Asia-Pacific Network for Global Change Research

Asian Ozone Pollution in Eurasian Perspective

Final report for APN project: ARCP2006-05CMY-Akimoto

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Asian Ozone Pollution in Eurasian Perspective

Project Reference Number: ARCP2006-05CMY-Akimoto

Final Report submitted to APN

Overview of project work and outcomes

Non-technical summary

The project aiming at elucidation of Asian ozone pollution in Eurasian perspective consists of collaborators from Japan (two including PI), China (one), India (three) and Malaysia (one). Three workshops were organized at Beijing/China, New Delhi/India and Yokohama/ Japan. The first two workshops/seminars were participated by many young scientists in each country and contributed to capacity building in the research field of atmospheric chemistry. Each workshop was followed by a visit to one of monitoring stations of each country. Data compilation of selected rural/remote ozone monitoring stations in each participating countries for a selected year was made and the prepared database is shared by the collaborators of the project. Synthesis report on rural/remote ozone in each country was submitted to the project. Model analyses using a regional and global chemical transport models were made.

Objectives

The main objectives of the project were:

1. to compile the surface ozone data at selected rural/remote sites in Asia in selected years including China, India , Japan, and Malaysia,
2. to synthesize the compiled observational data to elucidate spatial and seasonal variability in Asia,
3. to evaluate inter-continental transport to Asia and intra-continental transport of ozone in Asia with a chemical transport model,
4. to organize three workshops on Asian ozone pollution in China, India and Japan, and visit selected remote/rural ozone monitoring sites in China, India, Malaysia and Japan.

Amount received and number of years supported

2005/06: USD 40,000

2006/07: USD 37,000

Activity undertaken

(1) Workshops/Seminars and visit to monitoring stations

1) Kick-off Planning Meeting: August 3, 2005 (during IAMAS 2005)
Venue: International Convention Center, Beijing
Participants: H. Akimoto, S.L. Jain, J. Tang and other Chinese scientists

2) The 1st workshop and visit to monitoring station: November 21-22, 2005
Workshop/seminar: Peking University in Beijing
Number of participants: 32
Visit to monitoring station: Shangdianzi, one of Chinese WMO/GAW station near Beijing
Participants: All the collaborators of the project

3) Visit to institutions and monitoring stations: February 13-19, 2006
Visit to India: February 13-16, 2006
Institution: National Physical laboratory in New Delhi
Monitoring Station: Mt. Abu, a mountain site near Ahmedabad,
Visit to Malaysia: February 17-19, 2006
Institution: Malaysian Meteorological Service in Petaling Jaya
Monitoring station: Tanah Rata, a remote observational site at Cameron Hill in the central part of Malaysian Peninsula
Participants: H. Akimoto (Project leader), P. Pochanart (collaborator)

4) The 2nd workshop and visit to monitoring station: October 30-November 2, 2006
Workshop/seminar: National Physical Laboratory in New Delhi

Number of participants: 54
Visit to monitoring station: Darjeeling, a rural site on the foothill of Himalayan mountains in the northeast of India
Participants: All the collaborators of the project

5) The 3rd workshop and visit to monitoring station: April 16-18, 2007
Workshop: Frontier Research Center for Global Change/Japan Agency for Marine-Earth Science and Technology in Yokohama
Number of participants: 15
Monitoring Station: Cape Hedo in Okinawa Is., a Japanese super site for atmospheric chemistry and physics observation
Participants: All the collaborators of the project

(2) Compilation and Synthesis of surface ozone data in remote/rural stations in Asia

1) Data compilation

The data from the following stations has been compiled and distributed to collaborators.

Japan: Rishiri, Happo, Oki, Hedo, Minami-torishima
China: Waliguan, Shangdianzi, Lin'an; Hok Cui (Hong Kong)
Mt. Tai, Mt. Huang, Mt. Hua
India: Darjeeling, Mt Abu
Malaysia: Tanah Rata
Others: Mondy (Siberia/Russia), Issyk-Kul (Kyrgyz)

2) Synthesis report

The following synthesis reports has been submitted to the project

Japan report (P. Pochanart)
China report (T. Wang/J. Tang)
India report (S. Lal/T.K. Mandal)
Malaysia report (F.S. Lim)

(3) Model Analysis

1) Analysis of the seasonal variation of ozone in the boundary layer in East Asia using the Community Multi-scale Air Quality Model (CMAQ)
2) Analysis of intercontinental transport of ozone using the global chemical transport model (CHASER)

Results

(1) Workshops and Data Submission/Synthesis

The workshops in China and India had a characteristic of seminars on Asian ozone pollution for young scientists in each country and attracted about 35and 55 participants, respectively. The workshop in Beijing was the first opportunity for Asian scientists from East (China, Japan), Southeast (Malaysia) and South (India) Asia, studying tropospheric ozone in a regional/hemispherical perspectives got together for the first time. The first workshop provided the information on a present status of surface ozone monitoring at rural/remote sites in each participating countries, identified the issue and defined the scope of this project. The collaborators of the project reached a conclusion that the major focus of this project should be the synthesis of surface ozone data in Asia to obtain the overview of the Asian regional ozone pollution, and agreed to submit surface ozone data at selected rural/remote sites in each country for the selected period. It was decided that the preferred period of data to be submitted is to cover the year of 2005 although other years' data is also acceptable whenever the 2005 data is not available. The selected sites were Rishiri, Oki, Cape Hedo in Japan (EANET), Shangdianzi and Waliguan in China (CMA/WMO GAW), Mt. Tai, Mt. Huang and Mt. Hua in China (FRCGC), Darjeeling (NPL) and Mt Abu (PRL) in India, and Tanah Rata in Malaysia (MMS).

The third workshop in Japan was the final workshop for summarizing the project, and the project leader presented an overview report of variability of seasonal change of ozone for different part of the whole Asian region based on the submitted and pre-existing data from journal papers. All the above-agreed data have been submitted to the project and the compiled data will be circulated soon among the collaborators. The collaborators from Japan, China, Indian and Malaysia submitted

synthetic reports on the ozone variability in each country, which are incorporated into the final report of this project.

(2) Visit to monitoring stations
It should be stressed that visiting and seeing monitoring sites by his/her own eyes are very important for the use of data in order to capture the geographical characteristics of the station and credibility of data quality. However, usually it is not easy to make an arrangement of visiting the site particularly in foreign countries. In the present APN project, visit to each one of rural/remote site in each country on the occasion of workshop in China, India and Japan has been made. The characteristics of the visited sites are as follows. Shangdianzi, a rural site near Beijing is one of Chinese WMO/GAW regional station. Darjeeling, a rural site on the foothill of Himalayan mountains in the northeast of India, is now under development for one of key stations in India in near future. Cape Hedo at the northern tip of Okinawa Island in Japan is a remote marine site, which has recently been established by National Institute for Environmental Studies (NIES) as a Japanese "super site," and integrated observation of gaseous species and chemical and physical properties of aerosols are underway.

In addition to these three sites, the project leader and the collaborator in Japan had a chance to visit Mt Abu in India and Tanah Rata in Malaysia under the project. Mt. Abu is a remote mountain site near Armedabad in India, whose ozone data has been well analyzed and published in international journals. Tanah Rata is a remote observational site at Cameron Hill in the central part of Malaysian Peninsula, and has been registered as a Malaysian WMO/GAW regional station. Thus, the visited stations are all thought to be important sites for future analysis of regional ozone pollution.

(3) Model analysis of Asian regional ozone pollution
Using the dataset of Regional Emission Inventory in Asia (REAS) developed in Frontier Research Center for Global Change (FRCGC) [Ohara et al, 2007], analysis of the seasonal variation of ozone in the boundary layer in East Asia using the Community Multi-scale Air Quality Model (CMAQ) has been conducted. The regional scale model has been validated by the observational data of surface ozone obtained from EANET (Acid Deposition Monitoring Network in East Asia). The model could reproduce successfully seasonal variation of surface ozone for these stations in East Asian Pacific rim region. Controlling factors of ozone concentration around Japan have been analyzed by the model. The importance of contribution of ozone from outside region of East Asia was identified. The contribution of ozone to Asia from Europe, North America and other part of the world has been analyzed by using the "tagged" method by a global chemical-transport.

Relevance to APN's Science Agenda and objectives

This proposed project falls in the category of "Changes in Atmospheric Composition" under the APN Areas of Scientific Interest. Although tropospheric ozone increase in Asia has not called an attention as much as acid rain as a regional environmental issue so far, it has been pointed out that ozone pollution is much more immediate issue since "critical levels" of ozone exposure for vegetation has already well exceeded in various parts of Asia. However, regionally representative ozone data in Asia are still very scarce and not well compiled and publicized. The activity of the present project would be very useful for the analysis of trans-boundary air pollution in Asia as well as hemispherical transport of air pollution in the northern hemisphere, which meets well with the science agenda of APN.

Self evaluation

The proposed objectives of the project have successfully been accomplished. Particularly, compilation and synthesis of the targeted ozone data in the participating countries has been completed, and database and synthesis report have been prepared in the project. Workshops/seminars were very successful particularly in China and India in the sense that it promoted the project and also attracting many

young scientists to the regional/hemispherical ozone issue. It can be stressed that the visits to monitoring stations in China, India, Japan and Malaysia were very unique activity of this project and have significant potential impact for the future collaboration between scientists in this research field. Since modelers are not included as a collaborator of the project, necessary model analysis has been conducted in FRCGC collaborating with other project, and outputs were provided to this project. Strategic discussion for reduction of regional ozone in Asia considering the inter-and intra-continental transport has been left for future activity.

Potential for further work

Since the scientific as well as policy relevant interest on tropospheric ozone increase in Asia has been accelerated, further modeling study using the compiled data and synthesized knowledge in this project should be useful for future strategic discussion to mitigate ozone pollution in Asia. Particularly, transboundary transport within Asia and intercontinental transport in a hemispherical scale are of much concern in policy makers. For example, Task Force on Hemispherical Transport of Air Pollution (TF-HTAP) has been established under Convention for Long Range Transport of Air Pollution (CLRTAP). Although none of Asian countries has been included in this Convention, collaborating project participated by both Asian and North American scientists could be conceived as one of future APN projects.

Publications

(1) Non peer-reviewed documents

Abstracts of Workshpos/Seminars

Abstracts for the 1st Symposium on Asian Ozone Pollution in Eurasian Perspective, the APN Project Workshop/Seminar, Beijing November 21-22, 2005.

Abstracts for the 2nd Symposium on Asian Ozone Pollution in Eurasian Perspective, the APN Project Workshop/Seminar, New Delhi, November 21-22, 2006.

Abstracts for the 3rd Symposium on Asian Ozone Pollution in Eurasian Perspective, the APN Project Workshop/Seminar, Yokohama, April 21-22, 2007.

(2) Peer-reviewed paper

Yamaji, K., T. Ohara, I. Uno, H. Tanimoto, J. Kurokawa, and H. Akimoto, Analysis of the seasonal variation of ozone in the boundary layer in East Asai using the Community Multi-scale Air Quality Model: What controls surface ozone levels over Japan? Atmos. Environ.,40, 1856-1868, 2006.

Sudo K. and H. Akimoto, Global source attribution of tropospheric ozone: Long-range transport from various source regions, J. Geophys. Res., 112, D12302, doi:10.1029/2006JD007992, 2007.

References

Ohara, T., H. Akimoto, J. Kurokawa, N. Horii, K. Yamaji, and T. Hayasaka, An Asian emission inventory of anthropogenic emission sources for the period 1980-2020, Atmos. Chem. Phys. Discuss., 7, 6843-6902, 2007.

Acknowledgments

The project leader acknowledges very much to outside scientists in China, India and Japan who participated and gave high quality presentations at each workshop/ seminar as well as local organizers and assistant persons. Particular thank is for Hanako Shiomi at FRCGC who devoted herself to overall management of the project fund and accounting. We also thank to local staffs of the monitoring stations at Shangdianzi and Darjeeling, and Dr. Shimizu at NIES who guided us to Cape Hedo station.

Technical Report

Preface

Photochemical ozone pollution is getting more important regional environmental issue in various parts in Asia. However, regionally representative ozone data has not been well publicized yet. This project compiles observational data of surface ozone at remote and rural sites in Asia. The integrated dataset will illustrate the overview of ozone pollution in Asia, and synthesis of the data will be attempted in this project. International workshops are organized in China, India and Japan for the discussion of data compilation/analysis. Educational lectures will be included in two of the workshops in China and India for capacity building of young scientists. Visits to actual rural/remote monitoring sites of surface ozone in each country will be organized in conjunction with the three workshops.

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1.0 Introduction

Tropospheric ozone is the third important greenhouse gas (IPCC, Climate Change 2001) and ozone near the surface is a toxic gas to human health and vegetation. Importance of ozone pollution in Asia in a global perspective starts calling more attention both from the climate and environmental point of view since the total emission of air pollutants from Asian continent has recently exceeded those from North American and European continents (Akimoto, 2003). Surface ozone level has been increasing in the last couple of decades in many parts of Asia. The concentration levels often exceeded "critical level" for agricultural and natural ecosystems according to the European or American evaluation indices although such an index has not been developed in Asia yet. It is predicted that surface ozone levels in Asia will further increase in next decades due to the continuing increase of emissions of ozone precursors accompanying with economic development and population increase in this region.

Due to relatively long lifetime of tropospheric ozone, the issue is characterized by transboundary nature and international agreement will be the must to solve the problem. At this point, howerver, it should be emphasized that only considering the intracontinental transport in Asia alone is not enough to solve the issue, but intercontinental transport of ozone from Europe and North America over Eurasian continent to Asia should also be taken into account since the ozone pollution is now known as a hemispherical issue. For example, Task Force on Hemispherical Transport of Air Pollution (TF-HTAP) has been established under Convention on Long Range Transport of Air Pollution (CLRTAP). In this context although fair amount of discussions have been made on Asian influence to North America and North American influence to Europe, European and North American influence to Asia has rarely been discussed. Therefore, the purpose of the present APN project is to obtain

surface ozone data in Asia collaborating with existing networks, and to compile as a database for the discussion of regional ozone pollution. The dataset will be analyzed with an aid of global and regional chemical transport modeling to provide scientific base for future ozone control policy in Asia including both developed and developing countries in the northern hemisphere.

