4E5) A Study on Enhancements of Aerosol, Ozone, and Its Precursors over Korea during Asian Dust Events Related to Regional Climate Condition

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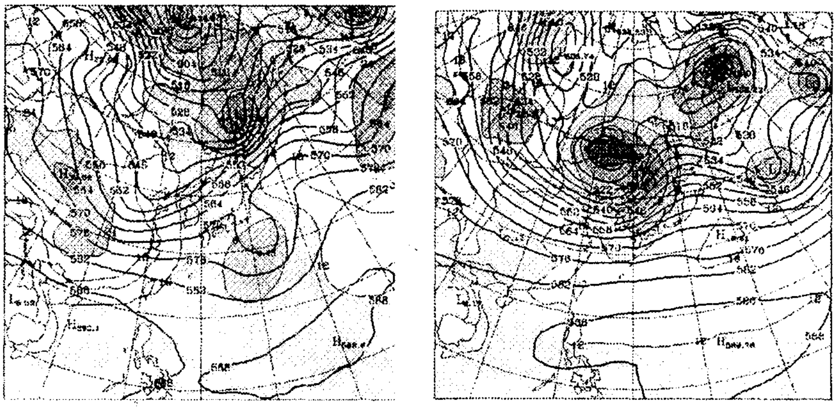
I. Introduction

The vertical exchange of trace gases and aerosols in upper regions of the atmosphere is primarily controlled by the atmospheric conditions. The study of the vertical and temporal variation of the upward transport of H_2O and the downward transport of O_3, NO_2, CO and other long-lived trace species will enable a better understanding of these transport mechanisms. In particular, stratosphere-troposphere exchange (STE) or free troposphere-boundary layer exchange (TBE) is associated with the upper trough/cut-off low due to the upper and lower jet stream at mid-latitudes (Moon *et al.*, 2002). Kim *et al.* (2002) also found that the enhancement of ozone and aerosols (or yellow sand) over Korea during Asian dust events occurred under the presence of the upper trough/cut-off low and surface high-pressure systems.

Recently we have observed the relative enhancement of ozone, CO, NO_2, and aerosols at the Earth's surface during Asian dust events in springtime in Korea. The first purpose of this study is to review the STE of ozone associated with a strong jet stream in the vicinity of the upper-level tropopause over Korea with meteorological elements such as potential temperature, potential vorticity, the backward trajectory, and the ageostrophic and vertical wind velocity. The second aim of this study is to analyze the origin of aerosols, ozone and its precursors transported from China under a slow-moving weather condition associated with the development of the upper trough/cut-off low and surface anticyclone system. Finally, we simulate the relative concentration of photochemical reactions and transport of ozone using the Mesoscale Meteorological Model 5 (MM5, http://www. mmm.ucar.edu/ mm5/ mm5- ome.html), and the Urban Airshed Model (UAM, http:// www.epa.gov/ asmdnerl/ urban.html).

2. Weather conditions for the long-range transport of aerosols, ozone and its precursors during Asian dust events associated with a regional climate.

The enhancement of aerosols, ozone and ozone precursors appears to be associated with both the upper cut-off low connecting with a surface low-pressure and a high-pressure (or anticyclone) located to the south or west of the upper trough as seen in Fig. 1. In China, low-pressure systems with vigorous cold fronts frequently travel from the desert regions of northwest and north China to southeast China and Korea. These systems are often accompanied by strong meandering winds of the upper and lower level jet. At this time, air pollutants with aerosols in China can be usually transported toward Korea along the basin of the Yellow River in the region of high-pressure behind the cold front system. These Asian dust events may be also related to the pattern of rainfall together with the East-Asian and Indian summer monsoon. The shift from winter to summer monsoon starts in March in the surface layers and extends throughout the troposphere by late June.



(a) (b)

Fig. 1. Weather maps overlapped between 500 hPa (thick line) and 1000 hPa (filled line) (a) on 11 April 2001 and (b) on 21 March 2002.

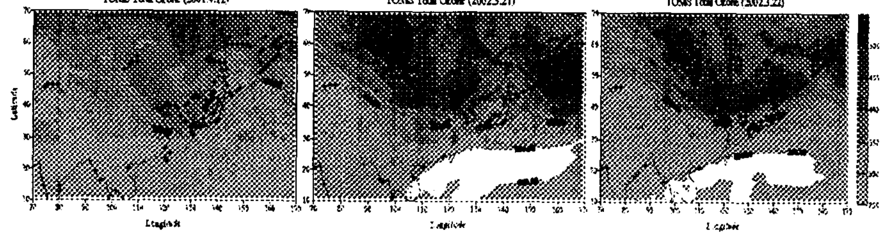


Fig. 2. TOMS total ozone and aerosol index during Asian dust events.

In general, there is high correlation between the synoptic pattern of geopotential heights at 500 hPa and the distribution of total ozone using Total Ozone Mapping Spectrometer (TOMS) during STE and Asian dust events as shown in Fig. 2. As a result, ozone-rich air in the troposphere and stratosphere of mid- and high-latitudes was transported toward the Korean peninsular by the downward movement of the upper trough/cut off low.

