4.4 Distribution of Air Pollutants

4.4.1 Introduction

Both reaction and weather condition give effects to the distribution of air pollutants. Therefore, the movement of concentration peaks associated with the intrusion of air flow is frequently observed when the long range transport of air pollutant occurs. In this section, the characteristics of distribution of the air pollutant, particularly that produced by photochemical reactions, will be explained.

4.4.2 Flow of Air Pollution from City to Suburbs

The chemical reaction and the weather condition have compound influence on the formation of air pollution. In the Japanese metropolitan areas of Tokyo and Osaka, the stationary sources of air pollution are concentrated on coastal areas. Also, another source of pollution, the automobile, is distributed throughout the city area. Furthermore, the form of appearance of the air pollution differs by urban and rural areas as it is strongly affected by local air flows typically represented by the sea-land breeze. The schematic diagram for spatial distribution of the air pollution in urban area is shown in Fig.4.4.1.

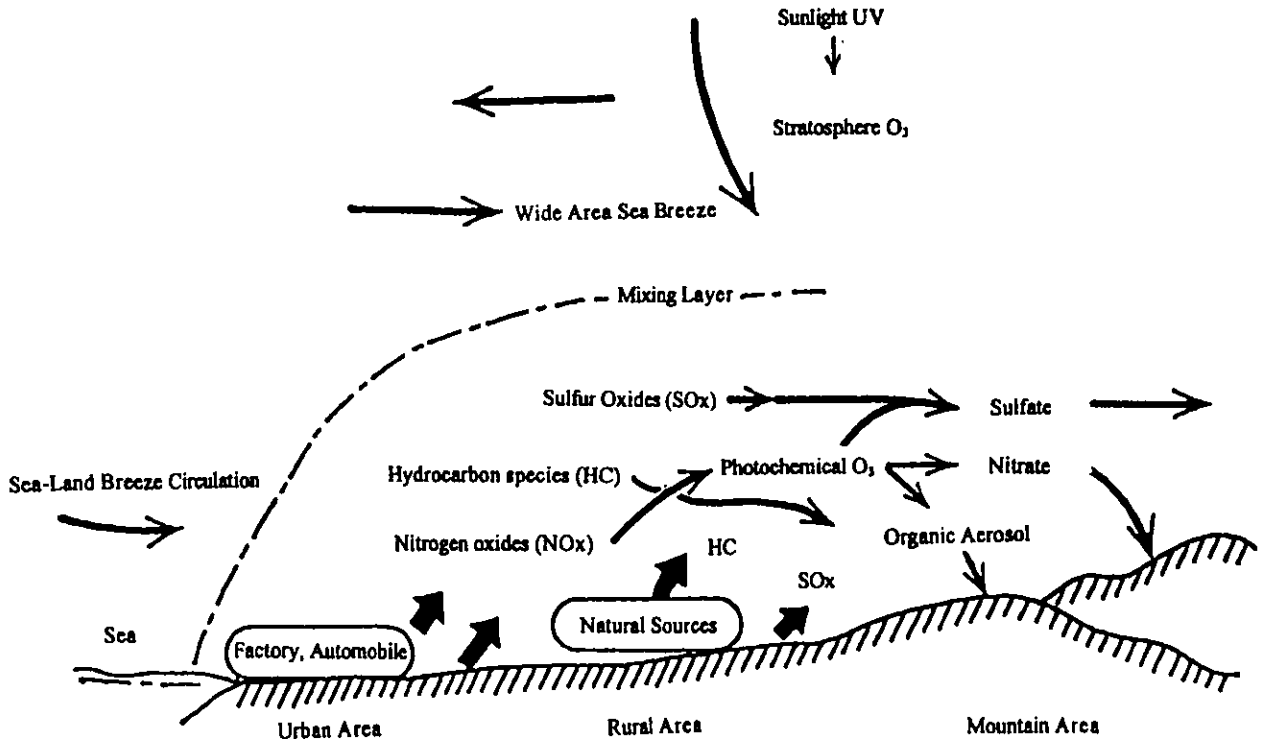
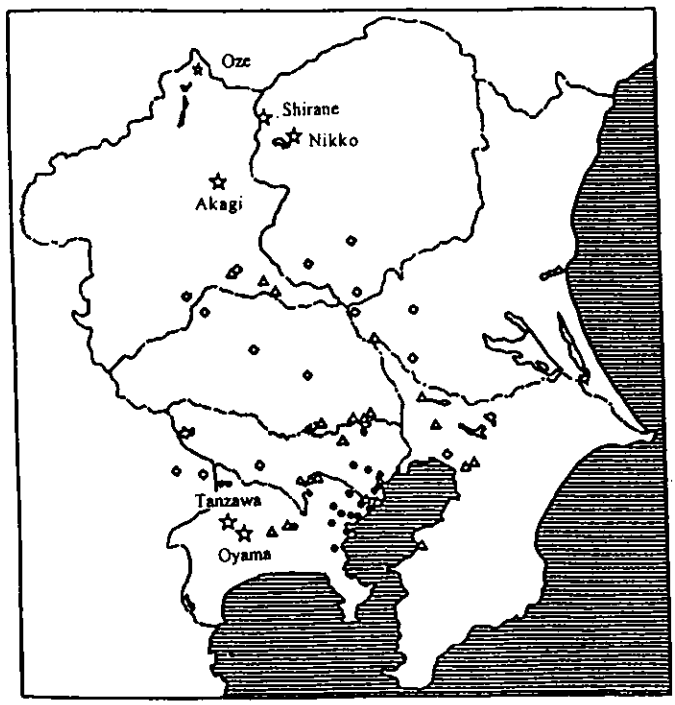


