B-12(4) Effects of Global Warming on Urban Atmosphere

Contact Person Satio Ohta and Naoto Murao
Faculty of Engineering, Hokkaido University
North 13 West 8, Sapporo 060, JAPAN
Phone 81-11-716-2111 Ext.6832
FAX 81-11-707-9750

Total Budget for FY1990-FY1992 9,387,000 Yen

Abstract Concentration of tropospheric ozone will increase due to global warming. We observed concentrations of ozone, PAN (peroxyacetyl nitrate) and nitric acid in Sapporo, and made sensitivity analysis based on the measurement. We found that urban air quality depends on the concentration of PAN and ozone in rural area in addition to pollutant emission in urban area. We developped photochemical reaction model and two dimensional trasnsport model. With the model calculation we studied the urban air quality, and the variation of ozone and PAN in the mid latitudes in the Northern hemisphere.

Key Words Urban air quality, PAN, Tropospheric ozone, Phtochmical reaction model, Two dimensional transport model

1. Introduction

Global warming enhances photochemical reaction in the atmosphere. It also increases emission of air pollutants such as nitrogen oxides, carbon monoxide and hydrocarbon due to increase of energy consumption for air cooling. Thus, the global warming increases concentration of tropospheric ozone. The growing tropospheric ozone also enhances the global warming. On the other hand, the growing ozone flows into urban atmosphere and affects the air quality. In the study, we evaluated the effect of global warming on the urban air quality, in particular, the concentration of ozone, PAN and nitrogen dioxide.

2. Research Objective

For the purpose of evaluation of the effect of global warming on urban atmosphere and reccomendation of reduction of the emission of urban air pollutants, we studied following subjects.

(1) Evaluation of effect of temperature change on photochemical reaction in urban atmosphere.

(2) Estimation of tropospheric ozone increase with air pollutant emission due to growing energy consumption.

(3) Development of atmospheric reaction and transport model to reccomend reduction of the emission of urban air pollutants under the future global warming.

3. Research Method

(1) Effect of temperature change on urban atmosphere

We made one-box atmospheric reaction model for Tokyo metropolitan area. Model simulation was made in clear atmosphere of summer and winter. We calculated the concentration of ozone and PAN with increased and decreased temperature from standard condition.

(2) Effect of tropospheric ozone change on urban atmosphere

① Field observation

We measured the concentrations of SO_2, HNO_3, PAN, and particulate sulfate and nitrate in Sapporo. Ozone concentration was measured at top of Mt.Teine, the height of which is 1000 m.

② Model calculation

We made one-box atmospheric reaction model to evaluate the effect of tropospheric ozone change on the urban air quality in Sapporo. Atmospheric pollutants flow into the box from the bottom and flow down from top of the box due to growing mixing layer. We used the reaction model by Atkinson et.al.(1982).

(3) Measurement of PAN concentration and the sensitivity anlysis

① Measurement of PAN concentration

We measured PAN concentration in Sapporo from April through November, 1989, and from October, 1990 through April, 1991. PAN was collected by cold trapping following GC-ECD analysis.

② Sensitivity analysis

We calculated the sensitivity of initial concentrations (at 13:00) of hydrocarbon, nitrogen oxides and PAN, and ultraviolet intensity and temperature to PAN concentration at 15:00.

(4) Development of atmospheric reaction and transport model.

We developped two-dimensional (longitude-altitutde) transport model for mid latitudes (30° ~60° N) in the Northern hemisphere. The model includes emission of pollutants, horizontal advection by westerly wind, vertical transport by convective cloud, diffusion, atmospheric reaction, and wet and dry deposition to the earth's surface.

For the model calculation we used following data.

① Emission data: We incorporated anthropogenic emission of NO, CO and volatile organics. Further, we took account of natural emission of NO by soil microorganism, NO by lightning discharge, and inflow of ozone and NO from stratosphere.

② Meteorological data: We used monthly mean wind and temperature data from NOAA. For the height and occurance probability of convective cloud, and precipitation amount, we used statistical data by artificial satelite.

