APPLICATION OF SATTLITE OBSERVATIONS OF CHANGES IN AIR QUALITY DURING THE 2010 ASIAN GAMES AND PARA GAMES IN GUANGZHOU, CHINA

Jie Guang[1], Yong Xue[1,2], Yingjie Li[1,3], Jianping Guo[4] and Guixiong Liang[5]

[1]State Key Laboratory of Remote Sensing Science, Jointly Sponsored by the Institute of Remote Sensing Applications of Chinese Academy of Sciences and Beijing Normal University, Beijing 100101, P.R.China
[2]Department of Computing, London Metropolitan University, London N7 8DB, UK
[3]Graduate School of the Chinese Academy of Sciences, Beijing 100049, P.R.China
[4]Centre for Atmosphere Watch and Services, CAMS, Beijing 100081, P.R.China
[5]Guangzhou Environmental Monitoring Center Station, Guangzhou 510030, P.R.China

Tel: +86-10-64889540; E-mail: guangj82@hotmail.com

KEY WORDS: Asian Games, Satellite observations, Guangzhou, Air quality

ABSTRACT: The 16th Asian Games and the 10th Asian Para Games were held in Guangzhou, China during November to December 2010. Strict controls on pollutant emissions and motor vehicle traffic were imposed on Guangzhou and neighboring cities to improve the air quality in and around the city. Satellite data were used to examine the impact of the 2010 Asian Games and Para Games on regional air quality. As local environmental protection agencies in China are only required to publish the daily levels of the dominant air pollutant among respirable particulate matter (PM_{10}), sulfur dioxide (SO_2), and nitrogen dioxide (NO_2), we mainly analyzed these three major air pollutants from satellite observations. PM_{10} were derived from MODerate resolution Imaging Spectroradiometer (MODIS) and ground measurements. SO_2 were measured with the SCanning Imaging Absorption spectroMeter for Atmospheric CHartographY (SCIAMACHY) instrument on ENVISAT, and NO_2 were retrieved from the Ozone Monitoring Instrument (OMI) onbroad EOS-Aura. PM_{10} retrieved from satellite measurements over Guangzhou showed -0.87 mg/m^3/per day reduction during October to December. SO_2 retrieved from satellite measurements over Guangzhou showed -0.01 DU/per day reduction during October to December. NO_2 retrieved from satellite measurements over Guangzhou showed -19.5×10^{13} mol/cm^2/per day reduction during November. Thus, based on satellites observations alone, noticeable reductions in these pollutant tracers were measured during both games.

1. INTRODUCTION

Over the Guangzhou region, there are often high aerosol concentrations. In 2004, Guangzhou city in China won the bid to host the 16th Asian Games (November 12-27, 2010) and the 10th Asian Para Games (December 12-19, 2010). The Guangdong government implemented a series of long- and short-term emission control measures to improve the air quality in and around the city for the duration of the games. The measures are scheduled to be implemented from November 1 to December 20, covering 11 cities in the southern province. Authorities will impose restrictions on vehicles and close down construction sites and production in factories that emit pollutant gas, in order to maintain good air quality during the event, according to the provincial environmental protection bureau. Sprinklers will be used to reduce dust. Barbecues and interior refurbishments that emit pollutants will also be prohibited in Guangzhou during that period (http://china.globaltimes.cn/society/2011-04/585551.html).

Satellite remote sensing of trace gases and aerosols for air quality applications has evolved dramatically recently. Global observations are now available for a wide range of species including aerosols, tropospheric O_3, NO_2, CO, HCHO, and SO_2 (Martin, 2008). In this study, we present satellite measurements of three major air pollutants in China, that are inhalable particulate matter (PM_{10}), sulfur dioxide (SO_2), and nitrogen dioxide (NO_2). We track their changes before, during and after the Games to examine the impact of the 2010 Asian Games and Para Games on regional air quality.

2. STUDY AREA AND DATA

The study area is in south-east part of China that includes Guangzhou and neighboring provinces, and the spatial region is 108º-122ºE longitudes and 18º-30ºN latitudes, as shown in Figure 1.