2.0 Methodology

2.1 Proposed scientific approach and policy relevance

Observational data of ozone pollution in Asia has not yet been compiled for obtaining views in whole Asian and Eurasian perspectives. This project concerns with continuous data of surface ozone concentrations at selected remote and rural sites in Asia. As for remote mountain sites, data at Waliguan (WMO/GAW) in China, Mt. Abu in India, Tanah Rata in Malaysia (EANET), Mondy in Russia and Happo (EANET) in Japan will be compiled. Mountain sites data in regionally polluted area at Mt. Tai, Mt. Hunag and Mt. Hua in China will be provided by the proponent group. Ozone data at remote and rural sites at near sea level will include those at Shandianzi, Lin'an and Hok Cui (WMO/GAW sites) in China as well as those at Minami-torishima, Yonaguni, Ryori (WMO/GAW), and Rishiri, Oki, and Cape Hedo (EANET) in Japan. The compiled data will be analyzed and evaluated by collaborators of the project in each national level and also overviewed in Asian scale.

Using the dataset of Regional Emission Inventory in Asia (REAS) developed in Frontier Research Center for Global Change (FRCGC) [Ohara et al, 2007], model analysis will be made with the Community Multi-scale Air Quality Model (CMAQ) for seasonal characteristics of surface ozone in East Asia. Further, model analysis by using a global chemical transport model, CHASER, conducted in another project will be provided to elucidate the contribution of ozone in Asia from Europe and North America and other part of the word demonstrating the importance of inter-continental transport.

These activities in the present project provides scientific database and understanding of the importance of ozone pollution issue in Asia, which start attracting growing policy concern such as Task Force for Hemispherical Transport of Air Pollution (TF-HTAP) under CLRTAP.

2.2 Workshops and capacity building

One planning meeting at the beginning, and three international workshops will be organized during the project. The workshops will be held in Beijing/China, New Delhi/ India and Yokohama/Japan. In order to enhance capacity building and to help understanding of the importance of this issue in Asia, seminar calling for young scientists will be included in the 1st and 2nd workshops in Beijing and India.

Visit to rural/remote observational sites for surface ozone will be made on the occasion of workshop in China, India and Japan. In China, the visiting site is Shangdianzi, a rural site near Beijing which is one of Chinese WMO/GAW regional station. In India, Darjeeling, a rural site on the foothill of Himalayan mountains in the northeast of India, will be visited. In Japan, a remote marine site at Cape Hedo at the northern tip of Okinawa Island is selected, where integrated observation of gaseous species and chemical and physical properties of aerosols are underway. In addition to these three sites, the project leader and the collaborator in Japan will visit Mt. Abu in India and Tanah Rata in Malaysia. Mt. Abu is a remote mountain site near Armedabad in India whose ozone data has been well analyzed and published in international journals. Tanah Rata is a remote observational site at Cameron Hill in the central part of Malaysian Peninsula, and has been registered as a Malaysian WMO/GAW regional station.

3.0 Results & Discussion

Tropospheric ozone has been known to increase since the early decades of the last century. Historical data show that the ozone increases matching well with the anthropogenic emission trends in the US and Europe. While these regions are now showing stabilized or decreasing trends of O3 accompanying the regional NOx emission trends, historical data from East Asia show the increasing trends of ozone and its precursors (Naja and Akimoto 2004). This increase is mainly attributed to the rapid increase of anthropogenic emission resulting from the rapid industrialization and economic growth in Asia. It is widely accepted nowadays that ozone pollution problem has extended from urban and local scales to regional and continental scales, and potentially have impact on both domestic and international level in East Asian countries. The purpose of the present APN project is to synthesize the surface ozone data in Asia collaborating with existing network. In order to gain insight information on the ozone pollution in Asia, ozone datasets from representative site from various sites over Asia have been collected, complied, and analyzed.

3.1 Data Analysis

3.1.1. Variability of surface ozone data in Japan (prepared by P. Pochanart)

3.1.1.1. Availability of ozone data sources

In this section, the ozone datasets from Japan are reported. Comparing with other regions in Asia, more comprehensive dataset of ozone have been available in Japan. In this report, we have used Year 2004 as our base year.

Surface ozone dataset in Japan could be gained from four main sources.

(1) Oxidant database from Environmental Information Center, National Institute of Environmental Studies

This is the largest source of oxidant data in Japan. The oxidant data are collected from more than 2100 air quality monitoring stations over Japan. These air quality monitoring stations are managed by local prefecture offices and Environment Agency. It is also the longest available database which could be dated back to 1970s. Most of the stations monitor directly oxidants, of which the majority component is ozone. Among 2100 air quality monitoring stations, approximately 1200 stations from 18 prefectures provide hourly averaged data, and about 30 stations are in the remote areas of Japan that could be regarded as national stations. The oxidant datasets are available upon request made directly to Environmental Information Center, National Institute of Environmental Studies. However, we did not use this datasets in this project since the monitoring sites are of mostly urban type.

(2) EANET (Acid Deposition Monitoring Network in East Asia)

The datasets are available from ambient air measurements from several countries in East Asia. Since the major components targeted by EANET are wet deposition, ozone is not a main species to be monitored. Nevertheless, from Year 2000, around 16 stations in EANET member countries provide ozone data, most of them from Japan. These ozone datasets are available upon request to EANET or Acid Deposition and Oxidant Research Center (ADORC) in Japan. In this work, we have used ozone datasets from four stations provided by EANET, e.g. Rishiri, Happo, Oki, and Hedo (see Table 1).

(3) WMO/GAW – WDCGG (World Data Centre for Greenhouse Gases)

WDCGG provides representative ozone dataset from all over the world. The data are submitted from the Global Atmospheric Watch (GAW) program and meteorological agencies in each country to WMO. Data could be classified to several categories based on the location of the monitoring sites and could be accessed directly from WDCGG web site. In addition, though not much, some information on surface ozone are available at WOUDC (World Ozone and Ultraviolet Radiation Data Centre) as well. In Asia, the ozone datasets in global and regional categories from WDCGG are available for 7 stations. The periods of available datasets vary among sites but mostly from 1990s. Data from WDCGG appear to be of high quality and representative. In this APN project we have selected 3 of WDCGG stations, one of them, Minamitorishima, is a remote Japanese island in the Pacific Ocean.

(4) Individual research groups.

This is the most varied information sources of ozone in Asia. The data sources, ozone monitoring sites, and data availabilities are varied. Most information could be

obtained from publications, news, academic meeting and conferences, institute/personal/project websites, and direct contact to each individual research group. Most of the data collections have been done as the parts of scientific works. Thus, the data appear to be of reliable quality. However, most of the ozone dataset are not open to public but available upon direct request. There is often limitation of the data access due to several factors including the funding authorities, institutional regulation, authorship concerns and the unpublished status of the datasets. In this report, we have not applied dataset from this source for the ozone dataset in Japan. However, our group (Atmospheric Composition Research Program of Frontier Research Center for Global Change) has provided ozone dataset from three sites for China and one site for Siberia region.

3.1.1.2 Ozone dataset in this work

Datasets for Japanese stations are total five, four from EANET (Rishiri, Happo, Oki, Hedo) and one from WDCGG (Minamitorishima). Base year for this study is year 2004. Data have been checked and complied into the same format and is open for every APN project collaborators. The geographical locations of the stations are shown in Figure 1 and Table 1.

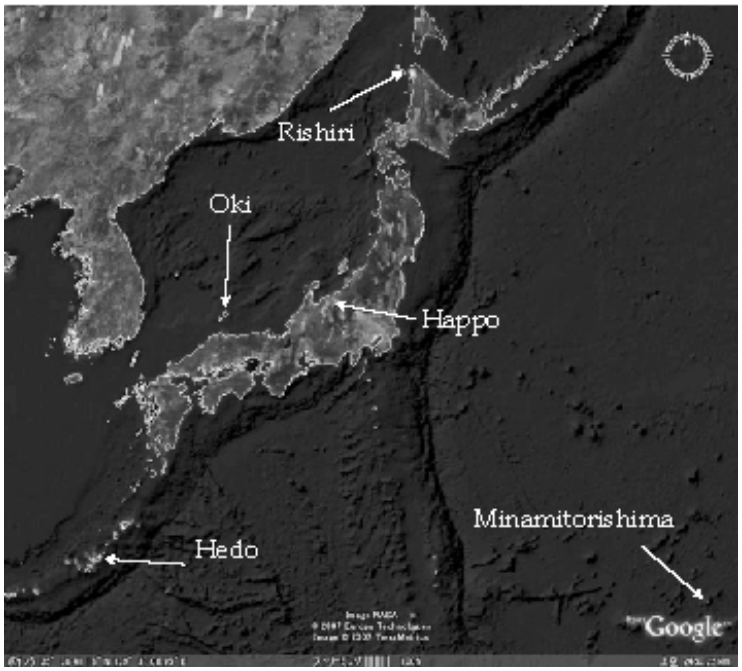


Figure 1 Locations of Japanese sites

Table 1 Locations of ozone monitoring sites in Japan for this APN project.

Station	Latitude	Longitude	Elevation	Provider
Rishiri	45 07N	141 12E	35 m asl	EANET
Happo	36 41N	137 48E	1840 m asl	EANET
Oki	36 17N	133 11E	90 m asl	EANET
Hedo	26 50N	128 15E	60 m asl	EANET
Minamitorishima	24 17N	153 59E	8 m asl	WDCGG

3.1.1.3. Seasonal cycles

The seasonal cycles of ozone at these five stations in 2004 are shown in Figure 2. In addition, ozone seasonal cycle at Eurasian background site, Mondy, is also presented. The monthly averaged ozone concentrations are shown in Table 2. All Japanese sites reveal spring maximum and summer minimum, similar to those previously reported at other boundary layer sites in Japan (Sunwoo et al., 1994; Pochanart et al., 2002). It is noted that the differences of ozone concentrations among sites are lowest during winter (Dec-Feb). The averaged wintertime O_3

concentrations at Rishiri, Oki, and Minamitorishima are 42-43 ppb while slightly higher wintertime O_3 concentrations, 46 ppb, are observed at Hedo. The highest wintertime O_3 appears at Happo, 53 ppb. In comparison, the averaged wintertime at Mondy is 42 ppb, same level as Rishiri, Oki, and Minamitorishima. The higher wintertime O_3 concentrations at Hedo and Happo are thought to be from the stronger influence of large-scale anthropogenic emissions in East Asia, in addition to the higher elevation for Happo.

The increase of springtime O_3 is more pronounced at the higher latitudes sites (Rishiri, Happo, and Oki). The averaged springtime (Mar-May) O_3 at Rishiri, Happo, and Oki are 55, 57, and 69 ppb, respectively. The lower springtime averaged O_3 concentrations are observed at Hedo and Minamitorishima, 34-35 ppb in average, due to the influence of marine air mass that prevails earlier than at the higher latitude sites. The large daily O_3 fluctuations that are observed at Hedo and Minamitorishima in April are results of the air mass exchange between high O_3 in polluted continental air mass from Asia and low O_3 in marine air mass from the Pacific Ocean. The springtime ozone level at Eurasian background site, Mondy, is 54 ppb.

Table 2 Annual and monthly averaged ozone concentrations from Japanese sites

Sites	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Rishiri	41	48	53	55	**58**	42	32	**31**	37	41	38	39	43
Happo	49	58	64	**74**	71	59	49	**46**	47	52	51	52	56
Oki	40	47	52	**61**	57	47	34	**33**	41	43	44	39	45
Hedo	46	**47**	35	38	28	21	**9**	14	15	41	49	44	32
MTS[1]	42	**47**	41	27	36	22	18	**13**	24	28	31	38	31
Mondy	42	45	48	53	**61**	46	42	42	39	41	40	**38**	45

[1] MTS = Minamitorishima, bold numbers indicate monthly maximum and minimum. Unit in ppb.

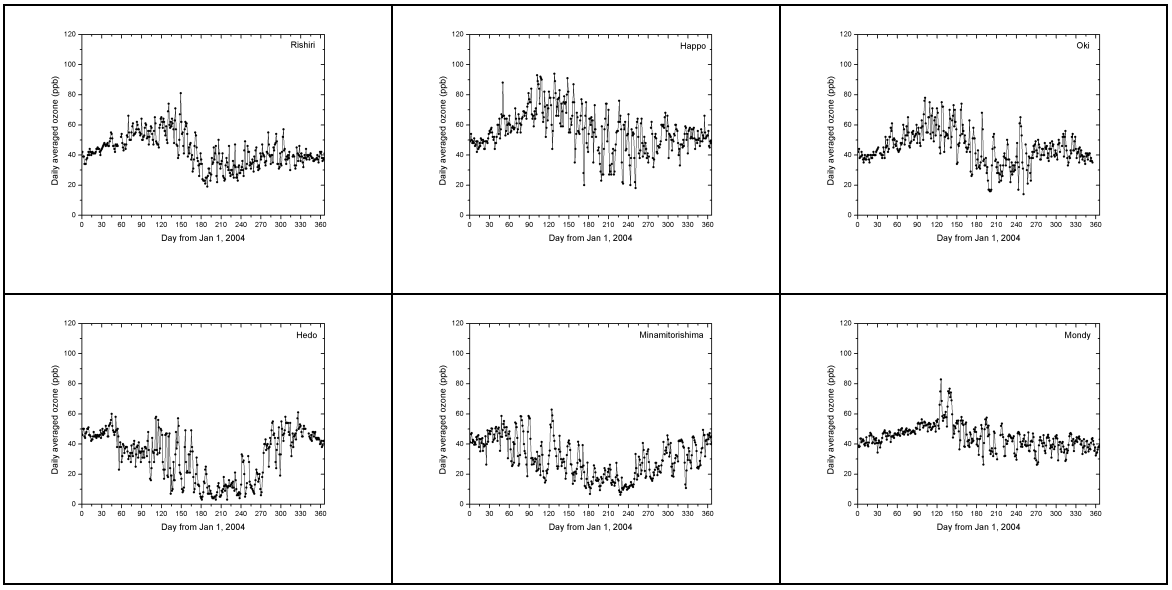


Figure 2 Seasonal cycles of ozone at five representative sites in Japan (Rishiri, Happo, Oki, Hedo, Minamitorishima) in comparison with the Eurasian background site in Siberia (Mondy) in 2004.

Decreases of O_3 at all sites in summer are mainly due to the long-range transport of marine air masses as previously mentioned. The summer drops of O_3 are more evident at Hedo and Minamitorishima, which are the lower latitude sites in the sub-tropical region. The summertime (Jun-Aug) averaged O_3 at Hedo and Minamitorishima are 15 and 18 ppb, respectively. The higher summertime O_3 concentrations at Rishiri, Happo and Oki, 35, 51 and 38 ppb, respectively, are mainly due to the sub-regional scale pollution from Japan (Pochanart et al., 1999). These seasonal O_3

concentrations are similar to the previously reported literature (Pochanart et al., 2002).

