RELATIONSHIP BETWEEN AEROSOLS AND SPM

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ABSTRACT A multi-spectral photometer was set up as an NASA/AERONET site at Kinki University campus in Higashi-Osaka in 2002 for measuring urban aerosols. In addition, the SPM-613D (Kimoto Electric) commenced measurement of suspended particles matter (SPM) as PM_{10} and $PM_{2.5}$ on March 15, 2004 at the same AERONET site. The obtained results revealed that the poor air quality of the Higashi-Osaka site is due not only to anthropogenic particles from local emissions, such as diesel vehicles and chemical industries, but also to dust particles brought from continental desert areas by large scale climatic conditions.

To understand the characteristics of background atmosphere over Higashi-Osaka, we examined the relationship between $PM_{2.5}$ concentration and aerosol optical thickness (AOT) at a wavelength of 0.87 μm based on AERONET data for background atmosphere (AOT<0.2). We obtained a linear regression line between AOT and $PM_{2.5}$ concentration. Using the linear relationships between AOT and $PM_{2.5}$, we show ground-level concentrations of $PM_{2.5}$ of background atmosphere from Terra/MODIS satellite measurements.

KEY WORDS: Aerosols, Aerosol Optical Thickness, $PM_{2.5}$, AERONET, MODIS

1. INTRODUCTION

Our city, Higashi-Osaka, is notorious for its heavy air pollution. The aerosol properties here are especially complicated due to a mixture of anthropogenic and natural compounds. Higashi-Osaka is located between Osaka bay and the Ikoma mountains, and is one of the industrial cities comprising the so-called Keihanshin Industrial Zone. In an attempt to understand the characteristic features of urban aerosols, a multi-spectral photometer CE-318-2 (Cimel Electronique) was set up as an NASA/AERONET (Hollben et al., 1998) site in Higashi-Osaka in 2002. This instrument has four observing channels for photometry with central wavelengths of 0.44, 0.67, 0.87 and 1.02 μm, and polarimetric facilities at 0.87 μm. The radiometer was calibrated using a standard AERONET procedure (Dubovik et al., 2000). In addition, observations of suspended particles matter (SPM) concentrations PM_{10} and $PM_{2.5}$ were started using the SPM-613D (Kimoto Electric) on March 15, 2004 at the same AERONET/Higashi-Osaka site (Mukai et al., in press a). PMx refers to the mass of particles with an aerodynamic diameter lower than x μm. The concentration of small particles, $PM_{2.5}$, is known to be closely related to human health. $PM_{2.5}$ concentration shows a good correlation to aerosols optical thickness (AOT) measured by radiometry.

Atmospheric particle monitoring from the ground is, however, limited. In its place, satellite remote sensing has been found to be an effective alternative, with Wang and Christopher (2003) utilizing MODIS on the Terra/Aqua satellites and Kacenelenbogen et al. (2006) utilizing ADEOS-2/POLDER data.

In this work, $PM_{2.5}$ concentration is estimated from AOT retrieved from Terra/MODIS data, by using the relationship between AOT and $PM_{2.5}$ in background atmosphere obtained from ground level.

2. MONTHLY CHANGE OF SPM AND AOT

Figure 1 presents the monthly averaged values of $PM_{2.5}$ (gray circles), PM_{10} (black circles) and AOT at a wavelength of 0.87μm (white circles) over Higashi-Osaka from 15 March, 2004 to 31 July, 2006.

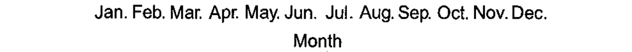

Figure 1. Monthly averaged values of atmospheric particles over Higashi-Osaka from March 15, 2004 to July 31, 2006. The left axis shows SPM concentrations and a right axis shows aerosol optical thickness at a wavelength of 0.87 μm.

The following results are drawn from Figure 1.

1. SPM and AOT varies with month.
2. SPM and AOT show a good correlation.
3. PM_{10} and AOT give peaks in April, July and November.
4. A peak in April is caused by coarse particles.
5. Both the peaks in July and November are due to fine particles ($PM_{2.5}$).

