Characteristics of Aerosols with ground-based optical observation at Nara, Japan

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Introduction

Aerosol is one of the agents that influences atmospheric environment. Air pollution caused with aerosol and gaseous components is getting worse in Asia in phase with the rapid economic development nowadays. It is generally concerned about transboundary air pollution at the lee side of a remote region in addition to a local emission source. It is therefore important to monitor the aerosol variation at the lower atmosphere with human activities in particular. In this paper, we show the results of the data analyses based on the observation with sun photometry, sampling, and eye observation.

Observation Data

We made an observation of sun photometry and air sampling using MICROTOPS II (Solar Light Inc.) and Optical Particle Counter (KR-12A or KC-52, RION Inc.; hereafter OPC), respectively.

- The MICROTOPS II observes aerosol optical thickness (AOT) under a clear sky condition with the five spectral bands: 380, 440, 670, 870, and 940 nm. The aerosol optical thickness τ (AOT) is defined in the following expression: $I_\lambda/I_{\lambda 0}=\exp(-\tau/\mu_0)$,where I_λ and I_λ are irradiances at surface and top of the atmosphere. μ_0 is a cosine of solar zenith angle.
  The observation was initiated from February 2014.
- The OPC estimates the number concentration for particle size bins in diameter of the optically equivalent sphere: more than 0.3, 0.5, 0.7, 1.0, 2.0, and 5.0 µm with KR-12A from August 2013 to September 2014; more than 0.3, 0.5, 1.0, 2.0, and 5.0 µm with KC-52 from October 2014 (Table 1). It measures the intensity for side scattering direction with laser of wavelength 780 nm. The observed intensity and pulse number of the scattered laser correspond to particle size and its number concentration, respectively.

The both observations are simultaneously carried out at 2 PM Japan Standard Time every week day basically at the campus of Nara Women's University (34˚N, 135˚E, 90 m asl)

- Ministry of Environment (MOE) observes concentration of Particulate Matter (PM2.5) in the atmosphere such that the particle size is not larger than 2.5 micron at western air pollution monitoring station in Nara (34˚N 135˚E). The station is away from the observation site at Nara Women's University by about eight kilometers. The observation frequency is 24 times a day, i.e., every one hour.
- Japan Meteorological Agency (JMA) makes visibility observation at Nara observatory (34˚N 135˚E). Visibility represents atmospheric turbidity as a distance in kilometer such that we can see objects at surface through the atmosphere. The observation is carried out in 9 AM, 3 PM, and 9 PM Japan Standard Time and the data are available on the JMA's web page.
  The observatory is away from the University by 780 m.

Table 1. OPC particle size bin for observation period.

Observation period	Particle size bin (µm)
August 2013 - September 2014	>= 0.3, >= 0.5, >= 0.7, >= 1.0, >= 2.0, >= 5.0
October 2014 -	>= 0.3, >= 0.5, >= 1.0, >= 2.0, >= 5.0

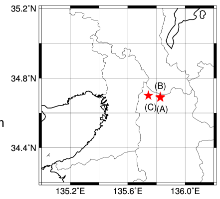

Fig. 1: The observation sites. The point A , B, and C correspond to the Nara Women's University site (34˚N 135˚E), Nara meteorological observatory (34˚N 135˚E), and air pollution monitoring station (34˚N 135˚E) in Nara. The distance is about 730 m between A and B while it is about 8 km between A and C.

Data analysis and Results

In this study, we made a correlation analysis with four kinds of data sets in terms of aerosol with sun photometer, OPC, PM2.5, and visibility to investigate the characteristics of atmospheric environment in Nara. It is important to confirm the consistency among the aerosol properties because these ground-based observations are carried out at each single location in the Nara basin. We could estimate whether the observations represent the characteristics of aerosol in Nara basin based on the different kinds of measurements.

(1) Number concentration vs. mass concentration

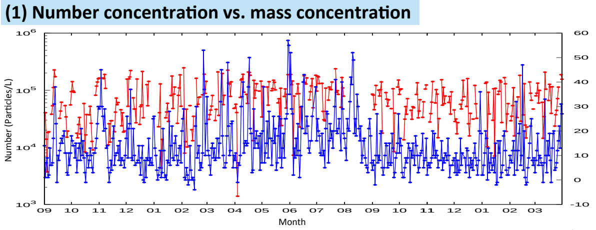

Fig. 2: Time series of number concentration (Particles/L) and mass concentration (µg/m³). The number concentration corresponds to smaller particles from 0.3 to 2.0 µm with OPC measurements, while the mass concentration is for smaller particles less than 2.5 µm. The left and right ordinates stand for common logarithm of the number concentration (red plots) and the mass concentration (blue plots), respectively. The abscissa shows months from 1 September 2013 to 31 March 2015.

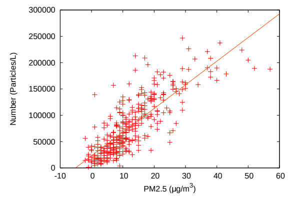

Fig. 3: A scatter plot between number concentration (Particles/L) and mass concentration (µg/m³) with the same data set shown in Fig. 2.

