Characterization of Asian aerosols at Fukue-jima island using in-situ observation and remote sensing data

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Abstract

We investigated particle size and shapes using in-situ observation and ground-based remote sensing data to characterize the Asian aerosols during Kosa events in particular. In this study, we analyzed the data observed in Fukue-jima island (32.6 ° N, 128.8 ° E) from 2003 to 2004. We estimated the particle size and sphericity using OPC and LIDAR observation data, respectively. We made a detailed match-up analysis based on the report of Kosa event at Fukue-jima by Japan Meteorological Agency. As a result, we have a linear relationship between particle size and sphericity in Kosa events, which is clearly different from the other seasons statistically. We further confirmed that larger and nonspherical particles were not exclusively dominated in Kosa events, compared to the other seasons. This also suggests that smaller and spherical particles, such as sea salts from the surrounding ocean or air pollution materials from mega cities, were mixed with Kosa aerosols statistically. We will further discuss the results with other match-up analyses using skyradiometry, and will compare the results to regional transport model simulations so as to identify the Asian aerosols around this region in detail.

Keywords **:** Aerosol, Asian dust, OPC, LIDAR, Skyradiometer

1. Introduction

Aerosol has a crucial role in earth radiation budget on a global scale as well as in a source of air pollution on a regional scale. We have Yellow Sand (Kosa) events over East Asia in springtime every year. Kosa aerosol usually consists of mineral dusts, which originates in Gobi or Taklimakan desert. Recently, several studies suggest that Kosa aerosol is mixed with smaller polluted materials after the air mass travels over mega cities in East Asia. [1)]

Aerosol has many aspects to be considered, such as amount, size, sphericity, composition, spatiotemporal distribution, and so forth. Consequently, it is better to combine several observation data to investigate the characteristics of Asian aerosols, such as mixture state of several component s in the atmosphere.

In this study, we investigate Asian aerosol characteristics through analyses of direct sampling data at surface and ground-based remotely sensed ones at Fukue-jima island from 2003 to 2004.

2. Analyses of data

Fukue-jima is considered as one of the best sites to observe the aerosol all through the year because it is located between Korean Peninsula and western Japan where we can observe the Asian aerosol including Kosa aerosol with little influence of local air pollution.

We have several kinds of in-situ observation data and remotely sensed data at Fukue-jima, such as Optical Particle Counter (OPC), LIDAR, skyradiometer, and so on.

We describe parameters from each sensors used in this study as follows.

a) Aerosol amount and size from OPC data at surface

From OPC data, we can define a parameter "Vtotal" as follows:

$$V_{total} = \sum_{j=1}^{5} \frac{4}{3}\pi \left(\frac{d_j}{2}\right)^3 n_j . \quad (1)$$

This Vtotal is a sphere-equivalent total aerosol volume in the unit of μm^3. We use this paramter as an index of aerosol amount at surface in this study.

We can also define a parameter "gamma" as follows:

$$\gamma = \frac{\log_{10}(\sum_j n_j \mid d_j \geq 2.0\mu m)}{\log_{10}(\sum_j n_j \mid d_j \geq 0.3\mu m)} . \quad (2)$$

This gamma is a logarithmic number fraction of coarse mode particles whose diameter is larger than and equal to 2.0 μm, to total particles whose diameter larger than and equal to 0.3 μm. the range of gamma value is from 0 to 1. the value 0 corresponds to no coarse mode aerosol and the value 1 to no fine mode particles. We use this gamma is an index for coarse mode particles on a number basis at surface.

