OZONE POLLUTION AT THREE FAMOUS SCENIC MOUNTAINS IN CHINA

Pakpong Pochanart*, Hajime Akimoto *, Zifa Wang**
* Frontier Research System for Global Change, Yokohama, Japan (pakpong@jamstec.go.jp, akimoto@jamstec.go.jp)
**Institute of Atmospheric Physics, Beijing, China (zifawang@mail.iap.ac.cn)

ABSTRACT

Rapid industrialization and economic growth in northeast Asia have led to an increase in anthropogenic emissions of air pollutants and greenhouse gases in this region to a level rivaling those of USA or central Europe in the 1990s. Since these emission increases are largely due to rapid development in China and are expected to continue, China will potentially dominate regional and global emissions in the earlier decades of the 21st century. The related problems of air pollution in northeast Asia seem unavoidable. The important concerns of this work are on the regional air pollution from ozone, its trans-boundary transport, and environmental impact in China. While increased numbers of report on air pollutants monitoring in China have been released recently, data from regional sites are not much available. Recently, we have established the ozone observatories at three famous scenic mountains in China, namely Mt. Taishan (36N 117N), Mt. Huashan (34N 110E), and Mt. Huangshan (30N 118E). Despite the remoteness of the sites, the unexpectedly high mixing ratios of ozone have been observed at these Chinese mountain sites as compared to those at other remote mountain sites in northeast Asia. In this study, we present our first data obtained from these monitoring sites.

INTRODUCTION

Regional air pollutions from large-scale anthropogenic sources in East Asia, especially China, and their increasing trend have become a well-recognized problem in recent years [1-2]. To address this issue, key research approaches including modeling, intensive observation campaigns, satellite data analysis, and long-term atmospheric measurements, are considered to be necessary. Previous research programs in East Asia have focused mainly on the intensive observation campaigns and modeling [3-5]. The results from long-term observation have been available largely over the coastal regions of the East Asian Pacific Rim [6-12].

Long-term ground-based observations of air pollution play a critical role in atmospheric chemistry and air pollution research by filling in gaps in the data obtained from modeling, intensive observational campaigns, and satellite images analyses. Results from continuous observations at representative sites can validate models. Continuous observations offer valuable insight into the long-term behavior of air pollution and transport schemes.

However, up to now, such data have neither been much available nor open to public in China, in particular in the inner region the country. This work examines the present regional ozone pollution situation in China based on the data obtained from recently established monitoring sites in remote mountain regions of China.

MONITORING SITES

Three monitoring sites located in mountain regions of China had been established as shown in Figure 1. Despite the relatively remoteness of the sites, these three mountains are very famous scenic spots in China and a large numbers of tourist visit these mountains every year. These mountains are also located in high emission areas of China as can be noticed from the anthropogenic NOx emission inventory map in Figure 1. The geographical locations of the monitoring sites are listed in Table 1. We stated monitoring ozone at Mt. Taishan in spring 2003 and subsequently at Mt. Huashan and Mt. Huangshan in spring 2004.

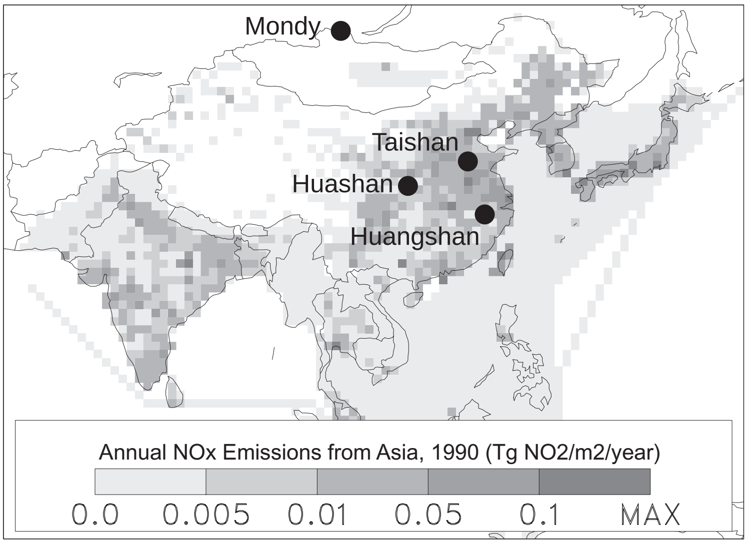


Figure 1. Locations of the three mountain sites in China, shown together with the annual NOx emissions for 1990 [13].