The daily 1 km aerosol optical depth (AOD) data were acquired by the SYNTAM method (Tang et al., 2005), using the data from Moderate Resolution Imaging Spectroradiometer (MODIS) aboard Terra and Aqua satellites (http://ladsweb.nascom.nasa.gov/). In recent years, many researchers have shown that AOD can be converted to PM_{10}

estimates (Gupta et al., 2006; Kumar et al., 2011). Li et al. (2009) demonstrate how AOD can be converted to PM_{10} estimates in Hong Kong. The SCIAMACHY instrument was launched onboard of ENVISAT, provides the capability for solar observation of atmospheric SO_2 columns through observation of global backscatter (Bovensmann et al., 1999). SCIAMACHY observes the atmosphere in the nadir view with a typical surface spatial resolution of 30 km along track by 60 km across track, crossing the equator at 10:00 local time (LT) in the descending node. The SO_2 slant column retrieval for SCIAMACHY is based on the algorithms Differential Optical Absorption Spectroscopy (DOAS) of Lee et al. (2008). Tropospheric column NO_2 is measured by Ozone Monitoring Instrument (OMI) onboard NASA's Aura satellite. OMI is a nadir-viewing image spectrograph that provides daily global coverage at a high spatial resolution (13-24 km at nadir) capable of mapping pollution products on urban scales. NO_2 is reported as the vertical column density (in mol/cm^2) between the surface and the estimated mean tropopause pressure height of 150 hPa and is interpolated to a horizontal resolution of $0.05^o \times 0.05^o$, and the retrieval accuracy estimates for the tropospheric column to be 25%, with a precision error of 0.25×10^{15} mol/cm^2 (Bucsela et al., 2006). The daily tropospheric NO_2 from OMI are available at the ESA-Tropospheric Emission Monitoring Internet Service (http://www.temis.nl/airpollution/no2.html).

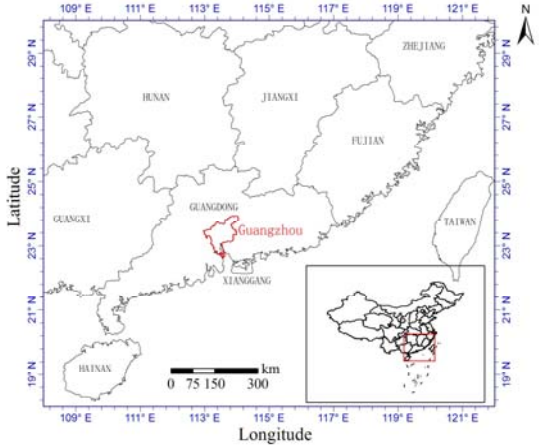

Figure 1. Map of the Guangzhou (red) and the surrounding provinces

3. ANALYSES AND DISCUSSION

In order to provide relevant data and decision support information to the Guangzhou Asian Games Organizing Committee (GAGOC), we are building up an environmental remote sensing monitoring system for Guangzhou 2010 Asian Game using multi-resolution, multi-band, multi-temporal remote sensing data and back trajectory analysis technique. This system can provide: 1) a stereo observation from space-borne remote sensing means, including daily AOD, PM_{10}, SO_2, NO_2, etc.; 2) air mass back-trajectory analysis based on the HYSPLIT model; 3) 7 days Parameters Linking Air Quality and Meteorology (PLAM) forecasting over Guangzhou area and its surrounding areas.

The tropospheric NO_2 column density, SO_2, AOD and PM_{10} were retrieved from OMI, SCIAMACHY and MODIS every over the study area during November 1, 2010 to December 19, 2010. Figure 2 shows the remote sensing retrieved NO_2, SO_2, AOD and PM_{10} results on November 11, 2010, just one day before the opening ceremony of the 16th Asian Games. The tropospheric NO_2 was at a low level in Guangzhou, and the value was about 650×10^{13} Mole/cm^2, as shown in Figure 2(a). A serious high NO_2 pollution belt was appeared in the southwest of Guangzhou, including the cities of Jiangmen, Foshan, and Zhongshan, and the highest concentration of pollution was up to 1300×10^{13} Mole/cm^2. The SO_2 was at a high level in the south of Guangzhou, and the value was about 1.8 Dobson Unit, as shown in Figure 2(b). Figure 2(c) shows the retrieved AOD result based on SYNTAM method. Figure 2(d) shows that PM_{10} values are between 0-50 μg/m^3 in the northern and central part of Guangzhou, and PM_{10} values are between 50-100 μg/m^3 in the southern part of Guangzhou. PM_{10} values are between 100-150 μg/m^3 in the southwest neighboring cities (Foshan city, Zhongshan city and Jiangmen city). From Figure 2, we can see that the air pollutions in the southwest neighboring cities may affect the air quality of Guangzhou.

The State Environmental Protection Administration of China has issued atmospheric quality standards, which evaluated air quality by air pollution index (API) based on the influences of air pollutions on human health. According to the daily air quality reports by the Environmental Protection Department of Guangzhou (http://www.gzepb.gov.cn/), API of Guangzhou was 80 and the primary pollutant was respirable particulate matter (PM_{10}) on November 11, 2010, and air quality condition belonged to "good". The Ministry of Environmental

Protection of China (MEP) defines that cut points of PM_{10} is 300 $\mu g/m^3$ when the air quality is "good" and 120 $\mu g/m^3$ when the air quality is "excellent" (Chen et al., 2011). According to the satellite retrieved PM_{10}, the air quality of Guangzhou also belonged to "good". Compare to ground-based monitoring stations, the satellite retrieved results can provide more continuous spatial information and larger coverage.

