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IMPACTS OF ATMOSPHERIC BLOCKING ON REGIONAL AIR QUALITY OVER EAST ASIA

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1. INTRODUCTION

An atmospheric blocking can be explained by an obstructing phenomenon of the normal west-to-east progress of migratory cyclones and anticyclones on a synoptic scale (Bluestein, 1993). In general blocking situations are made by pronounced meridional flow in the upper levels. The situations are often compromised by one or more closed anticyclonic circulations at high latitudes and cyclonic circulations at low latitudes (called as cut-off highs and cut-off lows). This anomalous circulation pattern typically remains nearly stationary or moves slowly westward, and persists for a week or more. Prolonged blocking in the Northern Hemisphere occurs most frequently in the spring over the eastern North Atlantic and eastern North Pacific regions (http://amsglossary.allenpress.com/).

A number of studies on the blocking in the Northern Hemisphere have been carried out. Lee and Jhun (2006) studied the Asian continental blocking and their relation to the winter monsoon in East Asia. Gangoiti et al. (2002) investigated the surface ozone episode related to the blocking over Europe in summer. And Lejenas and Holmen (1996) reported the relationship between air pollution episodes and the blocking in Arctic region in winter. However there have been limited studies on the air pollution episodes over East Asia related to the blocking.

This study aims to investigate the impacts of atmospheric blocking over East Asia and the Northwestern Pacific on East Asian regional air quality, especially in Korea.

2. DATA

Atmospheric blocking is defined as long-lived and recurrent system which does not progress at all within the latitude belt of baroclinic westerlies (Bluestein, 1993). In general, either persistent positive anomaly method or meridional gradient method for 500-hPa geopotential height has been used to detect blocking. The data used are the 2.5° × 2.5° NCEP-NCAR reanalysis data for 1979-2006. In this study, blocking event at each grid point is defined by the threshold crossing procedure of daily-mean 500-hPa geopotential height anomaly. The 500-hPa geopotential height anomalies are obtained by removing the local seasonal cycle which is defined as the first four harmonic terms of the 28-yr (1979-2006) mean annual cycle. Thus, if the 500-hPa geopotential height anomaly at a grid point persists beyond the threshold value (150 m) for a specified duration (7 days), we consider the entire period as one blocking event (Shukla and Mo, 1983).

In order to investigate the spatial and temporal distribution of atmospheric aerosols, several data sets are employed in this study. Satellite images (e.g., Aqua MODIS and MTSAT-1R) were used to monitor large-scale distribution of smoke and dust aerosols. Vertical profiles of aerosol light extinction with shape information were be obtained by LIDAR system, which was installed at Seoul. In addition, PM10 (particle size less than 10 micrometers) mass concentration data from the Korea Meteorological Administration (KMA)'s Asian Dust Monitoring Network were also used. Optical properties of smoke and dust aerosols were measured by the Sun/skyradiometer network which is operated by NASA/GSFC.

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3. SATELLITE VIEWS OF SMOKE AND ASIAN DUST EPISODES

In spring of 2003 and 2006, smoke and dust episodes were reported in the newspapers and scientific papers. The following two figures show the satellite images during the event days.

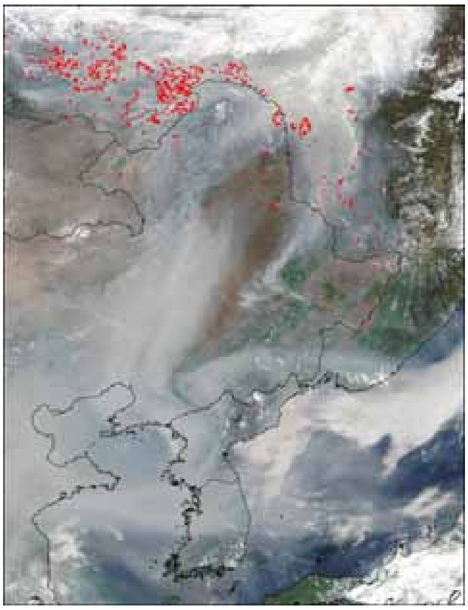

Fig. 1. MODIS image on 20 May 2003 over East Asia. Intense smokes emitted by biomass burning are covered in the East Asian region.

