EFFECT OF FOREST FIRES ON THE AIR QUALITY IN SEOUL FROM MOPITT MEASUREMENTS

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ABSTRACT
Measurements of CO whose principal sources arise from anthropogenic emissions such as biomass burning and forest fires, is very useful for tracing fire emissions in the atmosphere. In this study, intense fires in the southeast part of Russia in May, 2003 are studied with the satellite data from MODIS and MOPITT. The AOD distribution from the MODIS for May, 2003 show stretched regions of high AODs near the Korean Peninsula. The column densities of CO from the MOPITT for May, 2003 also show enhanced values. Correlation between CO and AOD are investigated for the forest fire case. In addition to this correlation between AOD and CO, the loadings of CO into the atmosphere are studied using the 5-year MOPITT data by estimating emission anomaly of CO in 2003 Russian forest fires.

Keywords: Aerosol, carbon monoxide, forest fire, MOPITT, MODIS

1. INTRODUCTION
The Measurement Of Pollution In The Troposphere(MOPITT) onboard the Terra satellite provides quantitative information of carbon monoxide(CO). Measurements of CO whose principal sources arise from anthropogenic and natural emissions such as biomass burning and forest fires, is very useful for tracing fire emissions in the atmosphere due to their long lifetime. Wild fires and biomass burning emit CO into the atmosphere and also inject large amount of aerosol resulting in high AOD. Large scale forest fire is an outstanding case to see the correlation between the CO and AOD. There have been persistent forest fires from spring to autumn in the southern areas of eastern Russia bordering China and Mongolia. They start with snow-melt and rapid drying of forest fuel at the onset of dry weather in March and April(Edwards et al., 2004). Statistics on the forest fires show two peaks in May and September in fire numbers (IFFN, 2003). Furthermore, both the number of fires and total area burned are increasing steadily from 1996 to 2002. In May of 2003, the air quality over Korea, located near the southeastern part of Russia, has been affected seriously from this Russian forest fires.

In this study, intense fires in the southeast part of Russia in May, 2003 are studied with the satellite data from the MODIS and the MOPITT. In addition to this correlation between AOD and CO, the loadings of CO into the atmosphere are studied using the 5-year MOPITT data by estimating emission anomaly of CO in 2003 Russian forest fires.

2. DATA
In order to have full spatial coverage in this East Asian region and to avoid instantaneous biases of the CO column density measurements, 8-day average datasets are used. Considering the typical aerosol’s lifetime of a few days in the atmosphere, this 8-day average has limitation in identifying instantaneous picture of aerosol source and sink, but it is the current limit to have meaningful spatial coverage and to provide general feature of the aerosol and CO simultaneously. Average datasets for shorter periods (e.g. 3 days) have been tried for the MODIS and MOPITT, but have shown problems in representing meaningful features after simple mathematics(ratio etc.) between the two datasets.

Figure 1 shows AOD and CO column densities for the forest fire case. The fine mode aerosol shows that the air quality was affected badly over Korea throughout the whole week of May, 2003 (Lee et al., 2004). The southward movement of aerosols and plumes are shown clearly in the series of satellite images and trajectory analysis during this period. The AOD at 0.5 micron measured at Anmyeon AERONET site, located southwest of Seoul, showed values exceeding 3.0 during this period. Although the data is not shown here, hourly mean values of PM10 at Seoul reached up to 250 g/m³, and the visibility was reduced to about less than 3 km during the whole week of May, 2003, compared to normal 6 to 10 km values at Yonsei University, Seoul, Korea. The direct component irradiance was
reduced down to about 20% of the diffuse component due to heavy aerosol loading in this period based on the measurements from the Rotating Shadowband Radiometer at the same location.

The CO column densities are also enhanced significantly over the region when compared with clear sky case in particular. The CO concentrations at 500 hPa from the MOPITT for May, 2003 also show enhanced values, which indicate the high rise of plumes into the atmosphere. The vertical cross section of column CO densities observed from MOPITT along the north-south line for the early May shows that the emitted CO plume has risen into the atmosphere up to the 500 hPa level and transported to the downstream of the airflow. The CO column density in clear sky condition over Korea may indicate the background CO level. In general, the surface concentrations of CO in Korea show seasonal variation with its maximum in winter and minimum in summer due to increase of fuel burning with concentrations ranging from 0.3 to 1.0 ppm in urban areas, and lower values with weaker seasonal variations in natural background areas as analyzed from the observed data by the National Institute of Environmental Research, Korea.