Table 1.

Region	Sites	Location			Provinces	Observation period
		Latitude	Longitude	Elevation (m asl)		
China	Mt. Taishan	36º15N	117º 07E	1524	Shandong	From 2003/03
	Mt. Husahan	34º 20N	110º 05E	2065	Shaanxi	From 2004/05
	Mt. Huangshan	30º 10N	118º11E	1841	Anhui	From 2004/03
Siberia	Mondy	51º 39N	100º 55E	2006		From 1996/06

Geographical locations of the three mountain sites in China as compared to background station in Siberia

INSTRUMENTS

The commercial UV absorption analyzers have been used at the three sites. At Taishan and Huashan, two TECO Model 49 have been used. At Huangshan, a Dylec Model 1010 has been used. The instrumental systems and monitoring criteria for O_3 in this study are similar to those at other monitoring sites in East Asia. Details regarding O_3 measurement, calibration, regular maintenance and data handling have been reported elsewhere [6-8].

DATA AVAILABILITY

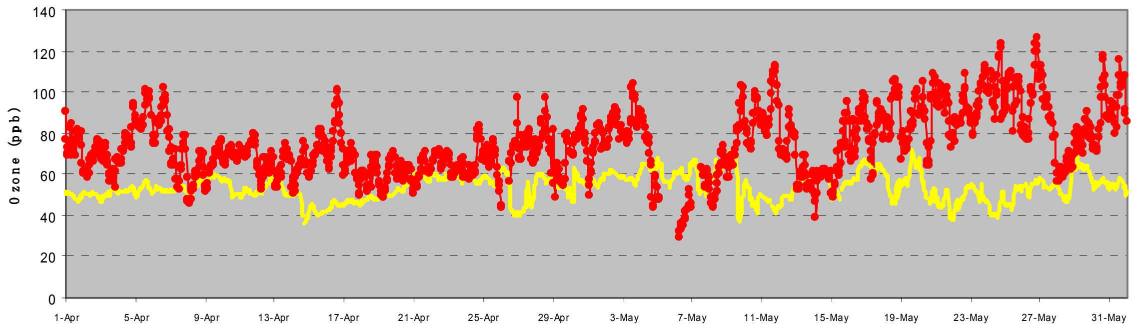
The initial plan of the project was to complete all monitoring set up within 2003 year. We began with setting up of ozone monitoring at Mt. Taishan in spring 2003. However, after this monitoring project started, the plan was delayed by several obstacles. These problems, both technical and non-technical, include the related troubles from SARS which halted almost all of our research activities during spring and early summer of 2003. Another serious problem was an instrument breakdown after 4 months of operating due to a “flooding” inside instrument by unidentifiable sources of water. As a result, the overall schedule of the project was revised and this delayed all the set up of Mt. Huashan and Mt. Huangshan to spring 2004. At present, only springtime data in 2003 are available at Mt, Taishan and the data from spring 2004 are available at the three sites.

SPRINGTIME OZONE IN CHINA

Figure 2 shows the springtime ozone in 2003 and 2004 at our monitoring stations. We also compared Chinese data with the ozone data obtained at background mountain station, Mondy in eastern Siberia. It can be clearly seen that the Chinese data exhibited higher ozone mixing ratios for both spring of 2003 and 2004. Temporal variations at these Chinese sites are also more vigorous than ozone variations at Mondy.

During April-May 2003, the averaged ozone mixing ratio at Taishan is 74.6±15.8 ppb whereas the averaged mixing ratio at Mondy is 53.9±6.4 ppb. The springtime averaged ozone mixing ratios are slightly lower in 2004, 61.8±14.7 and 62.6±14.2 ppb at Taishan and Huangshan, respectively (unfortunately, we lost data at Huashan due to communication failure between instrument and data logger). Meanwhile, the averaged springtime mixing ratio of ozone at Mondy is slightly higher in 2004, 56.7±8.9 ppb.