Fig.4.4.1 Schematic Diagram of Spatial Distribution of Air Pollution
—Transport and Chemical Change of Air pollutant from Urban to Rural Areas—

Generally, the concentration of nitrogen monoxide would first become high, and next that of nitrogen dioxide become high in urban area, and after that the concentration of ozone and aerosol would become high in rural areas.

Such characteristics are found in the time variation and area distribution of secondary products. Both chemical reactions and weather conditions are influencing the formation of such distribution. When there is a long range transport of air pollutants, it is frequently observed that the peak of concentration moves with an intrusion of air flow. An example of analysis of the distribution of air pollution in Kanto area is shown in Fig.4.4.2. The situation of transport and chemical change of the air pollutant from urban to rural areas are seen in this figure.



●: NO_2 Top ranked stations for annual average values (ranked among national worst 20)
△: SPM Top ranked stations for annual average values (ranked among national worst 20)
◇: OX Stations with many measurement days when hourly value in excess of 0.12 ppm was observed (ranked among national worst 20)
☆: Sites where effects to plant were recently reported in the newspaper, etc.

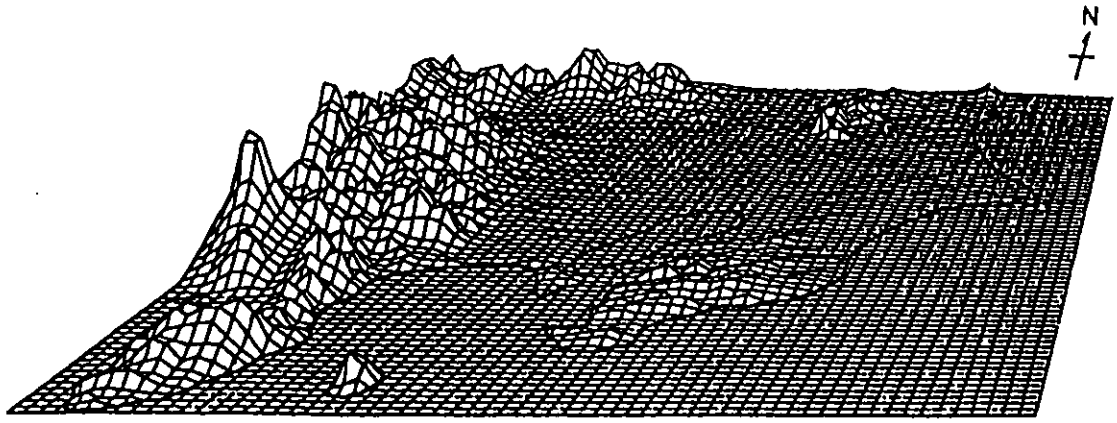
Note: All data are taken from the FY 1992 General Atmospheric Measurement Station Data.
Source: Yagishita, S., Matsugu, H., and Ohi, M. Consideration on the Development of Total Strategy toward Measures for Suspended Particulate matters, J. of Atmospheric Environment Society, Vol. 31, No. 2, P. A26 (1966)