3.1.1.4 Diurnal cycles

The monthly diurnal cycles of O_3 at Rishiri, Happo, Oki, and Hedo are shown in Figure 3. The ozone diurnal cycles at Minamitorishima resemble those of Hedo and are not shown here. The differences between averaged hourly maximum and minimum at each site are shown in Table 3.

Diurnal variations of ozone at any location are the indicators showing whether the observatory site represents the local, regional or true remote site, or is the interface of local, regional and remote regions. For Hedo and Minamitorishima, the absence of strong diurnal cycles in most seasons except spring indicates that the local photochemistry and in situ O_3 production is not significant, and that long-range transport of ozone is the major factor dominating ozone variations. The diurnal

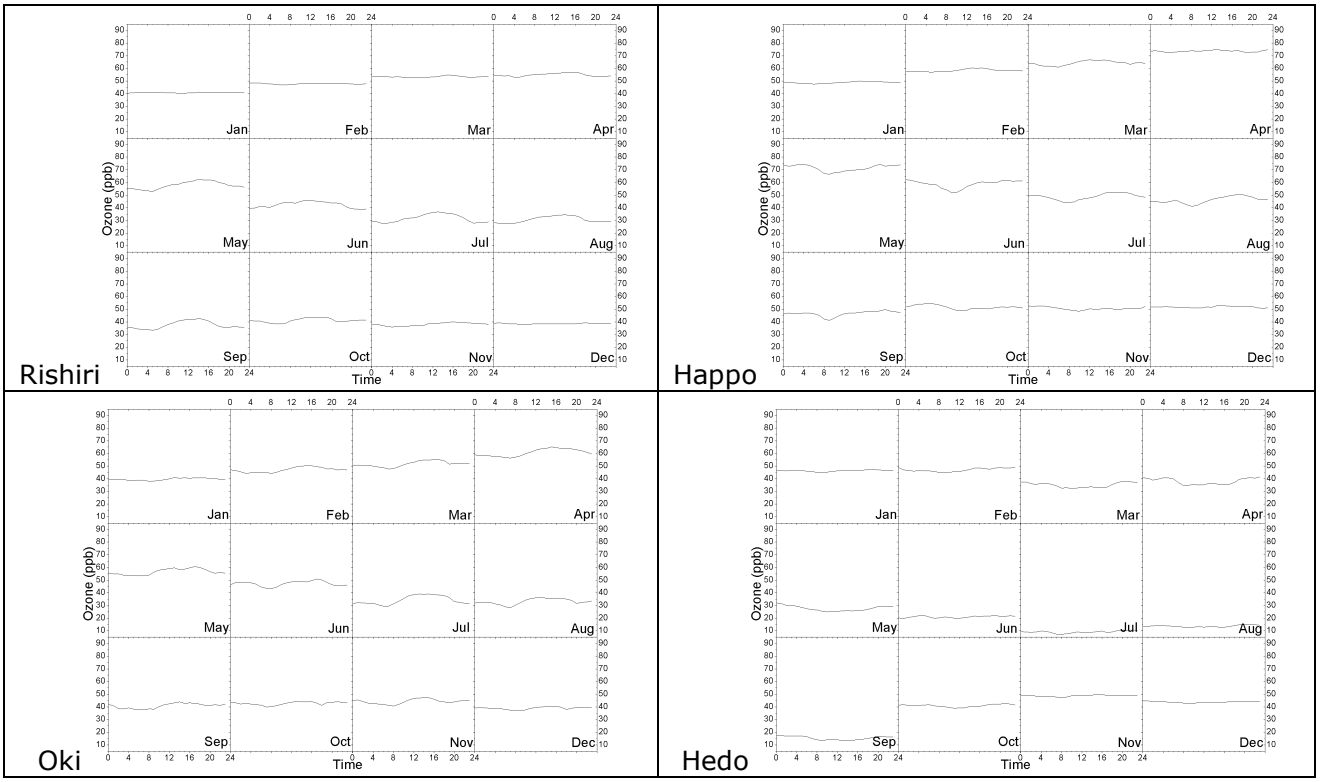


Figure 3 Diurnal cycles of ozone at Rishiri, Happo, Oki, and Hedo in 2004.

Table 3 Differences between averaged hourly maximum and minimum (diurnal range) of ozone at each site.

Averaged Difference	Winter (Dec-Feb)	Spring (Mar-May)	Summer (Jun-Aug)	Autumn (Sep-Nov)	Annual
Rishiri	1.2	5.2	**7.8**	6.3	5.1
Happo	2.7	5.4	**9.2**	6.1	5.8
Oki	4.3	7.9	**8.4**	5.8	6.6
Hedo	2.9	**6.3**	2.6	3.4	3.8
MTS[1]	2.8	**3.3**	1.7	2.6	2.6
Mondy	1.1	2.0	**4.5**	2.5	2.5

[1] MTS = Minamitorishima, bold numbers indicate maximum value. Unit in ppb.

variations of about 6 and 3 ppb, respectively, at Hedo and Minamitorishima during springtime is also a result of daytime decrease in ozone concentration probably by O_3 destruction process in the clean marine environment.

At Rishiri, Happo, and Oki, the diurnal cycles are not enhanced during wintertime but could be observed in other period of the year, especially during summer. The

daytime increase of ozone implies the in situ photochemical ozone production at these sites. In addition, at Happo which is a mountain site, the movement of boundary layer could additionally play critical role for the appearance of diurnal cycle. For the mountain site, during the nighttime the observatories are normally located above the boundary layer and thus represent the ozone characteristics close to the free tropospheric ozone where the long-range transport of ozone from regional-scale anthropogenic emissions dominates. However, during the daytime the convective boundary layer usually brings up the more-polluted air masses from the downhill regions. The averaged daytime increases at Rishiri, Happo, and Oki in the summertime range 8-9 ppb. In comparison, Table 3 also shows the diurnal range at Mondy, which is remote continental site and is not affected by regional emissions. Ozone mixing ratios at Mondy do not show diurnal cycle in the winter time and only small diurnal cycle, less than 5 ppb on averages in the summer time.

3.1.1.5 Controlling factors

The above explanation and other analysis including backward trajectories, remote sensing from satellite verify that the three main factors that control the regional ozone characteristics in Japan are the regional-scale anthropogenic emission of ozone precursors in East Asia, long-range transport of the ozone and its precursors mainly by East Asian monsoon, and seasonal variations of photochemical activities in East Asia. In addition, in the urban and more polluted sites, the local emission would play significant role in determining ozone variation. The effects will be dominant if the sites are more susceptible to these factors. For example, the ozone data from regional sites in China shows much higher concentrations than from Japan because of the more intense anthropogenic emissions. Meanwhile, the remote islands normally show the strong seasonal cycle owing to the stronger influence of air mass exchange by East Asian monsoon. Apart from these factors, large-scale biomass burning and forest fires in Siberia sometimes could enhance the ozone concentration in Japan but this happens on temporarily basis. The satellite hot spots show that the burning in Siberia in 2004 was not much significant.

3.1.2. Variability of surface ozone in China (prepared by T. Wang and J. Tnag)

While a large number of studies on ozone were conducted in Europe, North America, and in Japan, knowledge of the temporal and spatial distribution of tropospheric O_3 is comparatively limited on the Chinese subcontinent where rapid urbanization and industrial developments have been taken place in the latest two decades.

3.1.2.1 Seasonal Cycles

Seasonal patterns of surface ozone have been reported at Lin'an, in Zhejing Province in eastern China (Luo et al., 2000; Wang et al., 2001a; Xu et al., submitted to GRL), a coastal background site (Hok Tsui) and a suburban site (Tai O) in Hong Kong (Lam et al., 2001; Wang et al., 2005), a rural site (Shangdianzi) near Beijing (Liu et al., 2006), three polluted mountaintop sites (Mount Tai, Mount Hua, and Mount Huang) (Li et al., submitted to JGR), and remote Mt. Waliguan in Qinghai (Tang et al., 1996). Among these sites, only two (Hok Tsui and Mt. Waliguan) have long-term (>10 years) continuous data. Surface ozone data from several other sites in the Yangtze delta in 1999-2000 were also reported (H. Wang et al, 2006). Ozone data in 1994-1995 were also collected at Longfengshan (Heilongjiang) and Qingdao (Shandong) (Luo et al., 2000). (See Figure 4 and 5).

Monthly mean O_3 concentrations have been found to reach a maximum in early summer (May or June) in rural areas of central and eastern China and remote Mt. Waliguan, but in autumn in southern China. (The autumn maxima from the 1994-1995 data set reported in Luo et al., 2000 seems not representative of the climatologically average, as indicated from the multiple-year data at Lin'an.) Different meteorological conditions (affecting air-mass dispersion/long-range transport and photochemistry) have been attributed to the seasonal maxima. In eastern China, the summer peak, similar to that observed in North America and Europe, is due to photochemical production of ozone from anthropogenic sources in

summer whereas the autumn maxima in southern China can be explained by the favorable weather conditions in autumn (frequent stationary high pressure system and strong solar radiation) for pollution transport and photochemistry. (Summer monsoons bring wet and unstable weather and very clean maritime background air to southern China). The exact cause of the June peak at Waliguan is not certain, and evidence exists for contribution from both Stratosphere-Troposphere Exchange (Tang et al., 1996; Ma et al., 2005; Wang et al., 2006a; Ding and Wang, 2006) and transport of regional pollution from eastern China (Zhu et al., 2004).

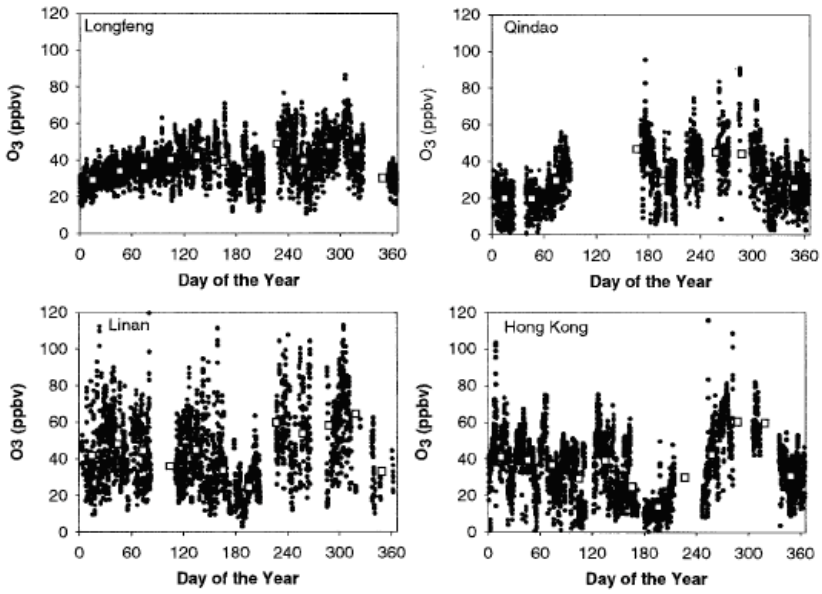
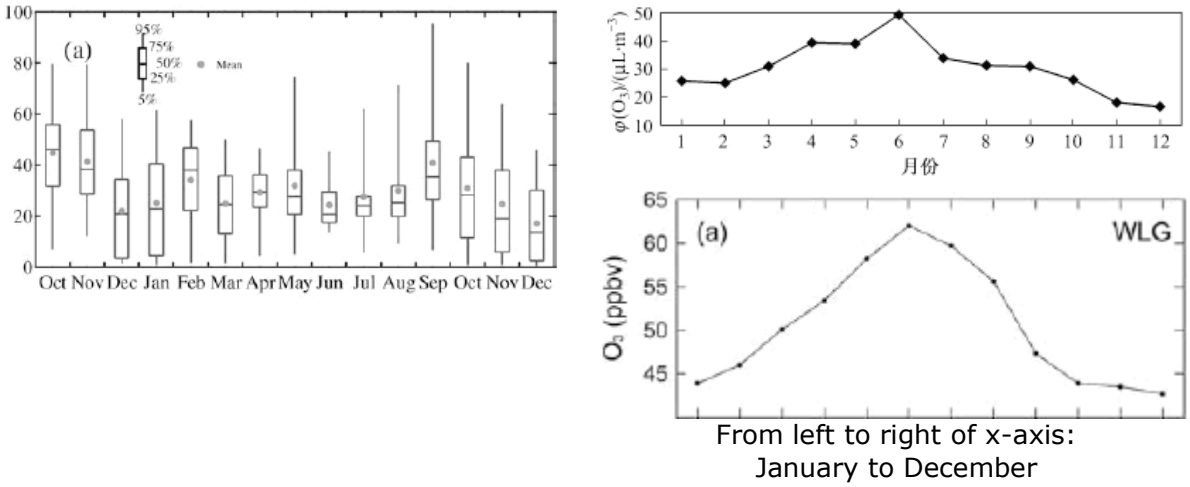


Figure 4 Seasonal variation of surface ozone at Longfeng (top left), Qingdao (top right), Linan (bottom left), and Hong Kong (bottom right) (1994-1995)(Luo et al., 2000)



From left to right of x-axis:
January to December

Figure 5 Seasonal variation of surface ozone at Tai O, Hong Kong (2001-2002) (left) (Wang et al., 2005), Shangdianzi (2004) (top right) (Liu et al., 2006), Mt. Waliguan (1994-2003) (bottom right) (Ma et al., 2005)

3.1.2.2 Ozone pollution

Frequent O_3 episodes have been observed at sub-urban and rural areas of China during photochemically active seasons (e.g., Wang et al., 1998; Wang et al., 2001b; Cheung and Wang, 2001; Wang and Kwok, 2003, Gao et al., 2005; Shao et al.,

2006; Z. Wang et al., 2006; Wang et al., 2006a, Zhang et al., 2007). Peak ozone concentrations (hourly average) of 200-300 ppbv were observed, indicating serious photochemical ozone pollution during summertime in industrialized/urbanized regions of China as shown in Figure 6 for Tai O, Hong Kong. Influence of meteorological conditions, pollution transport and role of precursors related to ozone episodes have been examined in a number of studies. O_3 episodes generally occur on warm days with stable atmosphere, as found elsewhere. The formation of O_3 appeared to be controlled by VOC in the industrialized Pearl River Delta of southern China (Zhang et al., 2007), while the data from Beijing seems to suggest an important role of NO_x (Wang et al., 2006b).