Considering that the ambient air quality standard for China (environmental level) is 60 ppb, we found that in overall 65% of our data show mixing ratios that exceed the ambient standard, meaning that approximately in one day, the ambient standard has been exceeded for sixteen hours on average. Especially, at Taishan in 2003 the exceeded hours are higher than 80% of the total observation period. At Mondy, only 20% of springtime ozone data exceed 60 ppb. These springtime ozone mixing ratios at Taishan and Huangshan are clearly higher than those data observed at other remote boundary layer and mountain sites in East Asia [7, 14].



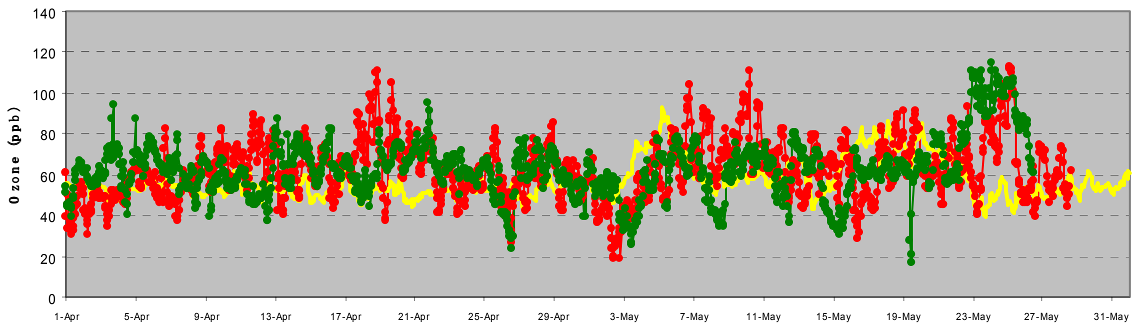


Figure 2. Time series plots of 1 hr averaged ozone mixing ratios at Taishan (Red), Huangshan (Green), and Mondy (Yellow) during April and May. The upper and lower panels show data in 2003 and 2004, respectively.

From Figure 2, the relative good day-to-day variations of ozone mixing ratios are observed at Taishan and Huangshan. This simultaneous changes suggest that regional pollution and long range transport are the important factors controlling ozone behaviors at these sites whereas local pollution is also thought to affect these ozone variations.

The seasonal cycles of ozone mixing ratios at the remote sites near the coastal regions of East Asia are strongly influenced by East Asian monsoon. As illustrated in Figure 3, from winter to spring, the Siberian High and its associated westerly continental outflow from Eurasia dominates this region [6, 15-16]. In contrast, during summer surface high-pressure systems associated with the Pacific anticyclone bring low ozone oceanic air masses to East Asia. Thus, ozone seasonal cycles in the remote sites in the coastal region of East Asia usually show the spring maximum and frequent ozone pollution episodes are often observed in spring. However, this may not be the case for the inner region of China. As also noticed in Figure 3, influences of the oceanic air are weaker in the inner region (Huashan) than in region closer to the coastal area (Huangshan). The very active photochemistry in summer could play more critical role in such regions. Although we have not yet obtained data in summer 2004, the four months ozone data at Taishan in 2003 show the maximum in June, a similar characteristic to the ozone seasonal cycle at GAW station, Mt. Waliguan in western China [10]. These seasonal variations of ozone in China are of interest and need further investigation as high spring –summer mixing ratios of ozone could have direct impact on global warming, natural environment change, agricultural production loss, and human health. For example, considering potential agricultural production loss due to ozone pollution, we found the 3-month AOT40 ozone exposure index[1] at Taishan in 2003 more than 10 times higher than a provisional threshold level validating the previous results from model studies regarding potential agricultural loss in China [17].