3. Case studies on enhancements of aerosols, ozone and its precursors during Asian dust events

Fig. 3 shows vertical profiles of ozone partial pressure selected during the period of Asian dust events. The primary maximum of ozone partial pressure was located around 20 - 25 km, and the secondary maximum of ozone partial pressure was shown in 10-15 km. The amount of ozone in the

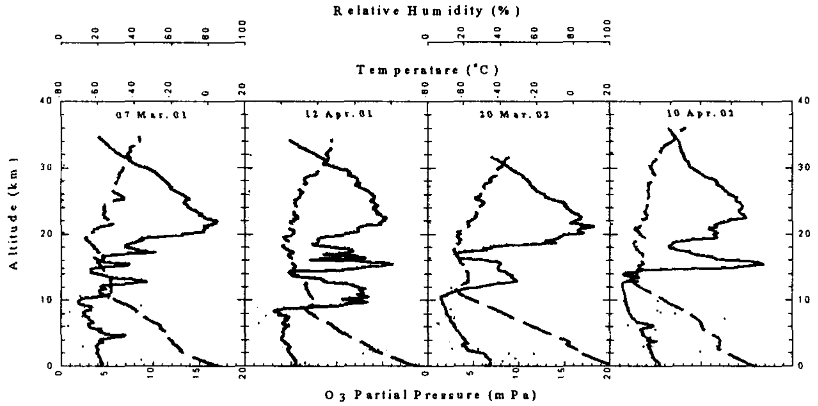


Fig. 3. Vertical profiles of ozone partial pressure, air temperature and relative humidity at Pohang for selected four days.

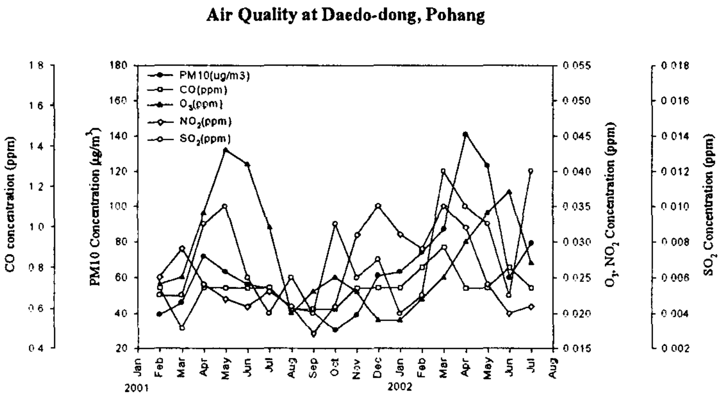


Fig. 4. Monthly variation of air quality measured at Daedo-dong, Pohang from January 2001 to June 2002.

upper troposphere was increased as a whole during the period of Asian dust events. This increase of ozone in the upper-level troposphere was presented as the result of STE of ozone due to the jet stream near the tropopause in springtime. The secondary ozone maximum was shown in the strong zonal wind speed near the jet core, the minimum ozone concentration was presented around the minimum air temperature over Korea.

STE occurs in the weather condition of the upper level trough/cut-off low system associated with the polar and subtropical jet stream over Korea (Kim *et al.*, 2002). Fig. 1 shows such a weather system during Asian dust events. As a result, the ozone concentration in the upper troposphere and Earth's surface increased in springtime in 2001 and 2002 at Pohang as seen in Fig. 4. It is clear that ozone-rich air in the upper level troposphere is transported by the downward movement associated with the upper level trough/cut off low, and then that of the middle troposphere is transported to the ground by anticyclonic subsidence related to TBE. That is, two explanations for a phenomenon of large ozone enhancement on the Earth's surface are possible: the downward transport from the free-troposphere by TBE and the long-range advection of ozone and ozone precursor gases originating from industrial combustion and biomass burning in China.

During springtime in Fig. 4, the sudden enhancement of ozone was also expected both due to the catalytic reaction of ozone precursors and to transport of ozone from a slow moving anticyclone located in the south of Korea. In Korea, severe ozone episodes often occur when a slow moving high- and low-pressure system develops in the late springtime. A slow moving high-pressure weather system is characterized by widespread sinking of air through most of the troposphere. The high- and low-pressure system at the Earth's surface is associated with the development of the upper trough/cut-off low due to the jet stream. As slow-moving air in the boundary layer passes over major metropolitan areas during Asian dust events, concentrations of aerosols, ozone and ozone precursors can increase significantly due to both transport and catalytic chemical reactions that occur when solar radiation is high and air temperatures are higher than those of the day of before.

4. Conclusions

Asian dust events in springtime play an important role in ozone and ozone precursor episodes. Furthermore, the enhancement of ozone and ozone precursors at the Earths surface is determined by three different sources. The first is photochemical production associated with the emission of ozone precursors by industry, biomass burning, and other combustion sources. The second is the long-range advection of ozone and ozone precursors transported from other source regions associated with a slow-moving high- and low- pressure weather system and a land-sea breeze within the boundary layer or the mixing layer. The third is the intrusion of ozone- and ozone-precursor-rich air from free troposphere boundary layer exchange due to vertical mixing or convection connected with stratosphere-troposphere exchange, and long-range transport of ozone and ozone precursors in the free troposphere associated with the upper trough/cut-off and surface high/low pressure weather system due to the jet stream. Above all, the vertical and horizontal distribution of meteorological parameters such as the wind velocity, the geopotential height, the air and potential temperature, and the potential vorticity play an important role in the enhancement of aerosols, ozone, and ozone precursors in springtime.

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