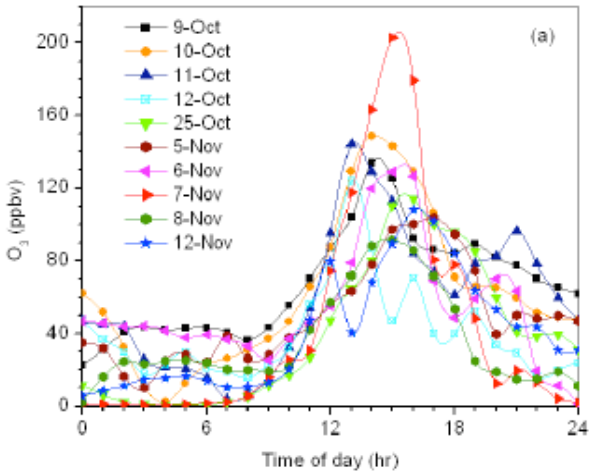


Figure 6 Diurnal variation of O_3 during episodes. Surban Tai O in Hong Kong (October-November 2002) (Zhang et al., 2007)

3.1.2.3 Long-term trend

Available long-term data (not yet published) from Hok Tsui (Hong Kong) and Mt. Waliguan (Qinghai) have shown an increasing trend of surface ozone concentrations between 1994 and 2005. (Detailed analysis of these long-term records is on-going.) An analysis of MOZAIC data also suggests increasing O_3 concentrations in the boundary layer over Beijing and the surrounding regions from 1995 to 2005 (Ding et al., submitted to ACPD).

3.1.3 Variability of surface ozone in India (prepared by S. Lal and T.K. Mandal)

3.1.3.1 Observation sites and general meteorology

Measurements of tropospheric ozone and its precursors are being made at limited sites in India. We report measurements of surface ozone made at Mt. Abu and Darjeeling in India. Both of these sites are mountain sites and represent levels of ozone in the two regions.

Measurements at Mt. Abu are made at a remote mountaintop called Guru Shikhar (24.6N, 72.7E, 1680 m asl) (hereafter, only Mt. Abu will be mentioned). This region comes under the southern end of Aravali range of mountains and is the highest in the entire western-central Indian region. The main town of Mt. Abu (about 10 km from Guru Shikhar) is situated at a height of 1220 m with a population of about 30,000–40,000. Nearest urban city Ahmedabad (23N, 72.6E, 49 m asl) is about 200 km towards south.

Another surface ozone measurements were carried out at Bose Institute, Darjeeling since 2004. Dr. A. J. C Bose Institute is relatively away from town. It may represent the background value of the Darjeeling town. The nearest major town is Kolkata. The weather conditions are normally overcast and rainy during the period of June-September. Dry periods are observed from November to May. The relative humidity was very high which varied from 85 % to 100 %.

Figure 7 Mount Abu (left) and Darjeeling (right) sites in India.

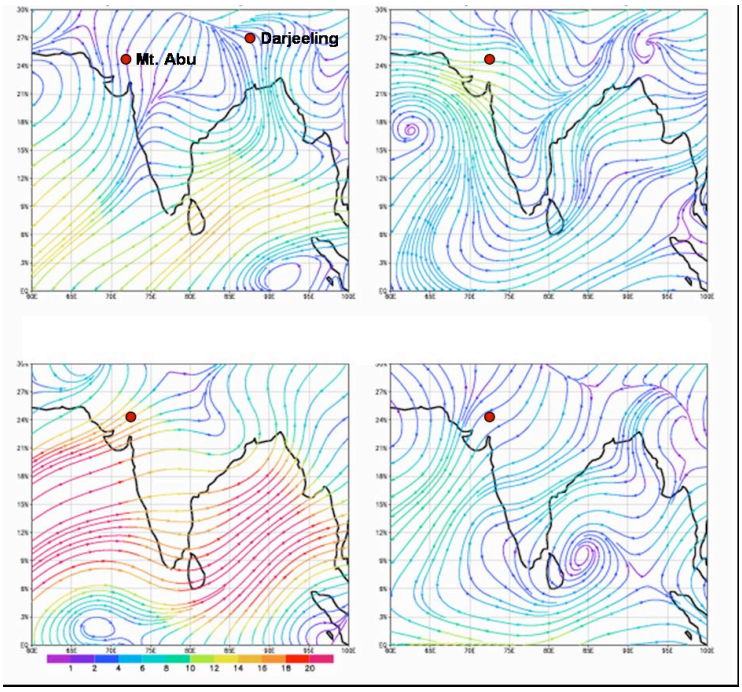


Figure 8 Average wind patterns at 925mb during December-January-February (upper left), March-April-May (upper right), June-July-August (lower left) and September-October-November (lower right) based on ECMWF data.

Figure 8 shows the average ECMWF wind fields at 925 hPa during different seasons in a year. These plots show the general meteorology in winter when northeast wind pattern dominates and in summer when southwest wind pattern dominates over the Indian region. The June-July-August (JJA) months represent south-west monsoon season. The wind pattern changes dramatically from southwesterly to northeasterly after September, which continues till January–February with some dominance of northerly winds over Mt. Abu. Wind pattern is northwesterly in early spring (March), which changes gradually to southwesterly in late spring in May.

3.1.3.2 Measurement Technique

Observations of surface ozone have been made at both these sites along with other related trace gases using standard UV absorption based analyzers for ozone. However, some times there were breaks in the data due to technical problems. Ozone data for full year are available for the year 2000 and 2004 for Mt. Abu and Darjeeling respectively. Data from the analyzer are averaged over 15 min. However,

average hourly or monthly data are presented in this study.

3.1.3.3 Diurnal Variations

Average diurnal variations in ozone for Mt. Abu and Darjeeling are shown in Figure 9.

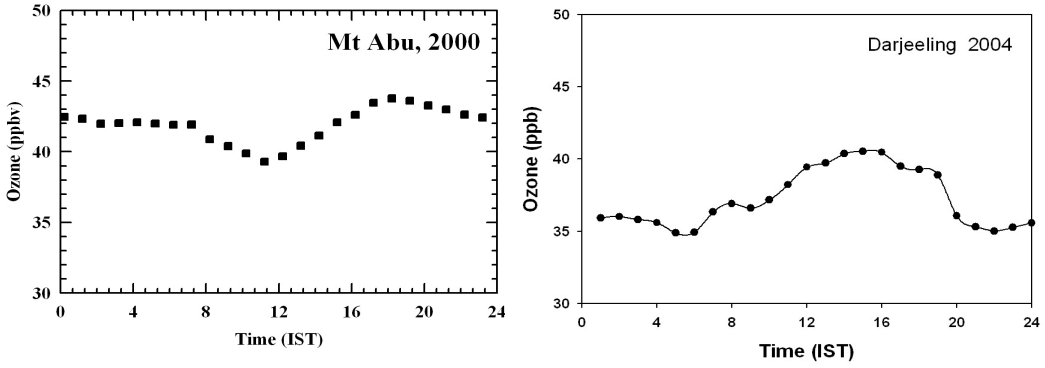


Figure 9 Average diurnal variations observed at Mt. Abu and Darjeeling

The mount Abu data show a dip around noon hours. The nighttime and early morning values are around 42-43 ppbv. The noon values are lower around 39-40 ppbv during 11-12 hours. The day time maximum (~45 ppbv) ozone occurs around 4 pm. This is typical mountain type of diurnal variation. There are mainly two processes, viz. mountain–valley induced wind system and chemical ozone loss in low NO environments, which generally explain lower ozone values during daytime at a high altitude site (e.g. Oltmans and Komhyr, 1986; Lin et. al., 1988). Solar heating warms the air near the mountain surfaces and causes warm upslope wind after the sunrise. This induces the ozone loss by surface deposition during this period. Further details are given in Naja et al. (2003)

The Darjeeling data, on the contrary, showa little diurnal variation and maintains rather large concentrations throughout the day. Low value of 34 ppbv is observed around 6 am. The day time maximum is around 42 ppbv and occurs in the late afternoon around 4 pm. It comes down to about 35-37 ppbv after 9 pm. This is a typical pattern of a semi urban site (Sapkota et al, 2004). Further details are given in Singh et al (2007).

During daytime up slope winds blow which enhance the vertical mixing (Zhu et al, 2006; Ramana et al, 2006). Sometimes during day time non-precipitating white clouds were also touching ground like fog and were moving up-slope. Whenever these clouds are passing through the inlet tube of analyzer O_3 concentrations were observed to increase suggesting that O_3 is being transported by clouds vertically. The ozone concentrations showed increasing behavior during nighttime hours with a distinct preference for midnight. This may be attributed to cooling of mountain causing down slope flow, which draws more ozone reach air from aloft and carrying, it to downward and maintaining high O_3 concentration during night.

3.1.3.4 Seasonal variations

The monthly average ozone values are sown in Figure 10 for both the sites. The Mt. Abu data show 40-43 ppbv during January to May and July months. June and August values are low around 33 ppbv. These values increase in September onwards. Highest average ozone (56 ppbv) is obtained in October. All the four months show higher ozone values. These variations are due to changes in the wind pattern. The monsoon months (JJA) bring cleaner marine air and due to cloud cover, photochemical production may not occur. In September the wind pattern changes from southwest to northeast. It brings the continental polluted air over this site.

The Darjeeling data are again different. The highest ozone values (in the range of 50 -65 ppbv) are observed in MAM months. The lowest of about 20 ppbv is observed

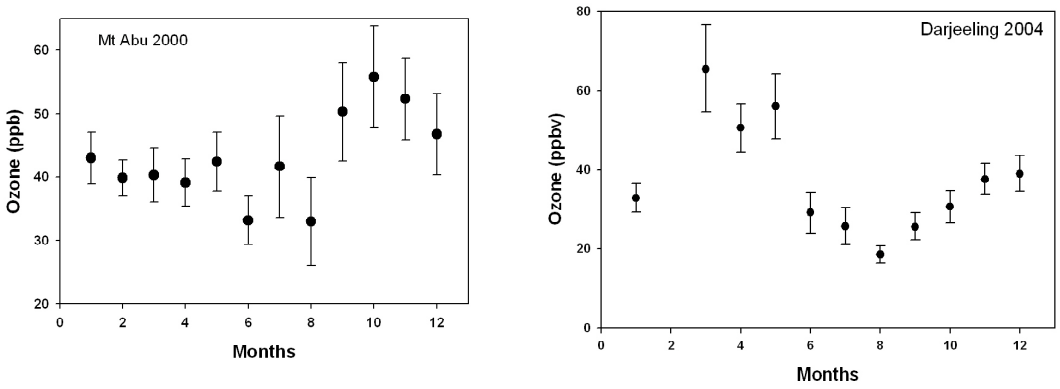


Figure 10 Average seasonal variations observed at Mt. Abu and Darjeeling

in August. There is an increase from September and continue till January. The data for Feb are not available. These variations are again related to the wind patters. The August is again the monsoon month.

3.1.4 Variation of surface ozone in Malaysia (prepared by S.F. Lim)

3.1.4.1 Ozone Monitoring in Tanah Rata

As tropospheric ozone is the third important greenhouse gas and ozone near the surface is a toxic gas to human health and vegetation, the Malaysian Meteorology Department (MMD) has embarked on a program to monitor and study the impact of this gas in the country including at a rural location such as the Tanah Rata Regional GAW Station. With this objective, the MMD has just installed the Thermo Environment 49c Ozone Analyzer at the GAW station to monitor the hourly surface ozone concentration at this rural site. The Tanah Rata meteorological and GAW station is located Lat. 4° 28' N, Long. 101° 23' E, elevation 1545 m above sea level (Figure 11). The ozone analyzer is a part of the multigas analyzer system at Tanah Rata which also monitors carbon monoxide, nitrogen oxides and sulphur dioxide concentration.

Besides the Tanah Rata site, the MMD has expanded its surface ozone monitoring network to include the baseline GAW station in Danum Valley.

Figure 11 Location of Tanah Rata Regional GAW Station (not to scale)

3.1.4.2 APN Ozone Studies in Malaysia

As a part of the APN project, ozone and other air quality data and information collected at the Tanah Rata GAW Station was used to the study the influence of biomass burning in Sumatra, Indonesia on ozone concentrations at Tanah Rata. In Indonesia, especially the island of Sumatra and Kalimantan Borneo, a large amount of forest is being converted to other uses such as plantation, agriculture and residential. This activity coupled with the dry weather during the Southwest Monsoon season, incidences of forest fires are common and with the prevailing winds blowing from the southwest, smoke particles and the associated gaseous pollutants emitted by forest fires are transported towards Malaysia and Singapore. Ozone, a secondary air pollutant is formed from these forest fires and transported along with the particles. As the Tanah Rata GAW station is downwind of these sources of air pollution, particulate and ozone data collected at the station were analysed to study the influence of biomass burning in Sumatra on surface ozone concentration in Tanah Rata. Data and information for the year 2006 was chosen for the study.

3.1.4.3 Haze Episodes

Rainfall amounts in May and June, the early part of the Southwest Monsoon were mainly below normal in South Sumatra and Java, Indonesia, and this rainfall deficiency spread to Borneo island and most parts of Sumatra and Java in August and September. Resulting from this dry period and the biomass fuel in the region, the Fire Danger Rating System (FDRS) Index showed extreme levels in southern Sumatra and most parts of Java in July and this condition deteriorated further to cover areas in South and West Kalimantan in October. With this prolonged dry conditions and extreme FDRS index, biomass burning were common in Sumatra and later in Kalimantan. With the low level prevailing wind blowing from the southwest direction, most of the emissions from biomass burning were transported across the Straits of Malacca to Peninsular Malaysia and to a certain extent, Singapore as well. Based on the horizontal visibility observed at principle meteorological stations in the country, four significant haze episodes were documented in Peninsular Malaysia, starting with one on 3 to 7 July followed by three others, on 16 to 18 July, 4 to 7 August and 3 to 23 October 2007. The first three episodes were of short duration but the fourth lasted about three weeks.

In Sabah and Sarawak, the Malaysian states in Borneo Island, the situation is slightly different as these states are not directly downwind of Sumatra during the Southwest Monsoon season but downwind of Kalimantan Borneo. As a result, the haze episodes in Peninsular Malaysia were not repeated in these two states. In Sarawak, which is nearer South and West Kalimantan, there were two relatively long lasting haze episodes, the first beginning on 15 until 30 August and the second on 23 September to 25 October 2007. In Sabah, there was only one haze episode reported, which occurred on 27 September to 15 October 2006.