Aerosol number is one of the important parameters for Aerosol indirect effect study for example. Nakajima et al. [2] studied the relationship between cloud droplet number and aerosol columnar number. Recently, NASA MODIS provides Fine Mode Fraction (FMF), which is defined as the optical thickness fraction of fine mode particles (radius less than 1.0 μm) to total particles. [3]

b) Aerosol sphericity from LIDAR data of the lower atmosphere

From LIDAR data, we can define a parameter "eta" as follows:

$$\eta = \frac{\tau_{lidar(dust)}}{\tau_{lidar(dust)} + \tau_{lidar(sphere)}}. \quad (3)$$

This eta is an optical thickness fraction of "dust" (non-spherical) particles to total optical thickness, which is consisted of both dust and "sphere "(spherical) particles. The aerosol extinction profiles for both dust (non-spherical particles) and sphere (spherical particles) are derived assuming S1 parameter 50. [4] The eta is an index for non-spherical particles on an optical measurement basis. It is also a proxy parameter as a depolarization for a lower atmosphere. The parameter is estimated based on extinction profiles for both dust and sphere particles. The integration of extinction profiles is carried out only from surface to the top height more than or equal to 3km, for which the non-negative extinction values of the lower atmosphere. The range of the value eta is from 0 to 1. The value 0 corresponds to the situation all aerosols consist of sphere particles only, while the value 1 do non-sphere (dust) particles only.

c) Aerosol optical thickness and size from skyradiometer data over Fukue-jima island

From skyradiometer data, we have aerosol optical thickness ("tau_a") and Angstrom exponent ("alpha") defined as follows:

$$\tau = \tau_{0.5}\left(\frac{\lambda}{0.5}\right)^{-\alpha}, \quad (4)$$

where tau_0.5 is aerosol optical thickness at wavelength 0.5μm and lambda is a wavelength in μm. [2] The alpha is an index for a columnar aerosol size.

In the following section, we show the results from match-up analysis that the three measurements with OPC, LIDAR and skyradiometer, are coincident within five minutes.

3. Results and discussion

We compare three parameters (gamma, eta, and alpha) in the cases of Kosa events defined by Japan Meteorological Agency (JMA) and in all match-up cases from 2003 to 2004 at Fukue-jima island. As a result, we have five match-up cases coincident to the JMA-defined Kosa events (9:00 and 15:00 JST April 3, 9:00 and 15:00 JST April 22, and 9:00 JST May 7, 2004).

a) Comparison between OPC and LIDAR

Figure 1 illustrates the relationship between gamma and eta for Kosa events defined by Japan Meteorological Agency at Fukue-jima island.

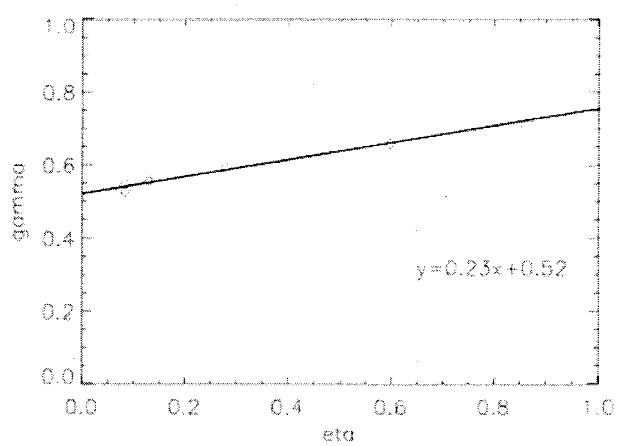

Fig. 1. A scatter diagram between gamma vs. eta, only for Kosa events defined by Japan Meteorological Agency. A linear regression line is overlaid.

From Fig. 1, we have linear relationship between gamma and eta, which suggests the more non-spherical particles, the larger particles size, even for only five events' case study. Figure 1 also suggests that larger and non-spherical particles necessarily dominate and there exist smaller and spherical aerosol particles while eye observer at surface reports Kosa events.

Figure 2 illustrates the relationship between gamma and eta for all match-up data at Fukue-jima island from 2003 to 2004. We have plots with three colors such as red, blue, and green, which correspond to the Vtotal value of more than and equal to 10^4.5 (μm^3), between more than 10^4.0 and lower than 10^4.5, and less than 10^4.0, respectively. The red means larger amount of aerosols which includes the Kosa events in Fig. 1.