Fig.4.4.2 Example of Analysis of the Distribution of Air Pollution in Kanto Area

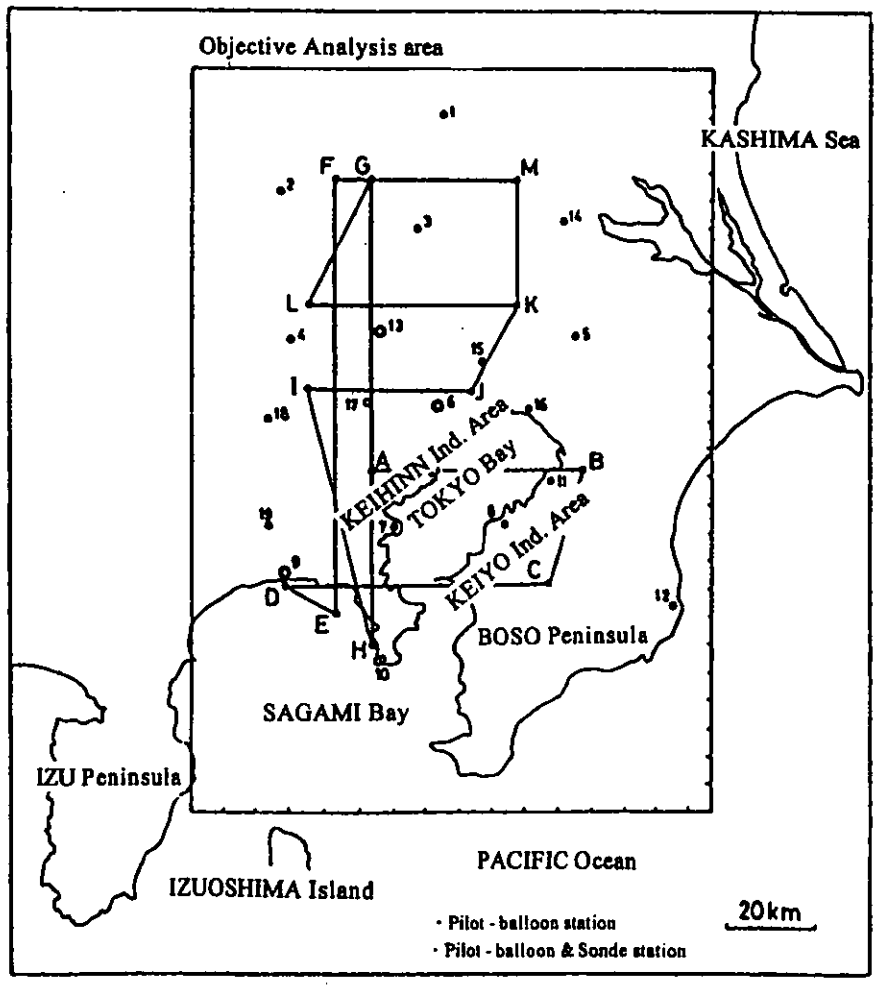
4.4.3 3D Distribution of Air Pollution

The 3D distribution (the three dimensional distribution) of air pollution depends on the height of source and the pollutant. The 3D distribution of single stack smoke from the stationary source such as the boiler is described in the predictive model of atmospheric diffusion in Chapter 10. In this section, the characteristics of 3D distribution of the air pollution of urban scale will be described. A typical vertical cross sectional distribution when the photochemical air pollution occurs is shown in Fig.4.4.3. It could be seen that, in the result of aerial observation