3.1.4.4 Ozone Concentration in Tanah Rata

Examining the daily average surface ozone concentration monitored at the Tanah Rata GAW station during the months of June until September 2007 (Figure 12), it was observed that except for the first two days, the average concentration is below 20 ppb. However in July, coinciding with the first haze episode on 3 to 7 July, the average concentration is above 20 ppb from 3 to 8 July. This is also the case during the second episode from 16 to 18 July, the average concentration is above 20 ppb for a much longer period, well past the 18th to the 28th July. This could indicate that although the haze episode in terms of visibility is over, ozone concentration remains high which may be due to in-situ formation of ozone from ozone precursors which remains in the atmosphere. In August, average ozone concentration rose above 20 ppb on the first day of the month and peaked at 40 ppb during the third haze episode of 4 to 7 August in Peninsular Malaysia. The average concentration remained above 20 ppb most of the time and decreased below it only towards the end of the month. In September, there were three occasions when the concentration is above 20 ppb starting with the first on 3 and 4, the second on 13 to 17 and the third on 21 and 22.

Although ozone concentration were high, the visibility did not deteriorate to warrant it to be a haze episode.

Thus, surface ozone concentration in Tanah Rata is generally between 10 and 20 ppb, as expected of a rural site. However, when there is biomass burning in neighbouring regions and with prevailing low level winds blowing towards the station from the biomass burning sources, ozone concentration was found to be well above the 10 and 20 ppb level. Besides ozone, particulate concentration was also found to be high during such periods. Satellite imageries taken during such events showed the transport of particulate from the sources to the Tanah Rata Station (Figure 13).

As there were no surface ozone measurements made in Sabah and Sarawak during the haze episodes of these two states, comparison of ozone and haze episodes were not possible. However, with recent developments at the Danum Valley Global Atmosphere Watch Station, a surface ozone analyzer was installed at the station in January 2007 and studies will be conducted on ozone transport over the two states.

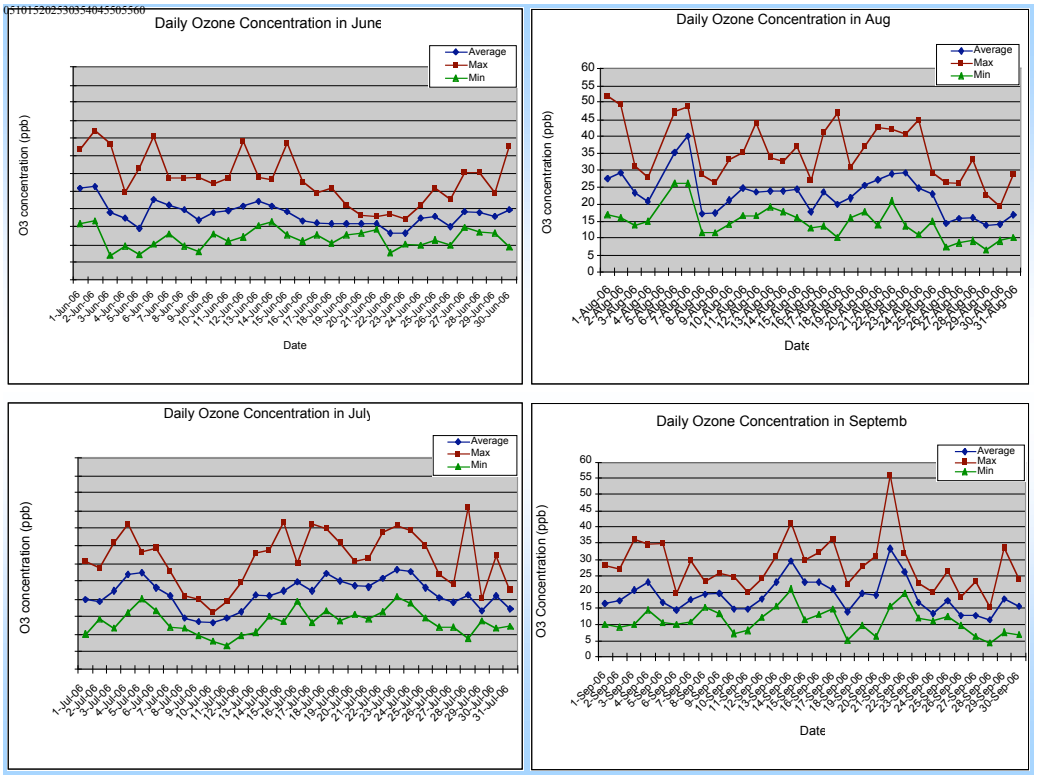


Figure 12 Daily surface ozone concentration in Tanah Rata June – September 2006.

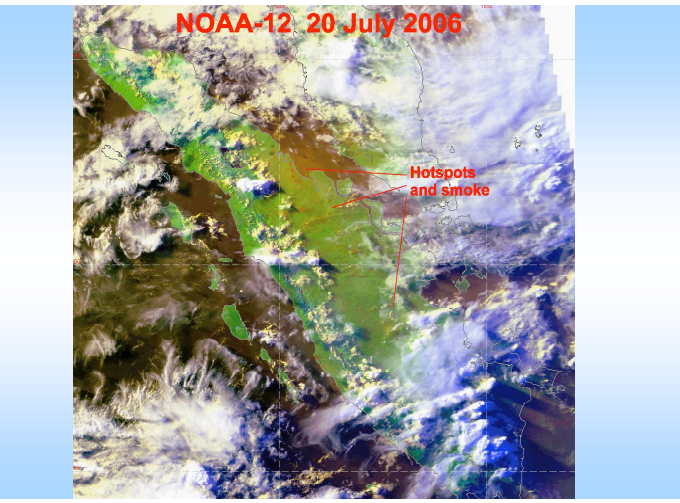


Figure 13 Satellite imagery showing transport of smoke haze from Sumatra, Indonesia to Peninsular Malaysia on 20 July 2006

3.2 Model Analysis

3.2.1 Seasonal variation of regional ozone in East Asia

Model analysis of boundary layer ozone in East Asia has been done under the project of Global Environmental Research Fund (Ministry of Environment, Japan) by Yamaji et al (2006).

Ozone concentrations in East Asia were simulated using the Community Multi-scale Air Quality model (CMAQ) and their performance was validated by comparing with observation data at Japanese monitoring sites. Surface O3 distribution over East Asia varies dynamically from season to season according to the meteorological condition as shown in Figure 14. In May and June, 2-month average O_3 concentrations in the boundary layer are the highest, 55–70 ppbv over East China and Japan in the latitude of 35–40°N. We estimated the seasonal variation of the contribution of chemically produced O_3 by east Asian regional emissions. In the summertime, the contribution of the regional Asian emissions to O_3 concentrations is around 40–70% over most of China, and the highest is 60–70% (35 ppbv) at the mouth area of Yantze River. This suggests that O_3 concentrations over East Asia are strongly influenced by the chemical production by regional emissions during summer season. However, the inflow from outside of this model domain also contributes substantial O_3 concentration over East Asia and its contribution is predominant in winter and early spring. The seasonal change of O_3 concentrations over Japan is characterized by two peaks in spring and autumn and summer minimum. The spring peak event in 2002 consists of split peaks: the first peak in Mar–Apr is mainly influenced by the inflow from outside of this model domain, the second spring peak between May and June is mainly influenced by chemically produced O_3 by regional emissions. During the summer season, O_3 concentrations are the lowest over year because of the weak Asian outflow and northward penetration of the marine air mass.

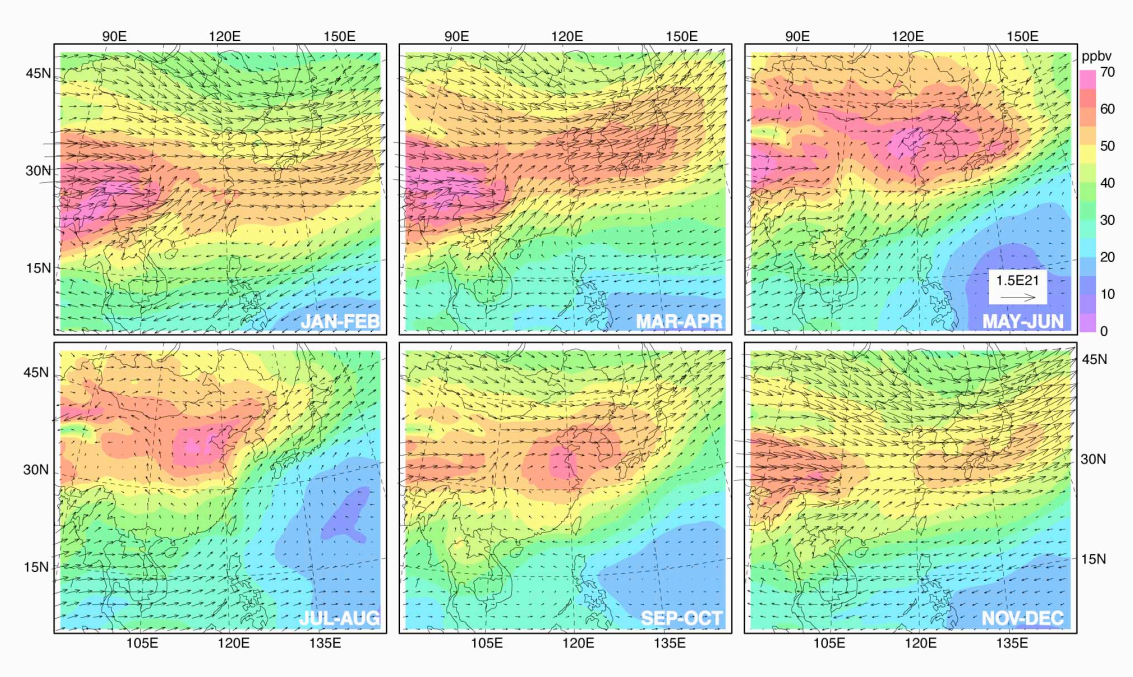


Figure 14 Seasonal variation of surface ozone concentration in East Asia calculated by CMAQ with REAS emission data (Yamaji et al., 2006).

3.2.2 Intercontinental hemispherical transport of tropospheric ozone

Model analysis of intercontinental transport of tropospheric ozone has been done under the Global Environmental Research Fund project (Ministry of Environment, Japan) by Sudo et al (2007).

We examined contributions from various source regions to global distributions and budgets of tropospheric ozone in the context of intercontinental transport, using tagged tracer simulation with a global chemical transport model. We define 14

polluted source regions (14 tracers) in the boundary layer (North America, Europe, China, etc.) and 8 regions (8 tracers) in the free troposphere; O_3 production in the remaining (remote) tropospheric region and O_3 transport from the stratosphere are also tagged as separate tracers (Figure 15). O_3 transport from the polluted source regions like North America, Europe, and Asia generally accounts for more than 40% of ozone abundances even in remote locations. O_3 exports from boundary layer in China and Asian free troposphere are discerned through much of the Northern Hemisphere, suggesting significant and extensive impacts of eastern Asian pollution. In particular, O_3 from Asian free troposphere plays the most important roles in distribution and seasonal variation of O_3 in the middle-upper troposphere almost globally. In June–September, the model calculates a large O_3 contribution (5–10 ppbv) from Asian free troposphere in the upper troposphere over the South Pacific associated with long-range interhemispheric transport from Asia to the southern midlatitudes (via the western Indian Ocean, Africa, and Atlantic) in the upper troposphere.

Contribution of ozone at Sapporo, Japan form various source region is shown in Figure 16. In the boundary layer, contributions the ozone from boundary layer Japan and China are comparable followed by that from the free troposphere in Asia. Intercontinental transport form Europe and North America also contributes 2-3 ppb each.

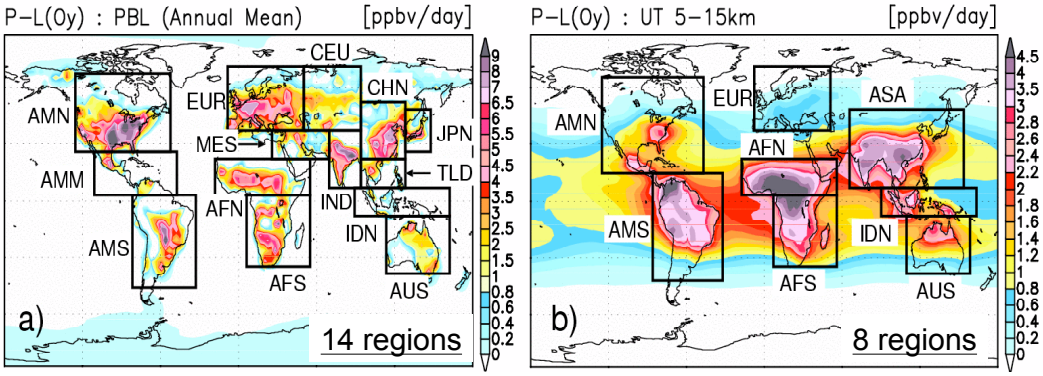


Figure 15 Regional separation for racer tagging. (Sudo et al, 2007)

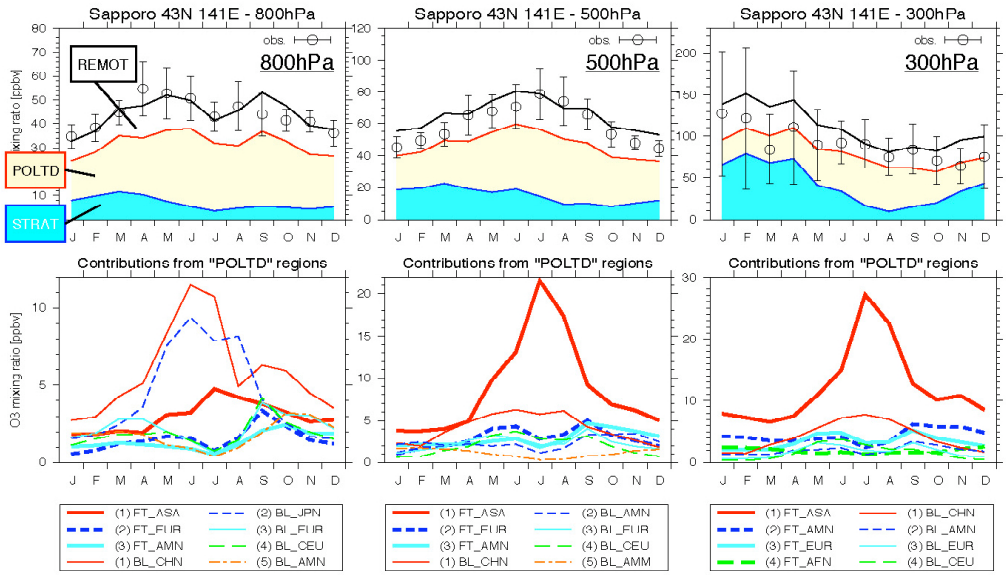


Figure 16 Contribution of ozone at Sapporo, Japan form various source region as calculated by CHASER (Sudo et al, 2007)

4.0 Conclusions

This project aimed at elucidation of Asian ozone pollution in Eurasian perspective . Specific objectives were (1) to compile the surface ozone data at selected rural/remote sites in Asia, (2) to synthesize the compiled observational data to elucidate spatial and seasonal variability, (3) to evaluate intercontinental transport to Asia and intra-continental transport of ozone in Asia with a chemical transport model, and (4) to organize three workshops on Asian ozone pollution in China, India and Japan, and visit selected remote/rural ozone monitoring sites. First, the three workshops were organized at Beijing/China, New Delhi/India and Yokohama Japan as scheduled and the first two workshops/seminars were participated by many young scientists in each country contributed to capacity building in the research field of atmospheric chemistry. Each workshop was followed by a visit to one of monitoring stations of each country. Data compilation of selected rural/remote ozone monitoring stations in each participating countries for a year of 2005 was made and the prepared database is shared by the collaborators of the project. Synthesis report on analyzing the ozone data in each country was submitted to the project. Model analysis using a regional and global chemical transport models was made associating with another project and revealed a general features of boundary layer ozone in East Asia and intercontinental transport in a global scale.