Figure 2 shows the time series of the number concentration for the particle size bin from 0.3 to 2.0 and the mass concentration from PM2.5 for about a year from 1 September 2013 to 31 March 2015. From Fig. 2, we can see that both aerosol properties have similar variations even though they are number and mass concentrations for smaller particles.

Figure 3 shows the correlation between the number and mass concentrations based on the data set shown in Fig. 2. From Fig. 3, we can see that the correlation is good with the correlation coefficient of 0.81. As a result, it is found that the OPC measurement is consistent to PM2.5, which further assures that we can estimate atmospheric environment over the area that contains the two sites.

(2) Number concentration vs. visibility

It is important to investigate the relationship between aerosol and visibility because solar light scattering by aerosol mainly affects to visibility in the troposphere [1].

From Fig. 4, you can see that the number concentrations for the smaller particles such as 0.3 to 0.5 (×) , 0.5 to 1.0 (+), and 1.0 to 2.0 (□) µm shows similar variation to visibility (●) while the number concentrations for larger particles such as 2.0 to 5.0 (▽) and more than 5.0 (◇) µm does not necessarily show significant correlation on a monthly-average basis.

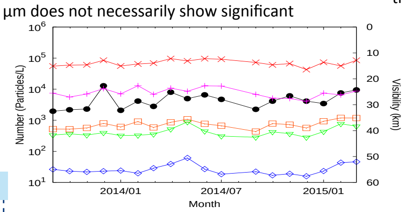

Fig. 4: Time series of the number concentration and visibility from September 2013 to March 2015. The left and right ordinates show the number concentration (Particles/L) and visibility (km), respectively. The abscissa is month. It is noted that the values are arranged in reverse in the right axis.

Table 2 summarizes the correlation coefficients for the data set shown in Fig. 4. From Table 2, you can easily see that the smaller particles, the higher negative correlations. As a result, it is suggested that the visibility is sensitive to smaller particles rather than larger ones.

Table 2: Correlation coefficient between particle size and visibility.

Particle size bin (µm)	Correlation coefficient
0.3 to 0.5 µm	-0.69
0.5 to 1.0 µm	-0.64
1.0 to 2.0 µm	-0.51
2.0 to 5.0 µm	-0.40
>= 5.0 µm	-0.31

(3) Number concentration vs. aerosol optical thickness

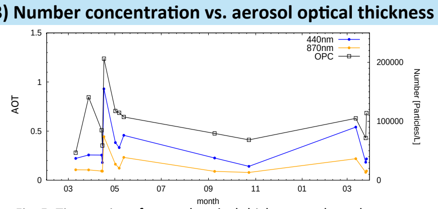

Fig. 5: Time series of aerosol optical thickness and number concentration from March 2014 to March 2015. The left and right ordinates are aerosol optical thcikness (AOT) and the number concentration, respectively. The blue and orange plots are optical thickness at wavelenghths of 440 nm and 870 nm, respectively. The black plot is the number concentration.

Figure 5 show a time series of the aerosol optical thickness at the wavelengths of 440 nm and 870 nm channels with particle number concentration. The aerosol optical thickness generally has larger values at 440 nm wavelength than 870 nm, which indicates that smaller particles dominated in these observations.

Figure 6 shows the scatter plots between the aerosol optical thickness and the number concentration on a logarithmic scale. As a result, the correlation coefficients are 0.82 and 0.79 for the aerosol optical thickness at 440 nm and 870 nm, rescpectively. The high correlation indicates that as the aerosol number concentration in the lower atmosphere increases, the columnar aerosol optical thickness increases as a whole.

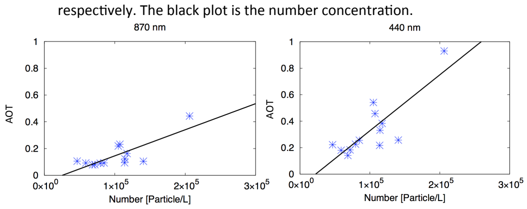

Fig. 6: Correlation between aerosol optical thickness and number concentration (Particles/L). The number concentration corresponds to the particle size more than 0.3 µm.
(Left panel) aerosol optical thickness at 440 nm
(Right panel) aerosol optical thickness at 870 nm.

Concluding remarks

We have made optical observations in terms of aerosol properties with sun photometry and air sampling optical particle counter (OPC) for more than a year at Nara Women's University (NWU) site in Nara.

- Comparison of the particle number concentration with the PM2.5 mass concentration reveals that the both concentrations are highly correlated, even though the both sites are away from each other by several kilometers.
- The comparison between visibility and the number concentration suggests that visibility reduces as smaller particles dominated in the lower atmosphere.
- It is better to make sun photometry observation to investigate aerosol loading in a vertical atmospheric column under a clear sky condition. It is found that the correlations are also high between the vertical aerosol loading and the number concentration in the lower atmosphere.

As a result of statistical data analyses, it is found that relationship among these observations is consistent to each other as a whole and we have smaller particles in Nara. That is, our observations with sun photometry and air sampling are useful to monitor the atmospheric condition at Nara. We will continue the observations for the validation of satellite remote sensing products, for example, with meteorological factors such as relative humidity, wind, temperature, and so on in future.

Acknowledgments

The PM2.5 data are provided by Nara city hall.

References

[1] Daniel Jacob, 2010: An Introduction to Atmospheric Chemistry. Oxford University Press.

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