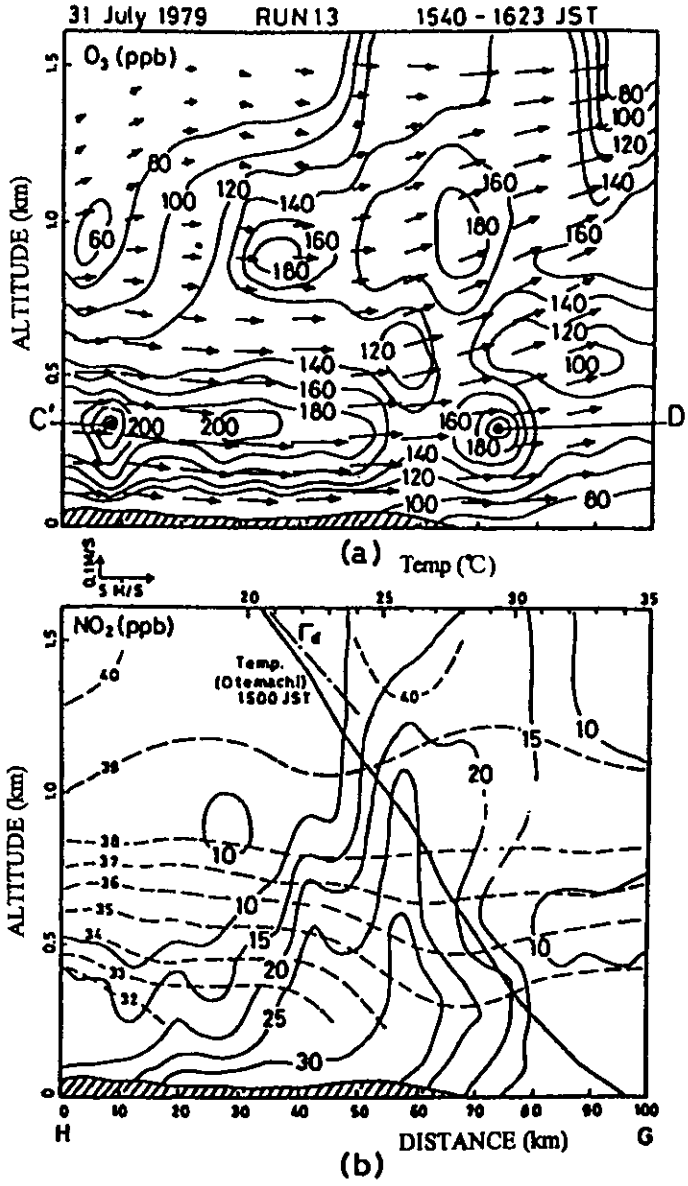
from July 31, 1979 to August 1, there is a close relationship between the distribution of O_3 and NO_2 and the sea-land breeze circulation or the vertical distribution of temperature. The height of mixing layer on that day was about 1500 m, but the vertical distribution of highly concentrated ozone differed greatly by in and out of the mixing layer, and the time variation coincides well with changes in the sea-land breeze. Also, a highly concentrated photochemical ozone in excess of 120 ppb, formed at the altitude from 500 to 1200 m in the previous day, was stagnant in the night through early morning. When the general wind is weak and the local sea-land breeze circulation would continue for several days, the accumulation of pollution would occur as the above described situation repeatedly occurs.



Topography of the Tokyo Metropolitan Area viewed from the south-east direction.
Horizontal grid size is about 3 km square.