These results clarify that various particles, such as dust, anthropogenic and sea salt particles, exist over Higashi-Osaka and change according to the season.

3. SPM AND AOT OF THE BACKGROUND ATMOSPHERE

3.1 Optical properties of aerosols

In general, AOT does not decrease even if wavelength increases in the case of large particles. Moreover, AOT of small particles decreases with wavelength. Therefore, the Ångström exponent (α) is reversely proportional to the size of the aerosols. That is to say, large values of α correspond to small particles, and the small represent large-sized particles. The value of α is calculated from the spectral tendency of AOT at wavelengths of 0.44 and 0.87μm.

Figure 2 shows the relationship between AOT at a wavelength of 0.87μm and α of background atmosphere for the Higashi-Osaka site from March 15, 2004 to July 31, 2006. Mukai et al. (in press b) showed that aerosols over Higashi-Osaka are roughly divided into three categories: dust events, anthropogenic particle events and background atmosphere. The value of AOT at a wavelength of 0.87μm of 0.2 or less is assumed to be the background atmosphere. The value of α is shown to be mostly larger than 0.8 from Figure 2. Many small anthropogenic particles exist in the background atmosphere over Higashi-Osaka.

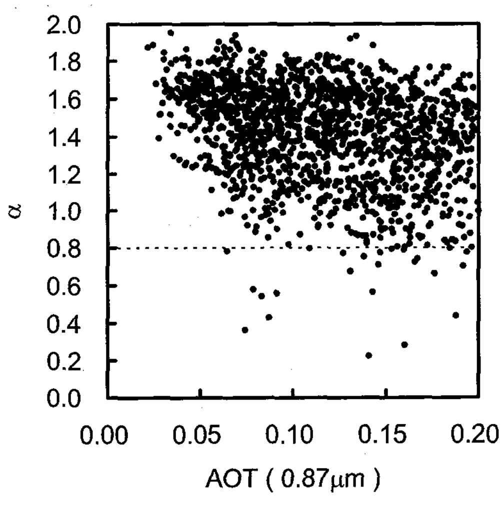

Figure 2. Scattergram of AOT at a wavelength of 0.87μm and α of background aerosols over Higashi–Osaka from March 15, 2004 to July 31, 2006.

3.2 Comparison between $PM_{2.5}$ and AOT

As mentioned above, there is a good correlation between SPM and AOT, and the relationship between the two has already been reported (Goloub et al. 2000; Smirnov et al. 2000). Here, the relationship between $PM_{2.5}$ and AOT in background atmosphere is described. Figure 3 shows the correlation of AOT at a wavelength of 0.87 μm and $PM_{2.5}$ of the background atmosphere for the Higashi-Osaka site from March 15, 2004 to April 30, 2006. When 1495 sets of corresponding data (gray circles) are used, the correlation coefficient is less than 0.6. When the median (black circle) is adopted in 10 groups based on the value of AOT, the correlation coefficient is over 0.9. The regression line does not change in either case (gray: all, black: median). Here, the regression line base on the median of the 10 groups ($PM_{2.5}$=137×AOT+6) is adopted.

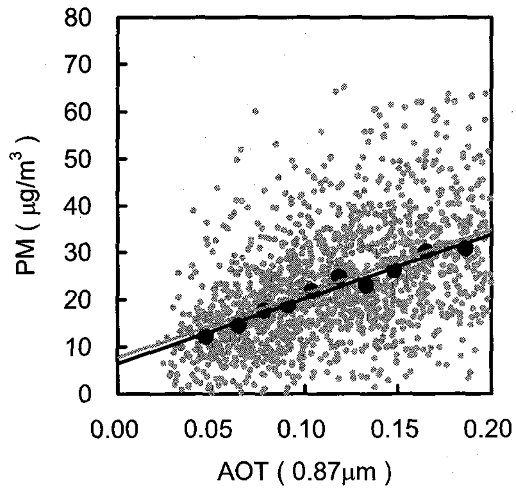

Figure 3. Scattergram of AOT at a wavelength of 0.87 μm and $PM_{2.5}$ in background atmosphere over Higashi–Osaka from March 15, 2004 to April 30, 2006.