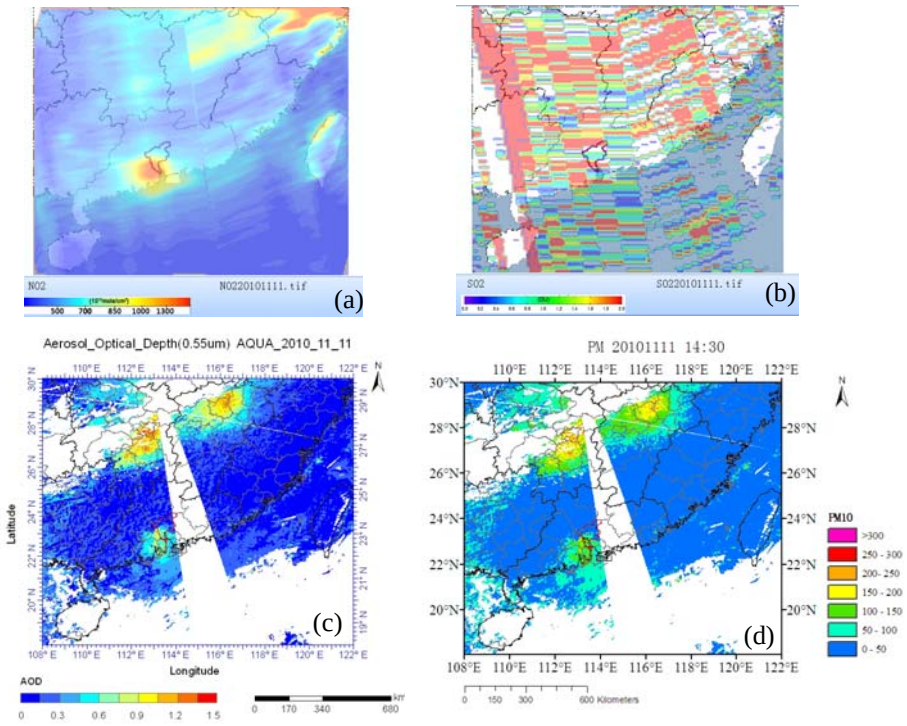

Figure 2. Satellite remote sensing of (a) NO_2, (b) SO_2, (c) AOD and (d) PM_{10} results on November 11, 2010.

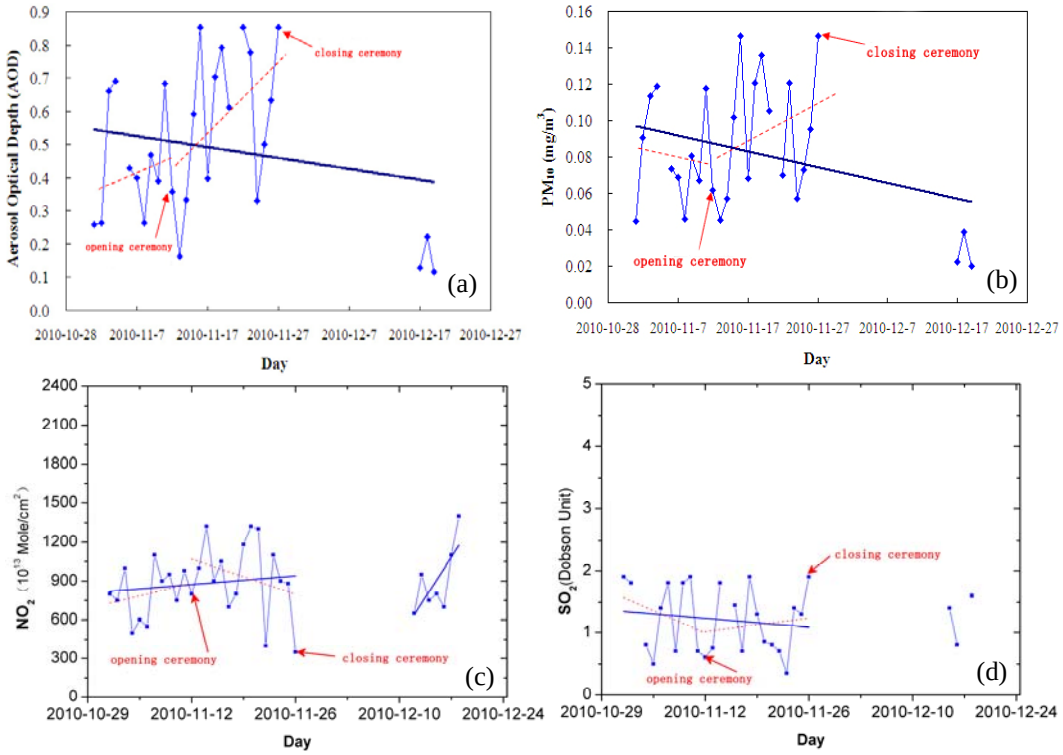

Figure 3. Time series of pollutant amounts retrieved from satellite for (a) AOD, (b) PM_{10}, (c) NO_2 and (d) SO_2 before, during and after the 2010 Asian Games and Para Games in Guangzhou, China.