In conclusion the original aims of the project has almost been accomplished successfully.

5.0 Future Directions

In future more systematic selection of observational sites for ozone covering more wide region in Asia is necessary, and particularly modeling efforts should be more strengthened. Regarding to the latter aspect, model scientists in atmospheric chemistry field is available only in limited countries in Asia e.g. in Japan, China, and Korea. Training school focused on regional chemical transport model would be necessary in future and APN support would be very beneficial.

References

Akimoto H., Global Air Quality and Pollution, Science, Vol. 302. no. 5651, pp. 1716 – 1719 DOI: 10.1126/science.1092666, 2003

Cheung, V.T.F., and Wang, T.: Observational study of ozone pollution in rural site in the Yangtze Delta of China, Atmospheric Environment, 35, 4947-4958, 2001.

Ding, A., and Wang, T.: Influence of stratosphere-to-troposphere exchange on the seasonal cycle of surface ozone at Mount Waliguan in western China, Geophysical Research Letters, 33(3), L03803, 2006.

Gao, J., Wang, T., Ding, A.J., and Liu, C.: Observation study of ozone and carbon monoxide at the summit of mount Tai (1534 m a.s.l.) in central-eastern China, Atmospheric Environment, 39, 4779-4791, 2005.

Lam, K.S., Wang, T.J., Chan, L.Y., Wang, T., and Harris, J.: Flow patterns influencing the seasonal behaviors of surface ozone and carbon monoxide at a coastal site near Hong Kong, Atmospheric Environment, 35, 3121-3135, 2001.

Li, J., Z.F. Wang, H. Akimoto, C. Gao, P. Pochanart, and X. Wang, Modeling study of the seasonal cycle of ozone in the boundary layer over East Asia, submitted to J. Geophys. Res.

Lin,X., M. Trainer, S.C. Liu, On the nonlinearity of the tropospheric ozone production, Journal of Geophysical Research, 93, 15879 – 15888, 1988.

Liu, J., Zhang, X.L., Zhang, X.C., and Tang, J.: Surface ozone characteristics and the correlated factors at Shangdianzi atmospheric background monitoring station, Research of Environmental Sciences (in Chinese), 19(4), 19-25, 2006.

Luo, C., John, J.C.St., Zhou, X., Lam, K.S., Wang, T., and Chameides, W.L.: A nonurban ozone air pollution episode over eastern China: Observations and model simulations, Journal of Geophysical Research, 105(D2), 1889-1908, 2000.

Ma, J., Zheng, X., and Xu, X.: Comment on "Why does surface ozone peak in summertime at Waliguan?" by Bing Zhu et al., Geophysical Research Letters, 32, L01805, doi:10.1029/2004GL021683, 2005.
Naja, M., S. Lal, Changes in surface ozone amount and its diurnal and seasonal patterns from 1954–55 to 1991–93 measured at Ahmedabad (23N), India, Geophysical Research Letters, 23, 81 – 84, 1996
Naja, M., Lal, S. and Chand, D. Diurnal and seasonal variabilities in surface ozone at a high altitude site Mt Abu (24.6N, 72.7E, 1680 m asl) in India. Atmos. Env. Vol.37, p.4205-4215, 2003.
Naja, Manish, and H. Akimoto, Contribution of regional and long-range transport to the Asia-pacific region: Analysis of long–term ozonesonde data over Japan, J. Geophys. Res.,109, D21306, doi:10.029/2004JD004687, 2004.
Ohara, T., H. Akimoto, J. Kurokawa, N. Horii, K. Yamaji, and T. Hayasaka, An Asian emission inventory of anthropogenic emission sources for the period 1980-2020, Atmos. Chem. Phys. Discuss., 7, 6843-6902, 2007.
Oltmans, S. J., Komhyr, W. D., Surface ozone distribution and variations from 1973–1984 measurements at NOAA geophysical monitoring for climate change baseline observations. Journal of Geophysical Research 91, 5229–5236, 1986.
Pochanart P., J. Hirokawa, Y. Kajii, H. Akimoto, and M. Nakao, The influence of regional scale anthropogenic activity in Northeast Asia on seasonal variations of surface ozone and carbon monoxide observed at Oki, Japan, J Geophys. Res. 104, 3621-3631, 1999.
Pochanart, P., H. Akimoto, Y. Kinjo and H. Tanimoto, Surface ozone at four remote island sites and the preliminary assessment of exceedances of its critical level in Japan, Atmos. Environ., 36, 4235-4250, 2002.
Ramana, M.V., V. Ramanathan, I.A. Podgormy, B.B. Pradhan and B.Srestha, The direct observations of large aerosol radiative forcing in the Himalayan region., 31, L05111, *Geophys. Res. Lett.*, doi: 10.1029/2003GL018824, 2006.
Sapkota, B., D. Pudasainee, M.L.Shrestha, A. Kaga, A. Kondo, Y. Inoue, Diurnal variations in ground level ozone concentrations in Kathmandu valley, Journal of the Institute of Engineering (Tribhuvan University, Nepal) 4(1) 35-40, 2004.
Singh, Ajay, T.K. Mandal, M.G. Lawrence, Yashodhara Yadav, R.S.Parmar, A. Adak, Sanjay K. Ghosh, B.S.Gera, S.C.Garg, Sibaji Raha and A.P.Mitra; Study of Surface Ozone behavior at Darjeeling (27.01N, 88.25E), a site of the Eastern Himalayas; (To be submitted to Atmospheric Environment), 2007.
Sudo K. and H. Akimoto, Global source attribution of tropospheric ozone: Long-range transport from various source regions, J. Geophys. Res., 112, D12302, doi:10.1029/2006JD007992, 2007.
Sunwoo Y. , G.R. Carmichael, and H. Ueda, Characteristics of background surface ozone in Japan, Atmospheric Environment 28, 25-37 (1994).
Tang, J., Li, X.S., Zhao, Y.C., Zhang, X.C., Zhu, Q.B., The observation of Surface Ozone and preliminary results at Mt. Waliguan of Qinghai Province, in Atmospheric Ozone and its impacts on the regional climate and environment in China, Ed. By Zhou Xiuji, Meteorological publishing house, Beijing, 19-29, 1996
Shao, M., Tang, X.Y., Zhang, Y.H., and Li, W.J.: City clusters in China: air and surface water pollution, Frontiers in Ecology and the Environment, 4(7), 353-361, 2006.
Wang, H., Zhou, L., Tang, X.: Ozone concentrations in rural regions of the Yangtze Delta in China, Journal of Atmospheric Chemistry, 54, 255-265, 2006.
Wang, T., K. S. Lam, and Agatha S. Y. Lee, S. W. Pang, and W. S. Tsui, Meteorological and chemical characteristics of the photochemical ozone episodes observed at Cape D'Aguilar in Hong Kong, J. Applied Meteorology, Vol 37, 1998, pp1167-1178, 1998.
Wang, T., Y. Y. Wu, T. F. Cheung, K. S. Lam, A study of surface ozone and the relation to complex wind flow in Hong Kong, Atmospheric Environment, 35, 3203-3215, 2001.
Wang, T., and Kwok, J.Y.H.: Measurement and analysis of a multiday photochemical smog episode in the Pearl River Delta of China, Journal of Applied Meteorology, 42, 404-416, 2003.

Wang, T., Cheung, V.T.F., Anson, M., and Li, Y.S.: Ozone and related gaseous pollutants in the boundary layer of eastern China: Overview of the recent measurements at a rural site, Geophysical Research Letters, 28(12), 2373-2376, 2001a.

Wang, T., Ding, A.J., Gao, J., and Wu, W.S.: Strong ozone production in urban plumes from Beijing, China, Geophysical Research Letters, 33(21), L21806, 2006b.

Wang, T., Guo, H., Blake, D.R., Kwok, Y.H., Simpson, I.J., and Li, Y.S.: Measurements of Trace Gases in the Inflow of South China Sea Background Air and Outflow of Regional Pollution at Tai O, Southern China, Journal of Atmospheric Chemistry, 52, 295-317, 2005.

Wang, T., Wong, H.L.A., Tang, J., Ding, A., Wu, W.S., and Zhang, X.C.: On the origin of surface ozone and reactive nitrogen observed at a remote mountain site in the northeastern Qinghai-Tibetan Plateau, western China, Journal of Geophysical Research, 111, D08303, doi:10.1029/2005JD006527, 2006a.

Wang, Z., Li, J., Wang, X., Pochanart, P., and Akimoto, H.: Modeling of regional high ozone episode observed at two mountain sites (Mt. Tai and Huang) in East China, Journal of Atmospheric Chemistry, 55(3), 253-272, 2006.

Xu, X.B., Lin, W.L., Wang, T., Yan, P., Tang, J., Meng, Z.Y., and Wang, Y.: Enhanced variability of surface ozone at a regional background station in eastern China 1991-2006, submitted to Geophys. Res. Lett.

Yamaji, K. T. Ohara, I. Uno, H. Tanimoto, J. Kurokawa, and H. Akimoto, Analysis of the seasonal variation of ozone in the boundary layer in East Asia using the Community Multi-scale Air Quality Model: What controls surface ozone levels over Japan? Atmos. Environ.,40, 1856-1868, 2006.

Zhang, J., Wang, T., Chameides, W.L., Cardelino, C., Kwok, J., Blank, D.R., Ding, A., and So, K.L.: Ozone production and hydrocarbon reactivity in Hong Kong, Southern China, Atmospheric Chemistry and Physics, 7, 557-573, 2007.

Zhu, B., Akimoto, H., Wang, Z., Sudo, K., Tang, J., and Uno, I.: Why does surface ozone peak in summertime at Waliguan?, Geophysical Research Letters, 31(17), L17104, 2004.

Zhu, T., W. Lin, Y. Song, X. Cai, H. Zou, L. Kang, L. Zhou, and H. Akimoto, Downward transport of ozone-rich air near Mt. Everest. Geophys. Res. Lett, 33, doi: 10.1029/2006GL027726, 2006.

Appendix

Conferences/Symposium/Workshops

Agenda and participants list for each workshop are cited here and the abstracts are attached at the end of the report.

(1) The 1st Symposium on Asian Ozone Pollution in Eurasian Perspective November 21-22, 2005, Peking University, Beijing, China

Programme

November 21 (Monday)

(Chair: J. Tang)

9:00-9:10 Introduction of the APN Project: Asian Ozone Pollution in Eurasian Perspective — H. Akimoto
9:10-9:50 The History of Atmospheric Chemistry Research in Peking University — X.-Y. Tang
9:50-10:20 Inter-continental Transport of Ozone — H. Akimoto

10:20-10:40 Coffee Break

(Chair: T. Wang)

10:40-11:10 Downward Transport of Ozone-rich Air Driven by Katabatic Wind in Mt. Everest — T. Zhu
11:10-11:40 Estimating Photochemical Ozone Production Rates Using Observed and Calculated OH and HO_2 Radical Concentrations — Y. Kanaya
11:40-12:00 Chemical Transportation of Ozone over China Continent — Y. Liu
12:00-12:25 Modeled Seasonal Variations in O_3 and CO over East Asia — M.-G. Zhang

12:25-13:30 Lunch

(Chair: P. Pochanart)

13:30-14:00 Observation of Ozone in China (tentative) — J. Tang
14:00-14:30 Study of Tropospheric Ozone in China — T. Wang
14:30-15:00 Surface Ozone Measurements Over Delhi — S.L. Jian, B.C. Arya
15:00-15:30 Study of Trace Gases at Some Special Selected Sites of India — T. Mandal

15:30-15:50 Coffee Break

(Chair: S.L. Jain)

15:50-16:20 Atmospheric Chemistry over the Indian Region — S. Lal
16:20-16:50 Surface Ozone Observation in Tanah Rata, Cameron Highlands — S. Kamaruddin
16:50-17:20 Ozone Database from Japan and Some Other Countries in East Asia: How the Data Could be Efficiently Utilized? — P. Pochanart

17:20-18:00 Discussion for the Project — (Chair) H. Akimoto
Data Compilation, Data Protocol, Data Analysis, Modeling

18:30- Reception

November 22 (Tuesday)

Visit to Shangtianzi, China WMO/GAW Regional Station

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(2) The 2nd Symposium on Asian Ozone Pollution in Eurasian Perspective October 30- November 2, 2006, National Physical Institute, New Delhi, India

Programme

October 30 (Monday)

Session I - Chair : T. Wang and B. Sengupta

09:15-09:25 Welcome Address Dr. Vikram Kumar (Director of NPL)
09:25-09-35 Introduction and update of the APN Project H. Akimoto
09:35-10:15 Keynote Address: Ozone: Multiple New Roles A.P. Mitra