The time series of CO column density and fine mode AOD at Seoul area are taken for May, 2003 from these satellite measurements and shown in Figure 2. The AOD was increased noticeably up to 2.4 for the period of May 17th – 24th, 2003 while the column density of CO does not change as steeply as AOD but show slightly enhanced values rather slowly during the same period. The temporal correlations between these two quantities are reasonably good. In order to estimate the emission anomaly of CO due to the Russian forest fire in 2003, MOPITT data of CO are used for 5 years from 2000 to 2004.
Institute of Environmental Research), Korea was analyzed. The time series of CO concentration in urban region, Seoul, Inchon and Daejon scattered throughout the country, show clear annual cycle while the series in rural part show rather weak annual cycle. Although the overall CO concentration levels are high, these annual cycles of CO are in opposite phase of the fire number and/or burned area of the Russian forest fires. Thus the surface CO concentration in May is in decreasing phase toward the summer minimum at about 0.5 ~ 0.6 ppm in average. As the main sources of CO are located at continental surfaces, the relative contributions of local sources to the total column amounts are not negligible. Thus, although the local effect of CO emission on the Russian forest fire emission was minimized, the effect of local sources near the Korean Peninsula is still not negligible. Increases of CO in May 2003 compared to 2002 are noteworthy for all stations both in rural and urban area. These local sources could have contributed by non-negligible amount to the above highly negative spatial correlation near the Korean Peninsula. However, it is evident that the major factor to change the spatial correlation between the CO and AOD is the time elapsed in the atmosphere, thus their respective movements away from the source.

Figure 3. Mean total column CO amount observed by MOPITT in the lower-(0-30 N, LL, black color), mid-(30-60 N, ML, red color), and high-(60-90 N, HL, blue color) latitudes for the period from 2000 – 2004.

Yurganov et al. (2004) analyzed the CO total column amounts at nine stations in the latitudes between 30° N and 80° N and assessed CO emission anomaly by using the ground-based FTIR (Fourier Transform Infrared) spectrometer measurements. They estimated the emission anomaly in 1998 was +96 Tg yr⁻¹, which was mostly attributed to the emission from boreal forest fires. Novelli et al. (1998) showed that the annual cycles of CO concentration in the Northern Hemisphere have maxima in March-April and minima in July-August. The annual cycle of CO concentrations reflect the year-round anthropogenic emissions and warm season peak of biomass burnings as the main source of CO are located at continental surfaces, and the variation of OH, a major sink for CO which show increased values in spring-summer and the decreased in fall-winter period (Yurganov et al., 1999; Zander et al., 1989). Thus, the annual cycle of total CO column density shows a maximum in spring and a minimum in late summer due to mentioned factors and time lags. Utilizing the global coverage of the MOPITT measurements, the mean total column CO amount can be estimated for the lower, mid and high latitudes for the 2000-2004 period as shown in Fig. 3. In general, the CO column amounts show typical annual cycle with its maximum of 2.5 x 10¹⁸ molecules cm⁻² in May and a minimum of 1.8 x 10¹⁸ molecules cm⁻² in July-August period, before 2001. However, since late 2002, the typical annual cycle of CO column density has been affected by the large scale forest fires. As explained above, the large-scale forest fire in Russia showed two peaks in spring and fall which corresponds to the maximum and minimum of annual cycle of total CO, respectively. Thus the effect of the forest fire peak in fall is more evident in the time series compared to the spring peak which overlaps the CO peak in spring. The CO column amounts in 2002 for the lower latitudes(LL) in black lines show similar annual variation with a maximum of 2.2x10¹⁸ molecules cm⁻² in April, dry seasons in tropic, and a minimum of 1.6x10¹⁸ molecules cm⁻² in August. However, in late 2002 after the summer minimum, the increase of mid-latitudes(ML) CO toward the next maximum in March-April, 2003 is abrupt from August to November in particular, and stay at higher densities till the beginning of 2003 which could be attributed to the effect of abnormal increase of the total CO amount from the mid-(ML) and high-latitudes(HL) due to large scale forest fires in fall, 2002 in Russia. In 2003, the basic LL annual cycles are maintained except for the flattened CO level from January to March, 2003 which is the residual effect of
enhanced CO levels in the fall/winter of 2002 in the mid-latitudes (ML). A peak CO column density at ML reaching up to 2.7 x10^{18} molecules cm^{-2} are found in May, 2003 which is increased by about 10\% compared to that in 2002.