Table 1. The change of retrieved PM_{10}, NO_2 and SO_2 over Guangzhou

Pollutant amounts retrieved from satellite	Diurnal variation (slope)		
	Overall trends	Before the 2010 Asian Games	During the 2010 Asian Games
PM_{10} (mg/m^3)	-0.87	-0.69	2.1
NO_2 (10^{13} mol/cm^2)	4.8	14.5	-19.5
SO_2 (DU)	-0.01	-0.05	0.02

Figure 3 shows the time series of pollutant amounts retrieved from satellite for AOD, PM_{10}, NO_2 and SO_2 before, during and after the 2010 Asian Games and Para Games in Guangzhou, China. PM_{10} over Guangzhou showed -0.87 mg/m^3/per day reduction during November 1 to December 19, 2010. SO_2 showed -0.01 DU/per day reduction during November 1 to December 19, 2010 and NO_2 showed -19.5×10^{13} mol/cm^2/per day reduction during November12 to November 27, 2010, as shown in Figure 3 and Table 1. Thus, based on satellites observations alone, noticeable reductions in these pollutant tracers were measured during both games.

4. CONCLUSIONS

In this study, we present a comprehensive space-based assessment of the chemical changes in major gaseous pollutants during the Guangzhou 2010 Asian Games and Para Games. PM_{10} retrieved from MODIS over Guangzhou showed -0.87 mg/m^3/per day reduction. SO_2 retrieved from SCIAMACHY over Guangzhou showed -0.01 DU/per day reduction. NO_2 retrieved from OMI over Guangzhou showed $-19.5*10^{13}$ mol/cm^2/per day reduction. We conclude that Guangzhou's stringent short-term emission control measures successfully lowered the levels of NO_2, SO_2 and CO during that period. The space-based observations provide an useful tool for monitoring air pollutants.

ACKNOWLEDGEMENT

This work was supported by the Ministry of Science and Technology, China under grant nos. 2010CB950803 and 2007CB714407. The authors are thankful to NASA (http://ladsweb.nascom.nasa.gov/) and ESA-TEMIS (http://www.temis.nl/airpollution/no2.html) for providing satellite data.

REFERENCES

Bucsela, E., Celarier, E.A., Wenig, M.O., Gleason, J.F., Veefkind, J.P., Boersma, K.F. and Brinksma, E.J., 2006. Algorithm for NO_2 vertical column retrieval from the Ozone Monitoring Instrument. IEEE Transactions on Geoscience and Remote Sensing, 44(5), pp. 1245-1258.

Chen, Y., Jin, G.Z., Kumar, N. and Shi, G., 2011. The Promise of Beijing Evaluating the Impact of the 2008 Olympic Games on Air Quality. National Bureau of Economic Research, Inc in its series NBER Working Papers with number 16907.

Gupta, P., Christopher, S.A., Wang, J., Gehrig, R., Lee, Y. and Kumar N., 2006. Satellite remote sensing of particulate matter and air quality assessment over global cities. Atmospheric Environment, 40(30), pp. 5880-5892.

Kumar, N., Chu, A.D., Foster, A.D., Peters, T. and Willis, R., 2011. Satellite Remote Sensing for Developing Time and Space Resolved Estimates of Ambient Particulate in Cleveland, OH. Aerosol Science and Technology, 45(9), pp. 1090-1108.

Lee, C., Richter, A., Burrows, J.P., Lee, H., Kim, Y. J., Lee, Y.G., and Choi, B.C., 2008. Impact of transport of sulfur dioxide from the Asian continent on the air quality over Korea during May 2005. Atmospheric Environment, 42(7), pp. 1461-1475.

Li, C.C., Mao, J.T. and Liu, Q.H., 2005. Remote sensing of High Spatial Resolution Aerosol Optical Depth with MODIS Data over Hong Kong. Chinese Journal of Atmospheric Sciences, 29(3), pp. 324-342.

Martin, R., 2008. Satellite remote sensing of surface air quality. Atmospheric Environment, 42(34), pp. 7823-7843.

Tang, J., Xue, Y., Yu, T., and Guan, Y., 2005. Aerosol optical depth determination by exploiting the synergy of Terra and Aqua MODIS. Remote Sensing of Environment, 94(13), pp. 327-334.