4. $PM_{2.5}$ FROM MODIS DATA

Based on the relationship between $PM_{2.5}$ and AOT taken from ground level, $PM_{2.5}$ is estimated from AOT retrieved from the Terra/MODIS data. MODIS-AOT data (Level 2, version 4) was used in this study. The MODIS-AOT is reported at 10×10 km^2 and when compared against AERONET measurements, the MODIS-AOT values are within uncertainty levels of ±0.05 ± 0.20 AOT over land (Chu et al., 2002). Figure 4 shows the comparison of AOT at a wavelength of 0.87μm over Higashi-Osaka derived from Terra/MODIS and AERONET data. AERONET data within ±30 minutes of the satellite observational time is adopted. Because the correlation coefficient is over 0.7, the accuracy of the retrieved MODS-AOT over urban atmosphere is high.

It is found from Figure 1 that the values of AOT are small in winter over Higashi-Osaka. In addition, we know that the values of AOT derived from MODIS data are small almost all over Asia on 20 December 2005, and the value of AERONET-AOT at Higashi-Osaka is less than 0.08. Therefore in this work, the MODIS-AOT data for December 20, 2005 is adopted.

Figure 5 shows remote-sensed $PM_{2.5}$ over the Asian region from the Terra/MODIS satellite data on December 20, 2005. The loss parts of data and cloud regions are shown in black, and AOT>0.2 in white. We confirmed that industrial cities in the Asian region show a high density of $PM_{2.5}$.

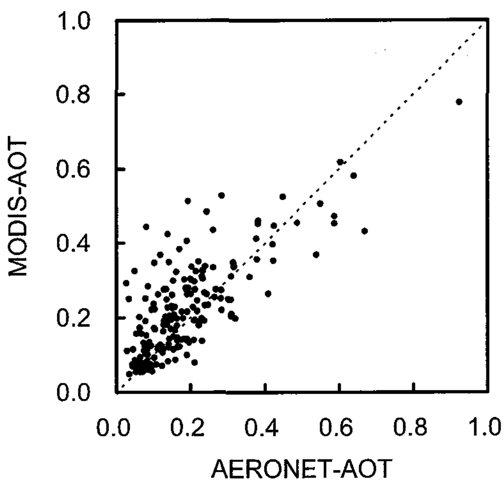

Figure 4. Comparison of AOT at a wavelength of 0.87 mm over Higashi-Osaka derived from Terra/MODIS and AERONET data.

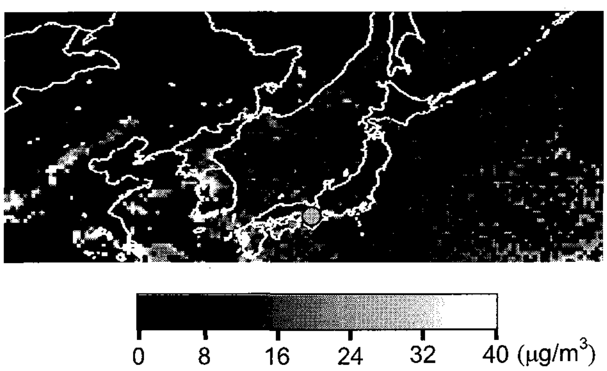

Figure 5. $PM_{2.5}$ concentrations over the Asian region from Terra/MODIS satellite data on December 20, 2005, where the circle indicates ground measurements of $PM_{2.5}$ over Higashi-Osaka.

5. CONCLUSION

Our observations have revealed the aerosol characteristics of industrial cities. To support this data, chemical analysis should be done from SPM data to further elucidate aerosol characteristics.

We obtained a linear regression line between AOT and $PM_{2.5}$ concentration over background atmosphere. Using this relationship, we showed $PM_{2.5}$ from Terra/MODIS satellite measurements. Future work will create $PM_{2.5}$ distribution maps from the satellite data based on the relationship between $PM_{2.5}$ and AOT of the three main categories of aerosols—of dust events, anthropogenic particles events and background atmosphere.

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