③ Atmospheric reaction model: We used photochemical reaction model by Kleinman (1986) which took account of 45 chemical species and 78 chemical reactions. For photo-dissociation constants, we used data by Demerjian(1980).

④ Deposition of pollutants: We considered two kinds of earth's surface; land and sea surface. We took account of dry and wet deposition velocity by Kastings and Singh (1986) and Rodhe and Isaksen (1980), respectively.

4. Results and discussion

(1) Effects of temperature change on urban atmosphere

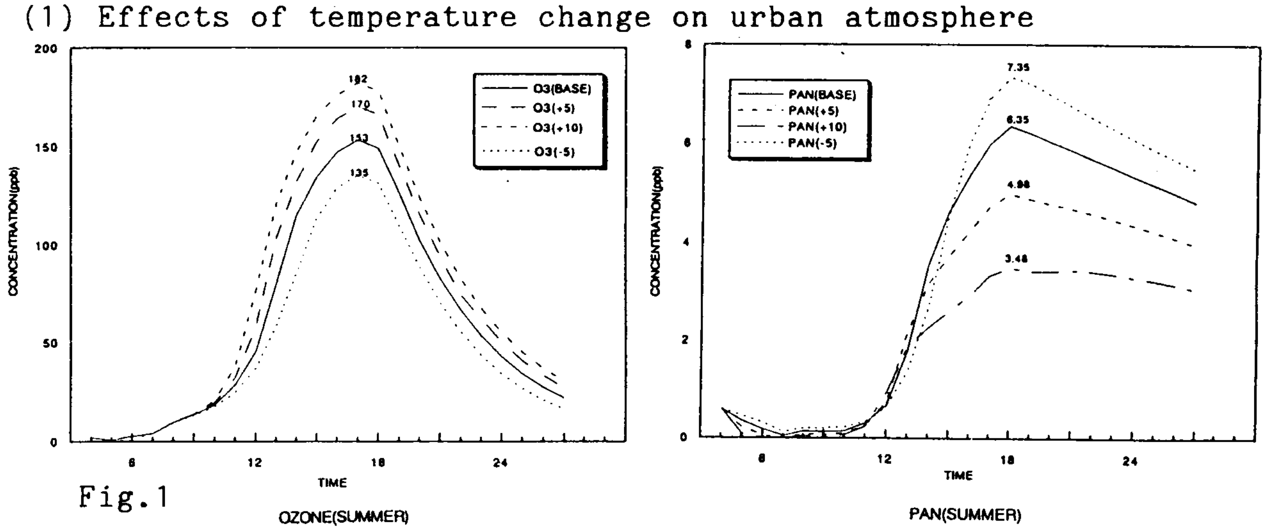

Fig.1

Figure 1 shows the computational results of ozone and PAN concentration for standard temperature or increased and decreased temperature in summer condition. With increase of temperature ozone concentration increases and PAN concentration decreases inthe afternoon. Decomposition of PAN in high temperature condition causes the increase of ozone and decrease of PAN conce ntra-tions.

(2) Effect of tropospheric ozone change on urban atmosphere

① Measurement results of nitrate in Sapporo.

Measurement results in Sapporo showed that total nitrate (gaseous and particulate nitrate) concentration had maximum (0.7ppbv) in spring and minimum (0.1～0.2 ppbv) in autumn. In spring (May 1 ～10, 1989) maximum concentration (0.8ppbv) occured at 5:00～8:00 in the morning and minimum (0.5ppbv) at 17:00～20:00 in the evening, which had not so large daily variation as that in photochemical smog episode in summer. Also in spring total nitrate concentration in the nighttime sometimes exceeded that in the daytime, which suggests importance of nighttime chemical reaction.

② Numerical simulation of nitrate formation

Numerical simulation showed that in spring inflow of high concentration of ozone from upper region above urban boundary layer causes the high concentration of nitrate in the nighttime.

(3) Measurement of PAN and the sensitivity analysis

① Measurement of PAN concentration

In Sapporo monthly mean concentration of PAN had maximum (1ppbv) in spring and minimum (0.2 ppbv) in autumn.

