Long-term and seasonal trend of SPM concentration and its spatial distribution in the Kanto Region, Japan

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Abstract

In the Kanto Region including Tokyo Metropolitan Area, annual mean concentration of suspended particulate matter (SPM) well reduced recently. Regulations to the artificial emissions have been enforced in these years especially in the southern part of this area. SPM concentration also has seasonal change. This study examines long-term and seasonal trends of SPM and its regional differences. PCA was employed to find spatial variations of SPM trend. It was found that the contrast of SPM concentration between urban and rural areas in these years become smaller compared to early 1990s. SPM concentration has reduced not only in heavy regulation areas but also in whole the Kanto Region with reflecting the seasonal character.

Key words: air pollution, SPM, spatial distribution

1. INTRODUCTION

The Kanto Region locates in the Kanto Plain, the largest plain in Japan. Population, industry, and traffic have concentrated on the southern part of the Kanto Region including Tokyo metropolis and its surrounding urban areas. Various regulations on anthropogenic air pollution sources have been enforced in Japan. Regulations on vehicle emissions also have been established during the mid-1990s. Besides, strict ordinances on diesel emissions have started since 2003 in four prefectures in southern Kanto. These controls may strongly influence on SPM concentration.

Current studies have suggested that SPM concentration in this area have reduced well recently (Mizuno, 2006; Minoura et al., 2006). However, it seems that the SPM concentration in this region is not only in decreasing trend but also has variety of long-term trend among the area. In addition, SPM concentration and its spatial patterns are strongly influenced by climatological factors.

The purpose of this paper is to report on long-term trend of SPM concentration and its spatial differences in the Kanto Region since 1990s. Spatial variations of SPM trend are detected by a principal component analysis (PCA).

2. DATA AND METHODS

We use SPM hourly monitoring data of SPM at over 300 stations in the Kanto Region. Figure 1 shows research area of this study and locations of ambient air monitoring stations. Diesel regulations are effective in southern four prefectures. The analysis period is 15 years, from 1991 to 2005 FY*.

In the experiment, long-term and seasonal trend of SPM concentration were summarized by year-day isopleth. PCA was conducted in order to detect regional characters and their time series of SPM concentration.

* FY=Fiscal Year in Japan (from April to March)
3. RESULTS

3.1. Long-term and seasonal characteristics of SPM concentration

Figure 2 shows yearly and seasonal variations of SPM for whole districts of Kanto. By using heptad mean, the differences of mean SPM concentration between weekday and weekend can be removed. The variation of SPM concentration in this area has two seasonal peaks. Winter peak of SPM appears in early winter around November-December, which shows high levels of concentration in early 1990s. Summer peak can be seen mainly in July-August. Both of these two seasonal peaks reduced in recent years. Minoura et al. 2006 proved that the reduction trend of SPM in winter was attributed to decrease of fine particles from motor vehicles by multi-year observations at downtown Tokyo.

In addition NOx concentration also shows reduction trend in winter. The results indicate that wintertime SPM concentration in the whole Kanto had decreased with artificial primary particles.

Although SPM trend in summertime also has started to decrease since the late 1990s, its reduction trend is weaker than winter. On the other hand, Ox concentration has increased spatially in the 2000s. Since it is known that photochemical reactant contributes toward production of SPM secondary particles during summertime, the contribution of emission control for SPM concentration is less than that of winter.

3.2. Distribution and decreasing trend of SPM

Since SPM concentration tends to have its seasonal peaks in winter and summer, we elaborate on spatial distribution of SPM in these seasons. Figures 3 (a) and (b) show the spatial distribution of seasonal mean SPM concentration during this period. Figure 3 (a) illustrates that high concentration areas locate around Tokyo bay and midtown in wintertime. And high concentration area spreads to northwesterly inland areas during summertime (Figure 3 (b)). These seasonal distribution patterns of SPM attribute to the climatology in this region. It is known that heavy air pollutions in winter occur under cold and calm

Fig. 2 Day-year isopleth for heptad mean SPM concentration in the Whole Kanto. Each value is obtained from averages of daily mean SPM concentration at every station in this area.

Fig. 3 Spatial distributions of seasonal mean SPM concentration during 15 years. (a) for winter (November-December) and (b) for summer (July-August).
weather conditions. Therefore the area with high concentration is expected to appear near emission sources in wintertime. The spatial distribution of winter mean NOx is similar to that of SPM.

In summer, because of southeasterly prevailing wind in the daytime, precursors from emission source around Tokyo bay are transported to the inland area while producing photochemical components over the region by the wind (e.g. Wakamatsu et al. 1999). Therefore, in spite of few emission sources, SPM concentration in inland area tends to be higher than that in southern urbanized area in summer. Thus spatial distribution of SPM shows different spatial patterns in winter and summer.

3.3. Spatial differences in SPM long-term trend of SPM

Regional differences of SPM long-term in trend of SPM concentration were analyzed by PCA. The PCA was computed using a correlation matrix for hourly SPM concentration. In order to avoid missing values during the period, monitoring data were converted into 15 minutes grid area-mean (see Figure 4). The results of PCA are summarized in Table 1 and Figure 4.

<table>
<thead>
<tr>
<th>Component</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proportions of variance (%)</td>
<td>64.8</td>
<td>10.4</td>
<td>5.2</td>
<td>3.5</td>
</tr>
</tbody>
</table>

Table 1. Proportions of variance explained by the first four principal components.

Fig. 4 Variations of monthly mean time coefficients (upper panel) and spatial distribution of eigenvector (lower panel) for PC1 and PC2. Both contours and symbols represent the eigenvectors.
The distribution of eigenvector for the first principal component (PC1) shows a concentrical pattern of which center is located in central Tokyo. Variation of time coefficients for PC1 is in increasing trend. From these results, PC1 was found to be a component that reflects regression trend of SPM concentration in the whole of this region. The eigenvectors in PC2 are distributed in two parts, southeast side and northwest side. A positive (negative) value of PC2 corresponds to the spatial distribution of SPM in winter (summer) as shown in Fig. 3. The variation of time coefficients has seasonal cycles with high value in winter and low in summer. These patterns reflect the seasonal patterns for SPM spatial distribution in winter and summer. In other words, PC2 associate with seasonal differences in spatial distribution of SPM for summer and winter. Absolute values of PC2 decrease with years. It is implemented that the regional contrast of SPM concentration between north and south parts of Kanto has been weaken.

The PCA results showed that the first two components could explain greater than 75% of spatial differences of SPM concentration in this region. The first component is consistent with SPM reduction in regulated urban area, the second component is in good agreement with seasonal and spatial patterns of SPM. In particular, spatial contrast of SPM concentration between urban and rural in this region has decreased with reduction of SPM by emission controls.

4. SUMMARY AND CONCLUSION

The results of this study can be summarized as follows:
(1) SPM concentration in the Kanto Region has seasonal peak, winter and summer. In winter highly polluted area appear in urban part of this region because of abundant artificial emissions and calm and cold air conditions. In contrast, SPM spatial distribution in summer is higher in the inland area in this region as a result of photochemical reactions with precursors from the windward urban area by southeasterly prevailing wind.

(2) Because of various emission controls, SPM concentration has been reduced well at high emission area in winter, and at inland area of leeward of prevailing wind in summer. SPM concentration has decreased not only in the diesel regulation area but also in the whole Kanto Region reflecting the seasonal characters.

References