10:15-10:40 Inter-continental transport and global source attribution of tropospheric ozone — H. Akimoto
10:40-11:00 Tropospheric ozone in China - recent studies in urban and rural areas — T. Wang
11.00-11.05 Vote of Thanks — P. Banerjee

11:05-11:30 Tea/Coffee Break

Session II - Chair : H. Akimoto and S. Lal
11:30-11:50 Surface ozone studies at NPL New Delhi during 1997-2006 — S. L. Jain, B. C. Arya, Y. Nazeer Ahammed, A. Kumar, D.K. Shukla, P.R. Sinha and P.S. Kulakarni
11:50-12:05 — B. Sengupta
12:05-12:25 Ozone monitoring over India — Sunil Peshin
12:25-12:45 Multi-year observation of early summer ozone pollution episodes over rural mountain regions in China — P. Pochanart
12:45-13:05 The observation of surface ozone at an elevated site of China Shangri-la area — J. Tang
13:05-13:25 Changing airspace environment in eastern Himalayas: A national facility at Bose Institute, Darjeeling — S. Raha

13:25-14:10 Lunch

Session III – Chair: S.F. Lim and B.C. Arya
14:10-14:30 Some characteristics of spring tropospheric ozone over China as observed in 2004 and 2005 — X.-D. Zheng
14:30-14:50 Influence of biomass burning in Sumatra, Indonesia on surface ozone concentrations in Tanah Rata, A preliminary assessment — S.F. Lim
14:50-15:10 Characteristics of surface ozone variations at Mt. Abu — S. Srivastava, S.Venkataramani, D. Chand, M. Naja and S. Lal
15:10-15:30 Characteristics of surface ozone at remote sites in India — T.K. Mandal

15:30-16:00 Tea/Coffee Break

Session IV - Chair: P. Pochanart and T.K. Mandal
16:00-16:20 Upcoming observation facilities at a high altitude site near the Himalayan region — M. Naja, P. Pant, R. Sagar, and S. Lal
16:20-16:40 Long-term variations of surface ozone at Lin'an — X.-B. Xu
16:40-17:00 Impact of Indian chemical emissions on the tropospheric ozone level in Asia — G. Beig
17:00-17:20 A Comparison of the TOMS and the MICROTOP data at IAO, Hanle — N.S. Singh & T.P. Prabhu
17:20- 17:30 APN Asian Ozone Database: What is the progress so far ? — P. Pochanart

Session V - Chair: H. Akimoto and J. Tang
17:30-18:00 Discussion of APN Project from now on

October 31 (Tuesday)-November 2 (Wednesday)
Visit to Darjeeling Observational Station

October 31, 2006	Departure from Delhi
	Arrival at Bagdogra
	Stay in Darjeeing
November 1, 2006	Visit to Darjeeling station
	Stay in Darjeeling

November 2, 2006 Departure from Bagdogra
Arrival at Delhi

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(3) The 3rd Symposium on Asian Ozone Pollution in Eurasian Perspective
April 16-18, 2007, Frontier Research Center for Global Change/ Japan Agency for Marine-Earth Science and Technology, Yokohama, Japan

Programme

April 16 (Monday)

Session I – Chair : S. Hatakeyama (TUAT)

09:30-09:40	Welcome Address	H. Akimoto
09:40-10:00	Overview of ground-level stations, observational and modeling evidence for ozone pollution in Asia	H. Akimoto
10:00-10:20	APN ozone dataset: what we know about ozone characteristics in Asia based on 15 regional sites.	P. Pochanart
10:20-10:45	Impact of urban pollution on ozone and PAN concentrations in the background atmosphere of western China: Preliminary results from the 2006 summer field campaign at urban Lanzhou and remote Mount Wualiguan	T. Wang
10:45-11:00	Tea/Coffee Break	

Session II – Chair : Y. Kajii (TMU)

11:00-11:25	Transformation of gaseous and particulate nitrogen oxides during the transport of air from China to Okinawa, Japan	S. Hatakeyama
11:25-11:50	An introduction: Study on the STE processes and its mass exchange over Tibet Plateau	J. Tang
11:50-12:15	Variability in surface ozone and related trace gases at Mt. Abu in India	S. Lal

12:15-12:40 Role of Chemistry/Transport on surface ozone at Darjeeling T. K. Mandal

12:40- 13:25 Lunch

Session III – Chair: Y. Kanaya

13:25-13:50 Ozone Monitoring and Research in Malaysia S.F. Lim

13:50-14:10 Future Prediction of Surface Ozone over East Asia using the Models-3 Community Multi-scale Air Quality Modeling System (CMAQ) and the Regional Emission Inventory in Asia (REAS) K. Yamaji

14:10-14:30 Development of the urban-scale chemical weather forecasting system M.Takigawa

14:30-15:00 Visiting Earth Simulator

15:00-15:15 Tea/Coffee Break

Session IV – Chair: T. Wang (HK Polytech U.)

15:15-15:40 Diagnosis of Urban Air Quality by OH Reactivity Measurement Y. Kajii

15:40-16:00 Urban photochemistry in central Tokyo: Rates and regimes of oxidant production in winter and summer Y. Kanaya,

16:00-15:6:25 Temporal Variabilities in Surface Ozone at NPL, New Delhi S.L.Jain and B.C. Arya

16:25-16:45 MAX-DOAS: the new ground-based measurements of NO_2 and aerosols H. Irie

Session V – Summary Session

16:50-17:40 Final Synthetic Discussion H. Akimoto

April 17 (Tuesday)-18 (Wednesday)

Visit to Cape Hedo Atmospheric and Aerosol Monitoring Station (CHAAMS), Okinawa

April 17 Leave from Tokyo (Haneda) airport
Arrive at Naha airport in Okinawa
Drive to Cape Hedo Station
Stay at Motobu, Okinawa

April 18 Drive to Naha Airport
Leave from Naha airport
Arrive at . Tokyo (Haneda) airport

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Funding sources outside the APN

Global Environmental Research Fund (Ministry of Environment, Japan)

Project Title: Spatio-Temporal Variability and Climate Impact of Ozone and Black Carbon in Asia (FY2005-2007)

The amount of the grant to JAMSTEC is US$ 210,000 for FY2006 (April 2006-March 2007).

Abstracts for the three workshops

-The APN Project (APN2005-22-NMY)-

The 1st Symposium
on
Asian Ozone Pollution in Eurasian Perspective

November 21-22, 2005
Peking University
Beijing, China

Introduction of the APN Project: Asian Ozone Pollution in Eurasian Perspective

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Tropospheric ozone is the third most important greenhouse gas (IPCC, Climate Change 2001) and ozone near the surface is toxic to health of human and vegetation. Ozone pollution in Asia starts calling more attention both from the climate and environmental point of view since the emission of ozone precursors, i.e. NOx, from Asia has recently exceeded those from North America and Europe. (Akimoto, Science 302, 1716-1719, 2003). UNEP has proposed ABC (Atmospheric Brown Cloud-Asia) project which targets on climate and environmental impact of air pollution in Asia focusing particularly on aerosols and ozone. The present project is in the line of the concept of ABC, but focuses on Asian ozone pollution near the surface and emphasizes Eurasian perspective. Surface ozone level has been increasing in the last couple of decades in many parts of Asia, and the concentration levels often exceeded "critical level" for agricultural and natural ecosystems if European or American evaluation indices are applied, although such an index has not been developed in Asia yet. Surface ozone levels in Asia will further increase in next decades due to continuing increase of emissions of ozone precursors accompanying with economic development and population increase in this region.

Observational data of surface ozone in Asia has not yet been compiled for obtaining whole Asian and Eurasian perspectives. This project concerns with continuous data of surface ozone concentrations at remote and rural sites in Asia. As for remote mountain sites, data at Waliguan in China, Abu and Hanle in India, and Mondy in Russia may be compiled. Ozone data at rural sites in China, i.e. Taishan, Huangshan, Huashan operated by the proponent group, Lin'an, Shandianzi and Longfengshan (WMO/GAW sites) and in Hong Kong as well as those at Minami-torishima, Yonaguni, Ryori (WMO/GAW), and Rishiri, Happo, Oki, and Okinawa (EANET) in Japan, and at Tanah Rata in Malaysia (EANET) may be used to evaluate the regional pollution of ozone in Asia. Other existing available data will also be utilized.

The integrated dataset will illustrates the overview of ozone pollution in Asia, and will be used to evaluate the contribution of emissions of ozone precursors in various parts of Asia as well as those from Europe and North America by using the "tagged" method of the global chemical-transport modeling.

The History of Atmospheric Chemistry Research in Peking University

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The Atmospheric Chemistry Research in Peking University started in 1970s, while the phenomena of photochemical smog had been observed in Lanzhou city of Ganshu Province in 1974. Since 1975 a team for working on field measurement, laboratory experiment and numerical simulation in atmospheric environmental research had been organized and step by step developed. Since then, a series of studies on chemistry of surface ozone and related precursors, the acid deposition chemistry and investigation of fine particles and supporting technical development have been conducted in this laboratory the last 30 years. The team has made big efforts on field observations of different geographical scale, on laboratory research of homogeneous and heterogeneous reactions and on the air quality and different types of model development. Several results of the studies in Beijing municipal area, Pearl River Delta and Yangtze River Delta are introduced.

Inter-continental Transport of Ozone

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Due to relatively long lifetime of tropospheric ozone, its distribution is characterized by long-range transport together with in-situ formation in regional and urban scale. The long-range transport is further characterized by both inter-continental and intra-continental transport. The inter-continental transport of ozone from Asia to North America, North America to Europe, and Europe to Asia is a rather recent issue of concern both from scientifically and policy-oriented point of view.

In this talk, overview of research activities on inter-continental and hemispheric transport of ozone and carbon monoxide will be presented based on our observational and modeling activities. Long-range transport of air across the Eurasian continent brings substantial amount of ozone and its precursors to Northeast Asia from upwind sources over Europe and North America. Model calculations using the UCI/FRSGC CTM with both of GISS-II' and ECMWF data sets were made with 4 degree latitude x 5 degree longitude resolution. Trans-Eurasian transport differs significantly from that over the Pacific and Atlantic Oceans due to weaker and less frequent frontal systems over the continent and over the European sources. European impacts of ozone is 0.5-3.5 ppbv at Mondy, Siberia and 0.3-2.5 ppbv over Happo, Japan in spring. Interestingly, the contribution of North American sources is very similar to those from European sources.

On order to solve the ozone pollution in the Northern Hemisphere, inter-continental transport should also be taken into account. In this context, Task Force on Hemispherical Air Pollution has been organized under "Convention on Trans-boundary Air Pollution" involving European and North American countries. Although European and North American influence to Asia has not fully been discussed yet, we need to solve the issue of ozone pollution in Asia collaborating with this kind of international initiative.

Downward Transport of Ozone-Rich Air Driven by Katabatic Wind in Mt. Everest

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Many studies on climate and environmental changes at high mountains rely on observations of chemical concentrations in ice core, snow and surface air. Downward transport from the free troposphere to boundary layer is critical in determining the chemical concentrations in these media. Yet studies on vertical transport at high mountains were limited and were focusing on upward transport from boundary layer to free troposphere. Here, we report that katabatic wind at Mt. Everest was transporting ozone-rich air down to the 5000 m.a.s.l. surface site. The anti-correlation between ozone and H2O concentrations and the ozone vertical profiles indicate the ozone-rich air was from the upper troposphere. With model simulation, we demonstrate that the cooling of glacier and snow on the mountain slopes plays an important role in forming katabatic wind, which, combing with the heating of bare soil in the valley, accelerates the vertical exchange between free atmosphere and boundary layer. We suggest that for high mountains with snow/ice covers, the "pump down" process driving by katabatic wind is an important process for atmosphere-land exchange of masses and energy.

Estimating Photochemical Ozone Production Rates Using Observed and Calculated OH and HO_2 Radical Concentrations

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It has recently been known that the budget of tropospheric ozone is controlled largely by the photochemical production and loss. Its net chemical production rate ($F\text{-}D(O_3)$) can be expressed by the following equation:

$$F\text{-}D(O_3) = (k_1[HO_2] + \Sigma k_{2i}[RO_2]_i)[NO] - \{J(O^1D)f + k_3[HO_2] + k_4[OH]\}[O_3], \quad (1)$$

where k_1, k_2, k_3, and k_4 are the rate coefficients of the reactions HO_2+NO, RO_2+NO, HO_2+O_3, and $OH+O_3$, respectively, $J(O^1D)$ is the photolysis frequency of O3 to give $O(^1D)$, and f is the fraction of $O(^1D)$ reacting with H_2O. It is evident that the OH, HO_2, and RO_2 radicals are important in determining the net rate. With co-workers, I have developed a laser-induced fluorescence instrument for measuring OH and HO_2 radicals with a sufficiently low detection limit (2×10^5 cm^{-3}). The instrument was operated during intensive field campaigns at three clean marine islands and in Tokyo, associated by simultaneous measurements of a full suite of chemical species and parameters controlling their production and loss (O_3, H_2O, CO, NO/NO_2, NMHCs, OVOCs, J values). The observed OH/HO_2 radical concentrations were compared with the box model predictions fully constrained by the ancillary measurements. I will talk about two cases where good agreement between the observed and modeled radical concentrations was achieved; one at Okinawa Island, a subtropical island in Japan and the other in Tokyo, for which the net ozone production rates are reasonably estimated by equation (1) using observed OH/HO_2 concentrations and calculated RO_2 concentrations.

In Okinawa in summer 1999, the net ozone production rate during daytime was calculated to be +0.2–3.4 ppbv h-1 due to moderate NO concentrations (36–244 pptv) there. Sensitivity studies showed that the ozone production rate was calculated within NOx-limited regime. Up to 20 ppbv of ozone would be photochemically produced in a day, explaining the amplitude of the typical diurnal variation of ozone during daytime (16 ppbv). In Tokyo in summer 2004, the calculated net ozone production rate during midday was +11-13 ppbv h-1, no matter whether smog condition (defined as O_3 > 60 ppbv) occurred or not. The ozone production rate was normally calculated within VOC-limited regime. Thus determined ozone production regime (NOx or VOC-limited) is useful to develop a solid strategy for ozone reduction.

