Abstract of Dissertation

A numerical study of the influence of meteorological conditions on summer ozone levels in the Kanto area of Japan

(関東地方における気象要因が夏季のオゾンレベルに及ぼす影響の数値解析)

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The trend for ground-level ozone concentrations to increase has recently been recognized in Japan, although concentrations of ozone precursors, nitrogen oxides and volatile organic compounds or non-methane hydrocarbons have decreased. One of the causes is thought to be an increase in long-range transported ozone and its precursors from East Asia, particularly China. However, ground-level ozone levels in the vicinity of major cities have also been rising during summer, despite the relatively clean air mass mainly transported from the Pacific Ocean during this season. It is well documented that along with global warming, urban warming has been recognized as one of the environmental problems resulting from rapid urbanization. The changes in local meteorological conditions associated with those events may significantly contribute to the variation in ground-level ozone concentrations. Ozone is a secondary pollutant, produced by a series of complicated chemical reactions, and overall concentration is influenced by different physical processes such as advection, diffusion, deposition processes, and so on. It is therefore difficult to understand the inner relationships among these processes and to identify which process is in control solely by observation analysis, due to the limited number of measurements available. Numerical

simulation establishes a link between emissions and ambient concentrations based on the assumed physical and chemical processes, thus providing a powerful tool to analyze the detailed processes of ozone formation. In this thesis, three studies of ozone for Kanto area of Japan were undertaken to add to the body of knowledge concerning the mechanism of ozone formation and the possible factors for increasing ozone levels during summer in the Kanto area.

The first study is "**Influence of meteorological and initial/boundary conditions on the ozone levels by MM5/CMAQ analysis**". In this study, the MM5/CMAQ model is applied to simulate ozone levels in the Kanto area of Japan and the influence of meteorological conditions on atmospheric pollution is investigated over the following two summer periods; (1) a period with mild weather, and (2) a period which is associated with a hot and dry weather pattern. Additionally, the influence of initial and boundary condition on ozone simulations is also investigated. The simulation results were compared with observation data, and are found to accurately replicate most of the important observed characteristics. It is found that the simulated O_3 concentrations are strongly influenced by meteorological conditions in the Kanto area. High temperatures with weak winds on hot and dry day lead to a significant increase in O_3 concentrations, especially in the afternoon. The initial and boundary conditions also have a significant effect on simulated O_3 concentration However, there are few observation data. The importance of external influence from transport outside the area study is very uncertain, it is, therefore, necessary to have more measured data and studies to evaluate the influence of initial and boundary conditions and develop a database for air quality models.

The second study is "**Process analysis on ozone formation under different weather conditions using the MM5/CMAQ model**". This study aims to assess the contributions of individual physical and chemical atmospheric processes on ozone formation under different weather conditions during a typical summer month, August 2005, using the MM5/CMAQ model. For this purpose, we have developed a simple method to clarify weather patterns and look at its relationship with high ozone levels. The role of processes on ozone formation is then quantitatively analyzed using the Integrated Process Rate analysis tool available in the CMAQ model. The results show that there is a close relationship between prevailing weather patterns and ozone concentrations in Kanto area. The process analysis at two selected sites in the Kanto area indicates that ozone formation is mainly controlled by advection, vertical diffusion, dry deposition, and chemical processes. The ozone concentrations in the surface layer are mainly enhanced by the vertical diffusion of ozone-rich air from aloft, whereas dry deposition and chemical processes mainly deplete ozone concentrations. By investigating the effect of each process under different weather conditions, it is found that the contributions of processes differ depending on prevailing weather patterns. Of the 3 major patterns that are identified, meteorological conditions for Pattern I are less favorable for photochemical and accumulation processes resulting in lower ozone concentrations. By contrast, under conditions of higher stagnation such as Patterns II and III, there is the significant increase in accumulated ozone and its precursors, and – as a result – increased ozone chemical production. On the basis of this study, it can be suggested that the incidence of high ozone levels in the central Kanto area is strongly affected by meteorological and photochemical conditions. The significant decrease in ozone removal due to chemical and advection processes under conditions of higher stagnation is the most important reason for the enhanced levels of ozone concentrations in this area.

The last study is "**Analysis of relationship between changes in meteorological conditions and the variation in summer ozone levels**". This study investigate the relationship between meteorological factors (e.g. temperature, wind speed) and ground-level ozone concentrations in summer over the central Kanto area of Japan using both statistical analysis and numerical models. It was found that there is a close relationship between changes in meteorological conditions and the variation in ozone concentrations over the central Kanto area. In summer, up to 84.1% of the long-term variation in peak ozone may be accounted for by changes in the seasonally averaged daily maximum temperature, and seasonally averaged wind speed, while about 70.3% of the short-term variation in peak ozone depends on the daily maximum temperature and daily averaged wind speed. The results suggest changes in meteorological conditions may be one cause leading to the rising ozone concentrations in this area. The results also indicated that significantly high ozone concentrations appear on days associated with urban heat islands. High temperatures and calm conditions under urban heat island (UHI) can cause high ozone levels in this area. UHI and its interaction with the sea breeze strongly affect ozone concentrations. Although the temperature difference between land and sea helps to develop a summer sea breeze, the sea breeze cannot pass through the city due to the persistent UHI. Therefore, dispersion of ozone is limited and the high ozone concentrations can be observed.