THE INFLUENCE OF LOCAL METEOROLOGICAL PHENOMENA ON THE BEHAVIOR OF AEOLIAN DUST OVER THE TOKYO METROPOLITAN AREA


*Chiba University, Japan; **National Institute of Information and Communications Technology, Japan; ***Meteorological Research Institute, Japan; ****Tokyo University of Marine Science and Technology, Japan

Abstract

Impacts of local meteorological phenomena on the behavior of aeolian dust particles that arrived in the Tokyo metropolitan area were investigated through aerosol lidar observations, coherent Doppler lidar observations, ceilometer observations, and numerical experiments by the use of regional-scale meteorological models and advection-dispersion models. The results showed that the developed stable layer and strong capping inversion formed over the metropolitan area can prevent Asian dust particles from spreading to the ground surface. Also, the transport of volcanic ash particles released from the Mount Asama volcano can be influenced by a return flow of south-to-southeasterly sea breezes and valley winds prevailing over the metropolitan area in the afternoon.

Key words: Aeolian dust, model simulations, Lidar observations, Tokyo metropolitan area

1. INTRODUCTION

Air pollution caused by aeolian dust such as Asian dust and volcanic ash is one of the important environmental problems in the Tokyo metropolitan area. Impacts of local meteorological phenomena on the behavior of the aeolian dust that arrived in the metropolitan area were investigated in this study. This study treated two Asian dust events and an ashfall event that occurred in April 2005, April 2007, and September 2004, respectively.

2. METHOD

Field observations by the use of an aerosol lidar, a coherent Doppler lidar, and a ceilometer were performed in this study. Numerical experiments were also performed using regional-scale meteorological models, such as WRF (Weather Research and Forecasting; Skamarock et al., 2005) and RAMS (Regional Atmospheric Modeling System; Pielke et al., 1992), and advection-dispersion models including WRF-Chem (Grell et al., 2005).

3. RESULTS AND DISCUSSIONS

Figure 1 shows a result of ground-based aerosol lidar observations performed in the Tokyo metropolitan area on 27–28 April 2005 when an Asian dust event occurred. The aerosol lidar was developed at Meteorological Research Institute, Japan. Figure 1 and results of radiosonde observations (Figures not shown here) indicated that strong capping inversion, which was formed over the metropolitan area, prevented the airborne Asian dust particles from spreading to the ground surface. Also, a ground-based Doppler lidar developed at National Institute of Information and Communications Technology observed airborne Asian dust that arrived at Tokyo on 1 April 2007 (Figure 2). Results of the observations and model simulations indicated that the developed stable layer (Figures not shown here) acted as an obstacle to the transport of the Asian dust particles from the upper air toward the ground surface. The development of the stable layer would be promoted by the wind-blocking effect of the mountainous region located to the west of the metropolitan area. This is considered to be one of the main causes of the low appearance frequency of Asian dust phenomena over the metropolitan area and eastern Japan.

Results of model simulations showed that the transport of volcanic ash particles released from the Mount Asama volcano can be influenced by a compensatory return flow of south-to-southeasterly sea breezes and valley winds prevailing over the metropolitan area in the afternoon (Figure 3). An aerosol lidar and a ceilometer installed in the metropolitan area appear to have observed the airborne ash particles (Figure 4).

4. SUMMARY

The results of this study showed that the developed stable layer and strong capping inversion formed over the Tokyo metropolitan area can prevent Asian dust particles from spreading to the ground surface. Also, the transport of volcanic ash particles released from the Mount Asama volcano can be influenced by a large-scale local wind circulation prevailing over the metropolitan area. Thus, the atmospheric boundary layer conditions and local wind circulations over the metropolitan area have a large influence on the behavior of aeolian dust particles.
Figure 1. Time-height cross sections of (a) the backscattering ratio (R) and (b) the aerosol depolarization ratio (δₐ; %) from 0800 LT April 27 to 2400 LT April 28, 2005. Figure 1c shows a schematic interpretation of Figures 1a and 1b. Figure 1d shows the hourly optical thicknesses of the Asian dust, which were calculated from results of the lidar measurements at a 532 nm wavelength. The white columns in Figures 1a and 1b indicate the missing profiles. The calculation of δₐ was carried out when the aerosol backscattering coefficient exceeded 0.000001/m/sr. The arrows arranged in the lowest part of Figure 1 indicate each time when routine radiosonde measurements were performed. This figure was cited from Tsunematsu et al. (2006).
Figure 2. Vertical cross-sections of the normalized signal-to-noise (SN) ratios for the range of horizontal distance from the lidar <10km and altitudes below 6km at (a) 0031–0036 LST, (b) 0407–0413 LST, (c) 0818–0823 LST, and (d) 1211–1216 LST 1 April 2007. The SN ratios were calibrated by the squared-distance-weighted method. The maximum value of the normalized SN ratios is 10. The blacked-out regions represent missing values. This figure was cited from Tsunematsu et al. (2009).

Figure 3. Vertical cross sections of the simulated ash distributions overlying the simulated wind vectors at (a) 1200, (b) 1500, (c) 1800, and (d) 2100 LST 16 Sep 2004. All simulated ash particles were projected onto an east–west plane. This figure was cited from Tsunematsu et al. (2008).
Figure 4. Time–height cross sections of (a) the total depolarization ratio ($\delta$; %) from the lidar at Tsukuba and (b) the attenuated aerosol backscattering coefficient ($\beta_a; 10^{-3}$ km$^{-1}$ sr$^{-1}$) from the ceilometer at Tokyo for the period from 1800 LST 16 Sep to 0530 LST 17 Sep 2004. The arrow in (a) indicates the time at a routine radiosonde measurement. Results of the lidar observations at altitudes below 2 km MSL were unavailable. This figure was cited from Tsunematsu et al. (2008).

References