② Sensitivity analysis

For every factor (concentration of hydrocarbon and nitrogen oxides, temperature and ultraviolet intensity) the sensitivity had large values in spring and summer, which suggests that the high concentration of PAN is caused due to photochemical reaction in the urban atmosphere. On the other hand, in winter they had less values. It suggests that concentration of PAN, which flowed into the urban atmosphere from rural large area, is maintained under the low temperature condition in winter.

(4) Developpment of atmospheric reaction and transport model.

With the model we calculated the two-dimensional distribution of NO_2, ozone and PAN in a year. We discuss result of PAN calculation. Around Japanese area PAN concentration near the surface had the maximum value in February and the minimum in July. The spring maximum is caused due to photochemical reaction of pollutants accumulated in autumn and winter, and due to less decomposition of PAN under the low temperature condition. On the contrary, the summer minimum is caused due to the decomposition of PAN at the high temperature condition.

Figure 2 shows the longitude-altitude distribution of PAN late in February. The concentration near the surface is high in Europe, east Asia and the eastern United States where are heavy emission area of atmospheric pollutants.

We further found that variation of PAN concentration affected the distribution of other species such as formaldehyde, NO_x and ozone in the troposphere. They had the maximum concentration on the western part of Pacific ocean and Atlantic ocean similar to the distribution of temperature. They are caused due to the temperature dependency of decomposition of PAN.

Based on above results, we will recommend reduction of emission of urban air pollutants under future global warming.

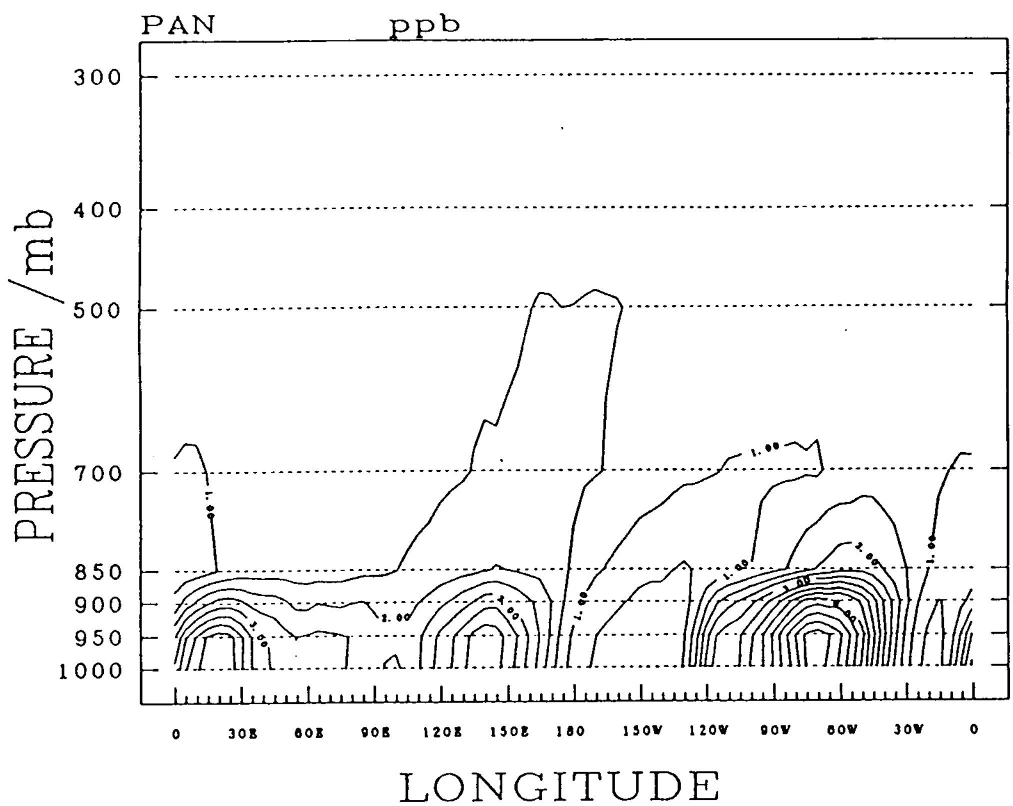

Fig.2 Distribution of PAN concentration late in February.