Fig. 2. Same as Fig. 1, except for all cases that are available in match-up analyses among OPC, LIDAR, and skyradiometer from 2003 to 2004. A regression line (solid) is overlaid for all match-up plots as well as the regression line (dashed) for the Kosa events in Fig. 1.

From Fig. 2, we find that the logarithmic number ratio of coarse mode particles are almost constant, while the linear regression line for Kosa events has some positive slope, which means larger variation in size with Kosa events. Comparing Figs. 1 and 2, non-sphericity, i.e., eta has the maximum value 1.0 in non Kosa events while it does up to 0.6 even in Kosa events, which suggests smaller and spherical particles are also increased in the Kosa events.

b) Comparison between skyradiometer and LIDAR

Figure 3 illustrates the relationship between alpha and eta for Kosa events defined by Japan Meteorological Agency at Fukue-jima island.

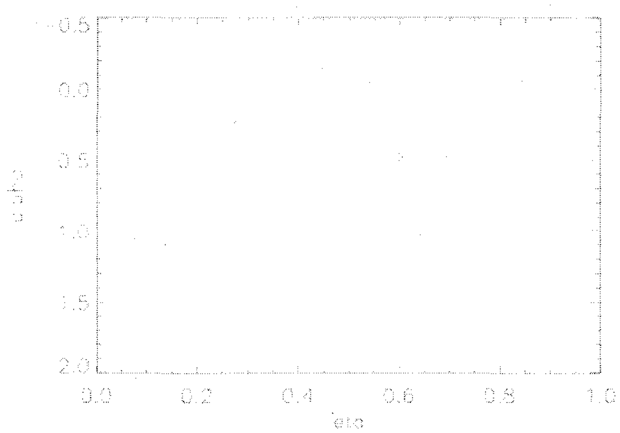

Fig. 3. Same as Fig. 1, except for relationship between alpha vs. eta. Note that the ordinate alpha is plotted in reverse order corresponding to particle size.

From Fig. 3, we have a positive correlation qualitatively, but it is not so clear as the relationship between gamma and eta in Fig. 1. One of the possible reasons is that skyradiometer has information of upper troposphere where OPC and LIDAR are not sensitive.

Figure 4 illustrates the relationship between alpha and eta for all match-up data at Fukue-jima island from 2003 to 2004.

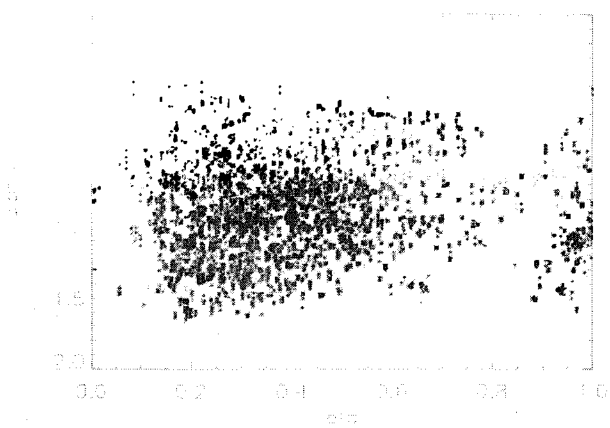

Fig. 4. Same as Fig. 2, except for relationship between alpha vs. eta.

From Fig. 4, we do not have clear relationship between alpha and eta at present. But, such comparison among OPC, LIDAR, and skyradiometer has a possibility to provide us a vertical aerosol microphysics distribution in future.

4. Concluding remarks

We analyze the data of optical particle counter (OPC), LIDAR, and skyradiometer so as to investigate aerosol characteristics observed at Fukue-jima island from 2003 to 2004.

We found that spherical and smaller particles are mixed with non-spherical and larger particles even in Kosa events defined by Japan Meteorology Agency. The comparison between OPC and LIDAR data analyses, also suggests that eye observer at surface has some specific sensitivity in terms of aerosol particle amount, size and sphericity of the lower-atmosphere.

It is necessary to investigate detailed processes for each specific event as well as wide area picture with regional model results and satellite remote sensing data.

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