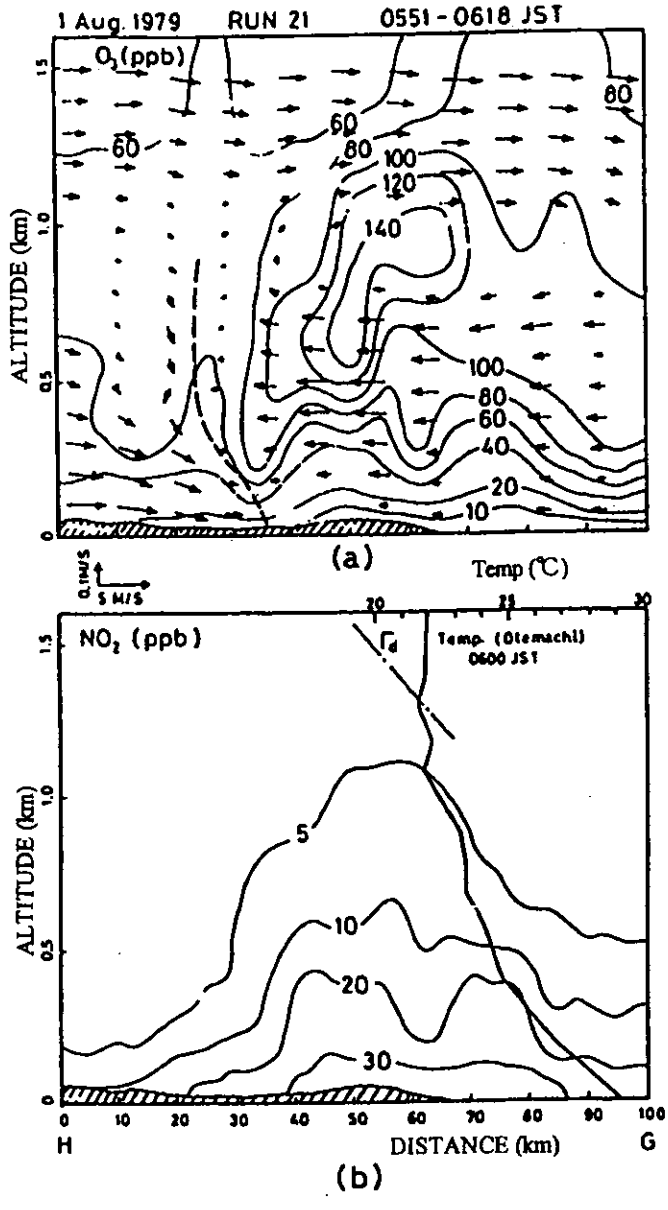
Map of Kanto District. flight paths and objective analysis area of wind field.
Pilot-balloon and sonde observation points are as follows: 1. Oyama; 2. Kumagaya; 3. Satte; 4. Iruma; 5. Inzai; 6. Otemachi; 7. Yokohama; 8. Sodegaura; 9. Chigasaki; 10. Miura; 11. Ichihara; 12. Ohara; 13. Urawa; 14. Tsukuba; 15. Nagareyama; 16. Tsudanuma; 17. Musashino; 18. Hachioji; 19. Atsugi.



Vertical distribution of pollutants in the afternoon of 31 July 1979 (RUN 13: 1450-1630JST. Cross-section H-G). (a) O_3 distribution and vertical wind profile (v and w components) calculated from the modified MATHEW method. Vertical wind component w is emphasized (see wind scale). The label C' and D in (a) indicate the marked air masses of Trajectories C and D in Fig. 10. (b)NO_2 distribution and potential temperature (dashed line) and temperature profile at Otemachi (1500JST).

Source: Uno, I., Wakamatsu, S., Suzuki, M. and Ogawa, Y., Three-dimensional behavior of photochemical pollutant over the Tokyo metropolitan area, Atmospheric Environment, 18, 751-756 (1984))

Fig.4.4.3.1 An Example of 3D Distribution of Air Pollution in Kanto Area



Vertical distribution of pollutants in the early morning of 1 August 1979 (RUN 21: 0445-0620 JST, cross-section H-G). (a) O_3 distribution and vertical wind profile (v and w components) calculated from the modified MATHEW method. The hard dashed line indicated the discontinuity line of wind and in the near of this line, the small downdraft wind zone are detected. (b) NO_2 distribution and temperature profile at Otemachi (0600 JST).