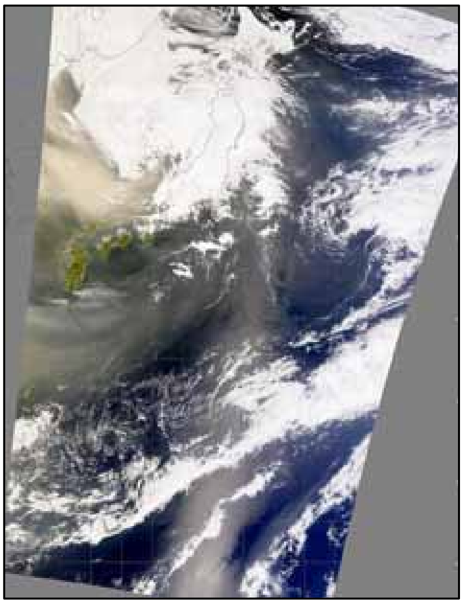

Fig. 2. MODIS image on 8 April 2006 over Japan and the Northwestern Pacific, showing severe dust aerosol loadings in the atmosphere.

4. AIR QUALITY LEVELS DURING TWO EPISODIC PERIODS

During the episodic periods there were poor air quality in Korea and East Asian countries. During the smoke episode (May 20-23, 2003) PM10 concentration at Seoul reached to 223 ug/m^3. According to data from the Asian dust monitoring network in South Korea, the maximum concentration of PM10 at Seoul (Mt. Gwanak station) during the episodic dust event on April 8, 2006 were 2353 ug/m^3. Sun/skyrdiometer measurements show that aerosol optical depth at 500 nm at Seoul ranged from 1.8 to 2.7 on the episodic dust day. On the day Angstrom exponent was less than 0.3, indicating most of the aerosols composed by dust particles. These high mass concentrations of fine and coarse aerosols should result in very adverse human health impacts. What causes this kind of high aerosol loading in the atmosphere in this region? It seems to be closely associated with the large-scale circulation pattern in the region (i.e., blocking). More details are discussed in the next section).

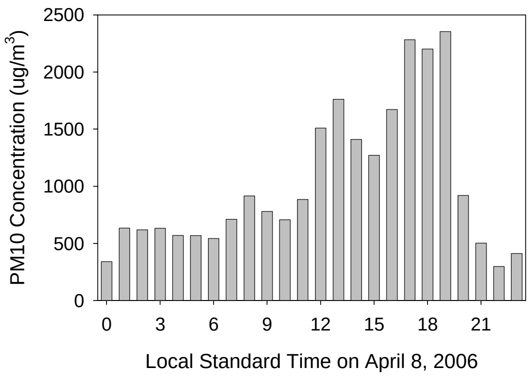

Fig. 3. Hourly variation of dust mass concentration at Seoul (Mt. Gwanak station, one of the KMA's Asian dust monitoring stations).

5. IMPACTS OF THE BLOCKING ON THE REGIONAL AIR QUALITY

In case of the smoke episode, blocking has been found during the period of 8 to 22 May 2003 over Central Asia. A typical Omega-type blocking was appeared. If we analyze the time-longitude cross section at 60 N (Fig. 4), strong positive anomaly of 500 hPa geopotential height was lasted from early to late of May 2003. In particular, persistent positive anomaly over the northwestern Pacific during the period of 22 to 30 May 2003 seems to be closely associated with the episodic smoke event, resulting in stagnant and stable atmospheric condition (Fig. 5).

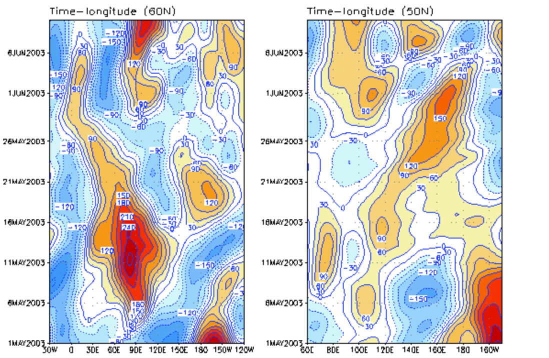

Fig. 4. Time-longitude cross section of 500 hPa geopotential height in May and June of 2003.