In an attempt to estimate anomaly of CO emission, anomaly of total column CO for the latitudes in the northern hemisphere are calculated for the low-(0^{\circ}-30^{\circ} N), mid-(30^{\circ}-60^{\circ} N) and high-(60^{\circ}-90^{\circ} N) latitudes and shown in Figure 4 from the MOPITT data with respect to the mean CO column densities. The mean CO column densities are weighted inversely by the total area burned based on the statistics in IFFN(2003) to minimize the effect of forest fires on the average CO column density. The 5-year average CO column density show typical annual cycle with its maximum of 2.39 x10^{18} molecules cm^{-2} in May and a minimum of 1.95 x10^{18} molecules cm^{-2} in September. The anomalies of total column CO in high- and mid-latitudes in the northern hemisphere(HNH) turns to positive values from the fall of 2002, reaching the maximum of about 3 x10^{17} molecules cm^{-2} in the late spring of 2003. The increasing anomaly can be attributed to the effect of Russian forest fires clearly.

The emission anomaly of CO by using the MOPITT measurements for the period of 2000-2004 are estimated following the methodology of Yurganov et al. (2004) basically and shown in Figure 5. It shows large anomaly in
the fall of 2002 and late spring/fall of 2003, which is consistent with the above mentioned CO anomaly. The 1-month running average of emission anomaly ranges from -8 Tg/month to 20 Tg/month. The maximum value of 41 Tg/month for the HNH (latitudes between 30 and 90 degree) is about half of magnitudes with the values for the 1998 emission suggested in Yurganov et al. (2004).

Figure 6 shows the averaged CO column density along the meridian between the latitude 30° and 60°N plotted against the time in May-June, 2003. This diagram, similar to Hov Müller diagram (cf. Carbone et al., 2002) shows the enhanced CO column densities due to forest fires in the region between the 100 and 180°E (e.g. marked “1”, “2”, and “3” in the figure), and also allows us to analyze the moving speed and persistency in the atmosphere. The low CO column density region appeared as vertical blue bands near 120°W and 100°E corresponds to the Rocky Mountains and the Himalaya/Tibet Plateau, respectively. The enhanced CO column densities between the 120° and 180°E correspond to the Russian forest fires, while the enhanced values between the 180°W and 120°W in late May in particular (marked as “1” and “3” in the figure) is the transported plume reaching the Gulf of Alaska from Russia across the Pacific. Thus, the CO concentrations in Alaska can be affected by the Russian forest fires in May and June, 2003. As the latitudes are confined between 30° and 60°N in this analysis, chances that forest fires occurred in Alaska affects the results are unlikely unless the air flow was from the north to the south in the region. The general air trajectories in May analyzed by using the HYSPLIT model were from south to north near the Alaska region. As the midlatitude region we consider is dominated by the westerlies in the upper troposphere, the moving direction of plume is to the east in general as marked. The moving speed of the CO emission feature as marked is obtained from its slope of enhanced density features and is estimated to be in the ranges between 700 km/day and 1000 km/day. Note that the high density values (3.5x10^{18} ~ 4.0x10^{18} molecules cm^{-2}) corresponding to the red color bar are maintained up to 10 days(feature “1”) ~ 15 days(feature “3”) at least. Thus the e-folding lifetime of the CO plume can be much longer. One can note from the figure that the CO column density ranges from 4.0x10^{18} molecules cm^{-2} down to 2.5x10^{18} molecules cm^{-2} at given longitudes, except for the Rocky Mountains and the Himalaya/Tibet Plateau region. Edwards et al. (2004) estimated the e-folding lifetime of CO varies from 1.5 months to 3.6 months.

4. CONCLUSION

AOD from MODIS and total column CO density from MOPITT were used to analyze the aerosol and CO loading in the atmosphere for the case of the Russian forest fire in May 2003. HYSPLIT trajectory model was used to aid the view of the transport during the event. Combining MODIS and MOPITT with other satellite data such as SCIAMACHY would provide better coverage and help us to locate source and sink for aerosol and CO. However, when we deal with the same CO measurements from the two different instruments, the calibration between the
MOPITT and SCIAMACHY needs to be considered carefully. Emission anomalies of the CO column density are also estimated to be up to about 20 Tg/month in 30-day average for the HNH from the MOPITT measurements. Comparison of the current results with the chemical transport model will help to understand the detail physical and chemical mechanisms.

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REFERENCES


