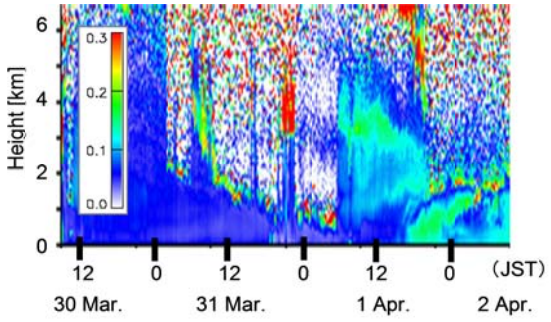

Fig 3. Time-height cross-section of aerosol depolarization ratio measured by the NIES lidar over Tsukuba during the period 30 March–1 April 2007. The Asian dust event occurred during the period 0000–0600 JST on 1 April 2007 at Tsukuba.

参考文献

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