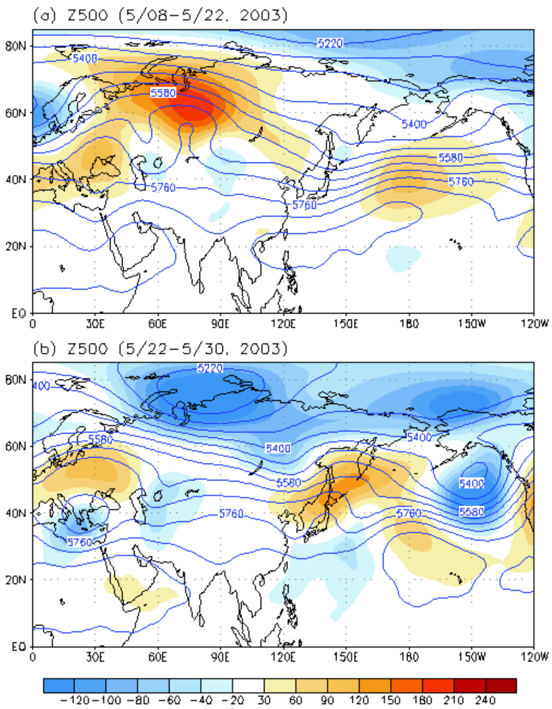

Fig. 5. Geopotential (line) and its anomaly (color-shaded) charts at 500 hPa during (a) 8-22 May and (b) 22-30 May 2003.

Figs. 6 and 7 show the time-longitude cross section and anomaly of 500 hPa geopotential height. As shown in the figures, positive anomaly at 45 N around 130 E during 8 to 20 April 2006 seems to be closely linked to the episodic dust event in early April 2006 over Korea and East Asian countries. As shown the time-longitude chart of Fig. 6, the strong positive anomaly around 150E-150W at 45N during March to late April 2006 are stationary and nearly not propagated to any direction.

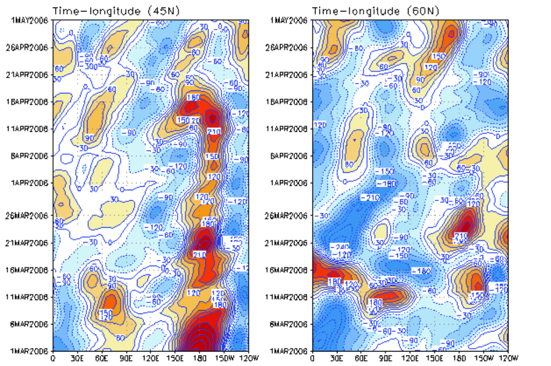

Fig. 6. Time-longitude cross section of 500 hPa geopotential height in the springtime of 2006.

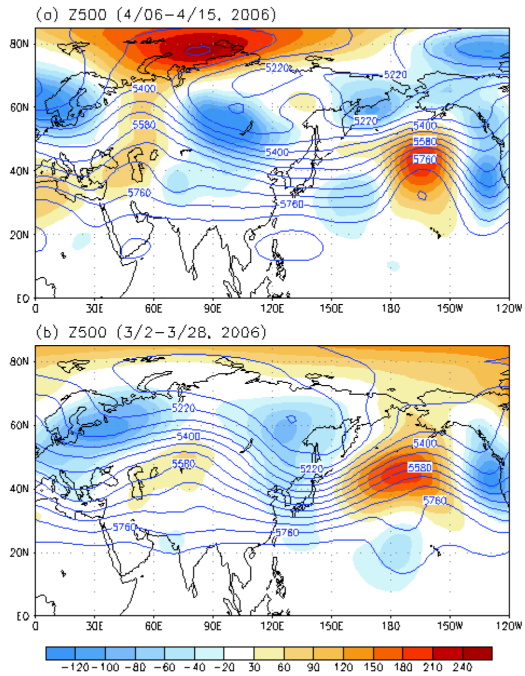

Fig. 7. Geopotential (line) and its anomaly (color-shaded) charts at 500 hPa during (a) 6-15 April 2006 and (b) 2-28 March 2003.

In particular, as shown in Fig. 7 a strong ridge is appeared in the Northern Pacific (180 –

150W) during 6-15 April 2006 while negative anomaly is appeared over East Asia. Blocking-like ridge in Central Asia seems to contribute to the development of negative anomaly over the lake Baikal.

6. SUMMARY

Atmospheric aerosols play a major role in direct and indirect effects of the climate system (Kim et al., 2006). These tiny particles are also very important to the atmospheric environment aspects, especially in East Asia due to the large population and still elevated concentration level of pollutant gases and particulate matters. Two episodic cases with severe air quality degradation, smoke in May 2003 and Asian dust in April 2006, were investigated to understand their relationships to atmospheric blocking over East Asia. In order to detect atmospheric blocking over East Asia and its surrounding region, the persistent positive anomaly method for 500 hPa geopotential height field was applied. The result shows the close relationship between the blocking phenomena and long-range transport process of atmospheric aerosols. Persistent positive and negative anomalies of large-scale circulation systems were found by the time-longitude cross section analysis of the geopotential field. The anomalous blockings seems to be linked with high atmospheric loadings of smoke and dust aerosols which are resulted in prolonged air quality problems in Korea and East Asian countries.

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