Source: Uno, I., Wakamatsu, S., Suzuki, M. and Ogawa, Y., Three-dimensional behavior of photochemical pollutant over the Tokyo metropolitan area, Atmospheric Environment, 18, 751-756 (1984))

Fig.4.4.3.2 An Example of 3D Distribution of Air Pollution in Kanto Area

4.4.4 Distribution of Wide Area Air Pollution

The weather condition has an important role in determining the regional distribution and time variation of photochemical ozone. Large cities in Japan such as Tokyo, Osaka and Nagoya receive strong influence from the

sea-land breeze because they are located in the coastal area. The air pollutants are transported toward inland by a sea breeze, undergoing chemical reactions on the way. As nitrogen monoxide reacts readily with ozone or RO_2 radicals in the atmosphere to form nitrogen dioxide, a concentration peak of nitrogen dioxide appears usually near the central urban area. Furthermore, in the process of its inland transport, the concentration of photochemical oxidant and secondary aerosol increases. When highly reactive hydrocarbon species components are discharged in large amount, the production rate of secondary air pollutant such as photochemical oxidant and aerosols is increased and a high concentration appears nearer to the center of the city. Also, when the wind velocity is high, the air pollutants are transferred faster to the inland. In this way, the chemical reaction and weather would determine the time variation and area distribution of air pollutant concentration, giving influence to each other. Depending on the weather condition, the air pollutants in and around the urban area are transported further to the inland to bring about a wide area air pollution.

The contents of air pollution is changing as the structure of environmental loads and the social system changes. The problems in atmospheric environment in Japan are becoming more and more widespread and diverse to have very close relationships with our life style. The primary source of today's urban air pollution is the automobile. As a result of the increase in number of automobiles and the expansion of road network, the amount of air pollutant including nitrogen oxides is increasing and becoming widespread. The increase in total amount of air pollutant is altering the problem of atmospheric environment qualitatively. Because of these changes, the air pollution is spreading from central city areas toward surrounding areas, in both Kanto area centered around Tokyo and Kansai area centered around Osaka. Associated with these changes, the frequency of appearance of relatively high concentration of photochemical air pollution and secondary aerosols is increasing in suburban areas rather than in urban areas. Also, as the pollutants become to contain not only a single substance but several substances, it becomes necessary to consider the mutual relationship of pollutants and other hazardous chemical species. On the other hand, the air quality problems spreading across the boarder should be seriously considered. Concerning to the aerosol and acid deposition, the contribution of transport across the sea caused by a rapid increase in the amount of air pollution from Asian countries, particularly China and Korea, can not be ignored, and the monitoring and data analysis for this problem is now very important.

4.4.5 Measurement of Distribution and Monitoring of Air Pollution

Against the air pollutants for which environmental standard and guidelines are determined, a constant monitoring based on the measurement of hourly average values is performed. Across the country, 1728 Air pollution monitoring stations and 395 automobile exhaust gas monitoring stations are in operation as of FY 1994. In Japan, the wet method using absorbent solution has been used as a measuring method for sulfur dioxide, nitrogen dioxide, and photochemical oxidant, but measurements with the dry method are also admitted as equivalent. It is necessary to establish a method of calibration for the measuring equipment to proceed the measurement. Most of the presently existing measuring station for air pollution are concentrated in the urban area because those have been primarily established for monitoring pollution of higher concentration based on the historical background of taking measures against public hazards. As those stations are managed by each administrative district, the consideration for

the formation mechanism of air pollution is not always taken into account in determining their location. As the distribution and life time of pollution source are different by each pollutant, it would be reasonable to consider the density and measuring area of the station independently for each pollutant. It will be necessary to perform a timely review of the measurement methods and items and the density of measurement in accordance with the progress in measuring technologies and changes in social necessities while assuring the consistency of measurement, as well as to clarify the purpose of air pollution measurement. It is also important to know the environmental concentration of VOC for predicting its component. Presently, however, the measurement of VOC components is not performed at the monitoring station in this country at all, and only NMHCs (non-methane hydrocarbons) are measured by counting total number of carbon by the FID (flame ionization detector). It will be necessary in the future to analyze the major substances of VOC components automatically, and to evaluate the measured values.

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