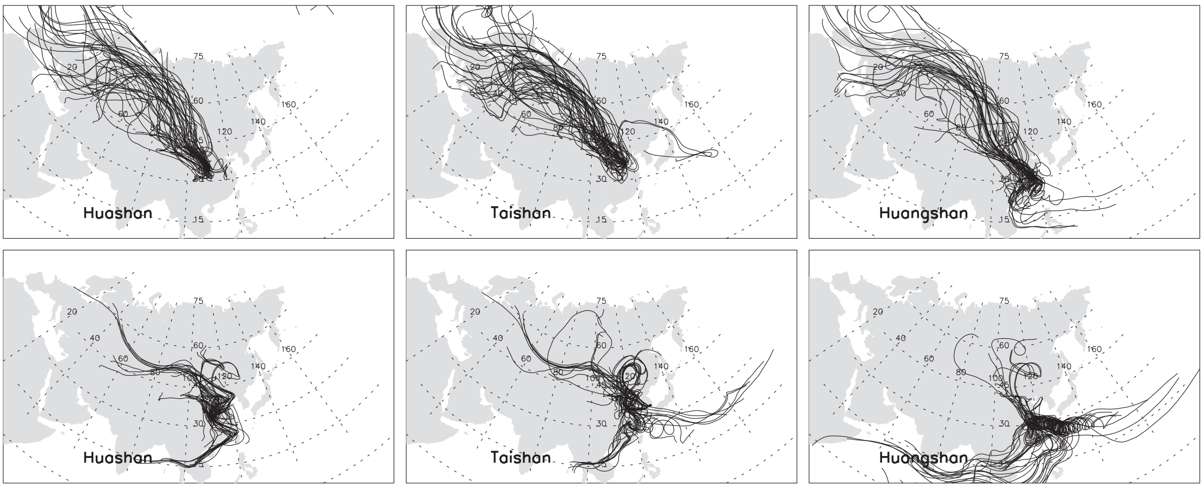


Figure 3. Climatology at the three mountain sites revealed by backward air mass trajectories. The upper panels are the examples of spring (April) and the lower panels are the examples of summer (August).

SUMMARY

Although this research project has just been initiated and we could show only the preliminary results and analysis at present, more complete data are expected soon. With the upcoming data from these three remote mountain sites in China, we hope that the situation of ozone pollution in regional view, its trans-boundary transport, and its environmental impact in China will be elucidated in the near future.

[1] AOT40 is the accumulated exposure over a threshold of 40 ppb. A traditional index use to evaluate the potential damage to plants by ozone. Although it is widely discussed now that a more appropriate exposure (or next generation) index should be based on ozone flux rather than mixing ratios, AOT40 is still practically in use in many literature.

REFERENCES

1. Streets DG, Tsai NY, Akimoto H, Oka K (2002) Water, Air and Soil Pollution 130:187
2. Naja M, Akimoto H, Staehelin J (2003) J Geophys Res 108:doi:10.1029/2002JD002477
3. Hoell JM, Davis DD, Liu SC, Newell R, Shipham M, Akimoto H, McNeal RJ, Bendura RJ, Drewry JW (1996) J Geophys Res 101:1641
4. Hoell JM, Davis DD, Liu SC, Newell RE, Akimoto H, McNeal RJ, Bendura RJ (1997) J Geophys Res 102:28223
5. Jacob DJ, Crawford JH, Kleb MM, Connors VE, Bendura RJ, Raper JL, Sachse GW, Gille JC, Emmons L (2003) J Geophys Res 108:doi:10.1029.2002JD003276
6. Pochanart P, Hirokawa J, Kajii Y, Akimoto H, Nakao M (1999) J Geophys Res 104:3621
7. Pochanart P, Akimoto H, Kinjo Y, Tanimoto H (2002) Atmos Environ 36:4235-4250
8. Tanimoto H, Kajii Y, Hirokawa J, Akimoto H (2000) Geophys Res Lett 24:4073
9. Chameides WL et al. (1999) Geophys Res Lett 26:867
10. Luo C, St. John JC, Zhou X, Lam KS, Wang T, Chameides WL (2000) J Geophys Res 105:1889
11. Cheung VTF, Wang T (2001) Atmos Environ 35:4957
12. Wang T, Cheung VTF, Anson M, Li YS (2001) Geophys Res Lett 28:2373-2376
13. Carmichael GR (2003) http://www.cgrer.uiowa.edu/people/carmichael/Carmichael.html
14. Pochanart P, Akimoto H, Kajii Y, Potemkin VM, Khodzer TV (2003) J Geophys Res 108:doi:10.1029/2001JD001412
15. Ogawa T, Miyata A (1985) J Meteorol Soc Jpn 63:937-946
16. Tsuruta H, Shinya K, Mizoguchi T, Ogawa T (1989) Seasonal behavior of the tropospheric ozone in rural Japan. In: Bojkov RD, Fabian P (eds) Ozone in the atmosphere. Deepak, Hampton, p 433
17. Aunan K, Berntsen TK, Seip HM (2000) Ambio 29:1157