Modeled Seasonal Variations in O_3 and CO over East Asia

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The Models-3 Community Multi-scale Air Quality (CMAQ 4.2) modeling system with meteorological fields calculated by the Regional Atmospheric Modeling System (RAMS 4.3) was applied to simulate transport and transformation processes of tropospheric ozone in East Asia in the period from 1 January 2000 to 31 December of 2004. In this study the model domain is 8000 x 5600 km^2 for RAMS and 6240 x 5440 km^2 for CMAQ on a rotated polar-stereographic map projection centered at (25^{o}N, 115^{o}E) with 80 km mesh covering Japan, Korea Peninsula, Southeast Asia and most part of China.

Chemical mechanism used in CMAQ is SAPRC99 with modification to include dynamics and chemistry of aerosols and cloud chemistry. Anthropogenic emissions used in this study were mainly obtained from the emission inventory of 1^{o}x1^o prepared to support TRACE-P (TRAnsport and Chemical Evolution over the Pacific) and ACE-Asia (Asian Pacific regional Aerosol Characterization Experiment), while the emissions from biomass burning were adopted from the Global Emissions Inventory Activity (GEIA/POET). For evaluating the model performance modeled O_3 and CO were compared against observations obtained at three Japanese stations (Yonagunijima, Ryori and Tsukuba), and further their seasonal variations were discussed

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Study of Tropospheric Ozone in China

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Ozone in the troposphere is of great interest to atmospheric scientists and policy makers. At high concentrations, O_3 harms human health and vegetation; it controls atmospheric oxidizing capacity and affects climate change. Rapid urbanization and industrial developments in China have led to a sharp increase in emissions of ozone precursors–oxides of nitrogen and volatile organic compounds, which are expected to cause serious ozone pollution around major urban areas and in the surrounding rural regions. However, compared to the developed countries, much less is known about the ozone pollution in China – the spatial and temporal nature of this pollutant, the interplay of emission, chemistry, and meteorology in different regions, and local versus regional contributions. The limited knowledge on ozone is due in part to a lack of atmospheric data on ozone and its precursors, particularly in large areas outside urban centers.

In this talk, I will give an overview of measurements of ozone and precursors made by mainly our research group in China's most developed Pearl River delta, Yangtze River delta, and the Huabei region, as well as the remote Qinghai-Tibetan Plateau. The discussion of the data will include long-term trend, seasonal, and diurnal versions, transport and chemical processes that influenced the formation and transport of ozone.

Surface Ozone Measurements Over Delhi

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Tropospheric ozone is a secondary pollutant, its concentration depends upon its precursors (CO, CH_4, non methane hydrocarbons, NOx) as well as meteorological conditions and transport. Ozone is a oxidizing agent, increasing concentration of which can modulate the oxidizing capacity of the atmosphere and in turn can affect climate. It is also health hazard for human beings, animals and plants if it exceeds certain limit. The regular information of its concentrations on ground levels is needed for setting ambient air quality objectives and understanding photo chemical air pollution in urban areas. In view of the above the regular measurements of surface ozone on round the clock basis are being carried out in NPL since 1997. Seasonal variation in ozone concentrations shows pronounced maximum in the months of summer and autumn seasons and minimum in monsoon and winter months. Diurnal pattern in ozone concentrations shows day time in situ photochemical build up throughout the year. The analysis of data shows that on large number of days the surface ozone values at Delhi exceeds the WHO ambient air quality standard for ozone (hourly average 80 ppb) which is a health hazard and is of serious concern. Number of occurrences of hourly ozone more than 80 ppb were found to be 83, 39, 113, 158, 112, 111 and 173 during 1997, 1998, 1999, 2001, 2002, 2003 and 2004 respectively. The monthly average values show highest ozone during 2002 since 1997 which can be attributed to very low water vapour during 2002 due to drought conditions. The surface ozone measurements were also carried out at other locations in the country including at high altitude stations like Leh/Hanle (one of the highest observatory in the world) in campaign mode. The pattern of diurnal variation at Hanle is altogether different from that observed at urban environment like New Delhi. The night time increase of surface ozone have been observed under stable boundary layer conditions in nights and also during thunderstorms. In addition to surface ozone NOx, CO, aerosols and meteorological parameters such as temperature, humidity, solar radiation, wind speed and wind direction are also being monitored on regular basis. The correlation of ozone variation with these different atmospheric parameters have been derived. In the present communication the salient features of the instruments used and results obtained will be discussed in detail.

Study of Trace Gases at Some Special Selected Sites of India

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We report our observation of trace gases at some specially selected sites: Darjeeling, Sunderban, Port Balir. As a follow-up of INDOEX (Indian Ocean Experiment), measurements were done at Darjeeling, Sunderban, Port Balir and Hanle from 1999 onwards in continuous and campaign modes.

At Darjeeling the seasonal variation of ozone shows a summer peak during March-May and low values during July-August. Campaign mode observation of Ozone, CO and NOx at Darjeeling and associated places shows that transport plays a major role. Seven-day isentropic back trajectory calculations at Darjeeling indicate

that, in addition to the emission from the Indo-Gangetic Plain, air parcels also receive substantial contributions from the Arabian region and Western China for most of the year, except during August and September. We also discuss the role of local biomass burning on the concentration of ozone and precursor gases.

Measurements of atmospheric trace gases viz, Ozone, CO, NOx, GHGs and aerosol at Kolkata, a mega city and Kaikhali/Sunderban, a coastal site of Eastern India was carried out 2001, 2003, 2004. The hourly average ozone concentration at Kolkata varies from 10 ppbv at night to 60 ppbv during midday, whereas carbon monoxide shows large variation from 1.0 to 10 ppmv. It is interesting to note that ozone at Kaikhali also shows the variation from 25 ppbv to 70 ppbv with carbon monoxide concentration from 1.5 to 3 ppmv. Methane concentration at Kolkata is observed around 2.04 ppmv, whereas, at Kaikhali it has varied from 1.7 to 2.9 ppmv. TSP at three sites of Kolkata varies between 225 to 629 μg/m3 with the average value of 447 μg/m3. Concentration of NOx observed at Kolkata during this campaign varies from 40 to 130 μg/m3, whereas, at Kaikhali it has been varied from 5 to 30 μg/m3. Comparative study of trace gases (CO_2, CH_4 and N_2O) at Kolkata and Kaikhali suggests that Kaikhali has registered higher value of concentration of CH_4, CO_2, N_2O than that of Kolkata. This indicates that occasional large local biomass burning may have lead to large AOD increment. In addition, we have calculated the seven days isentropic back trajectory at Kaikhali.

Coordinated campaign were made for the measurement of surface ozone, CO, NOx, CO_2, Aerosol concentration and its size, UV radiation at Port Blair during the period of March 16 -26, 2002. Near zero surface ozone of different time scales has been observed several times during the measurements of trace gases for the period of March 16-26, 2002. NOx (NO +NO_2) has been observed very high value (~40 ppbv) during low ozone concentration. Carbon monoxide was also observed very high (300-600 ppbv) during this period. Source of this high pollutant are not clear although 7-days isentropics back Trajectory analysis suggest that airmass has come from eastern side of Indian subcontinent. The continuous measurement of ozone has been started from August, 2005 at Portblair.

Atmospheric Chemistry over the Indian Region

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Atmospheric chemistry in the tropical region is different due to availability of intense solar radiation and higher water vapour. The strong industrial growth makes the Asian tropical region an important region to study environmental and climatic changes taking place. PRL has been involved in the measurements of surface ozone and its precursors at selected sites over India since early 1990s. The sites selected include urban, rural, coastal and mountain regions. We have also made such measurements over the surrounding marine regions.

Results of these studies will be presented. I will also present future programmes in this field.

Surface Ozone Observation in Tanah Rata, Cameron Highlands

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It is well known that surface ozone is hazardous to human health and vegetation. And, sad to say that it has been increasing in many parts of Asia. It's about time that

most of Asian countries sit together to come up with a solid scientific approach for future ozone control policy in Asia.

In this paper, first of all I would like to present the actual picture of Tanah Rata, Cameron Highlands Malaysia's most famous highlands. This site has attracted much interest among the international scientific community in recent years due to its strategic location for monitoring regional emissions and its excellent facilities. Malaysian Meteorological Department (MMD) has established a meteorological station in Tanah Rata back in 1983 and later on, it has been recognized as a GAW Station. A set of observations including the surface ozone observation is currently on-going at the station to address regional issues.

The surface ozone data at Tanah Rata has been collected since April 2004. We have chosen certain months of dataset to be plotted. This will give a general idea of the surface ozone daily variation. For recent month, the graph has shown a decrease in the average value. We have not determine the reasons yet and we open this topic for further discussions.

Ozone database from Japan and some other countries in East Asia: How the data could be efficiently utilized?

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Surface ozone observation works in Japan and other countries of East Asia have been carried out for decades. Most of the observations have targeted at the ozone pollution and photochemical smog problems in urban areas. Especially in Japan, large oxidant monitoring network, covering more than 1000 stations, have been operated. Nonetheless, most of these stations are located in the cities. The situations are similar in other countries of East Asia where the primary purpose of ozone observation is to monitor the pollution level in the large cities. Although all observations works are not confined to city areas, much less numbers of observatories have been established in rural and remote areas. The ozone data in rural and remote regions of Asia are however critical when the problems of ozone long-range transport raised in the nineties. Scientific evidences from observation, global and regional CTM studies, and satellite data analysis, revealed that the large-scale ozone pollutions exist over East Asia and that by the long-range transport, the impact of these ozone pollutions could be found even in the intercontinental or hemispherical scale. To gain insight into these large-scale ozone pollutions, observatories in the remote regions are of importance as the regional representative database is needed. Although with a small numbers of remote ozone observatories in Japan and some other counties in East Asia, in this work the available ozone database from such observatories is investigated. I will report the details, coverage, and the availability of these ozone data. The approach to efficiently utilize these data for the maximum benefit of science community, in particular those who are studying the regional-scale ozone problems, will be discussed.

- The APN Project (ARCP2006-05CMY) -

The 2nd Symposium
on
Asian Ozone Pollution in Eurasian Perspective

October 30, 2006
National Physical Laboratory
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Introduction and Update of the APN Project

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Tropospheric ozone is the third most important greenhouse gas, and ozone near the surface is toxic to health of human and vegetation. Ozone pollution in Asia starts calling more attention both from the climate and environmental point of view since the emission of ozone precursors from Asia has recently exceeded those from North America and Europe. UNEP has proposed ABC (Atmospheric Brown Cloud-Asia) project which targets on climate and environmental impact of air pollution in Asia focusing particularly on aerosols and ozone. The present project is in the line of the concept of ABC, but focuses on Asian ozone pollution near the surface and emphasizes Eurasian perspective. Another scientific and policy-related issue on tropospheric ozone is the intercontinental transport and hemispherical pollution. Task Force on Hemispherical Transport of Air Pollution (TF HTAP) has recently been established under Convention on Long Range Transboundary Air Pollution (CLRTAP). Although Asian countries are not the participants of the Convention, the Task Force has invited scientists and governmental officials of Asian countries to their workshops and meetings.

Observational data of surface and tropsopheric ozone in Asia has not yet been compiled well and overview of ozone pollution in Asia has not been obtained in Eurasian perspective. This APN project concerns with surface ozone concentrations at remote and rural sites in Asia trying to synthesize the Asian ozone data at remote and rural sites with regional representativeness. This Delhi workshop is the second one of this kind following to the first workshop in Beijing in October 2005. It is hoped that further discussion will be developed among East, Southeast and South Asian scientists in this field toward the Eurasian perspectives of the tropospheric ozone issue.

The APN project also tries to compile surface ozone data obtained at remote/rural sites in China, Japan, Malaysia and India in 2004/2005. It is hoped that the compiled datasets will be useful to obtain the overview of ozone pollution in Asia, and will also be useful for the verification of regional and global chemical transport models to simulate tropspheiric ozone from climate and environmental point of view.

Inter-continental Transport and Global Source Attribution of Tropospheric Ozone

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Relevant to the issue of global and regional air pollution, intercontinental transport and hemispherical air pollution are attracting an international concern. For example, Task Force on Hemispherical Transport of Air Pollution (TF HTAP) has been established under Convention on Long Range Transboundary Air Pollution (CLRTAP). Ozone, aerosols, Hg and POPs are the most concerned species in the Task Force in this order. In this talk, intercontinental-transport and its global source attribution of tropospheric ozone pollution will be discussed to give a preliminary view of global source-receptor relationship.

In order to study the global source-receptor relationship of ozone, two methods are conventionally used; one is a zeroing method and another is a tagged method. In the former method, the difference between the calculated ozone at a receptor site with and without the precursor emissions in a specific source area is attributed to the ozone from that area. In the latter method, ozone produced in a specific source area is "tagged", and its contribution to a receptor site is the ozone from that area. There are advantage and disadvantage for the two methods. In the zeroing method, budget closure is not guaranteed due to nonlinearity of ozone formation, but responsible source emissions can clearly be specified. On the other hand, in the tagged method, budget closure is guaranteed, but responsible precursor emissions are not necessarily specified, since the ozone produced in the specified area may be partly due to the precursor emissions from different source area.

An example of global source attribution of tropospheric ozone by using the tagged method will be presented. Our simulation demonstrates that global tropospheric ozone comes from various source regions as well as remote regions. Ozone transport from the polluted source regions like North America, Europe, and Asia generally accounts for more than 40% of net ozone even in remote locations. Ozone exports from Asian free troposphere are discerned through much of the northern hemisphere, whereas Asia receives substantial effects from Europe, North America and other continents.

Tropospheric Ozone in China - Recent Studies in Urban and Rural Areas

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Urban and industrial areas are the dominant source region for ozone precursors, NOx and VOC. As urban plumes transport to rural areas, they combine with emissions from rural areas (particularly from biogenic sources) producing a significant fraction of ozone in the lower troposphere. It is thus important to understand the sources, chemical and physical processes that influence the budget of ozone in and around the major urban/industrial areas.

In this talk I will give a summary of recent measurements in Beijing, Shanghai, Pearl River delta, and compare these results with those from two mountaintop sites. Data on ozone precursors and pollution tracers, and meteorological and chemical models are used to elucidate the key factors contributing to ozone pollution. Results revealed that very high concentrations of ozone, with hourly value up to 286 ppbv, were produced in urban plumes in major urban centers of China. The formation of ozone appears to have different dependence on NOx and VOC, indicating differences in chemical mix/and meteorology among these regions. Results indicate that ozone pollution has become another regional air-quality issue facing China and may also affect the chemistry and radiative budget of the atmosphere a large spatial scale.

Surface Ozone Studies at NPL, New Delhi during 1997-2006

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Ozone is an important trace gas in the troposphere. It is not directly emitted into the troposphere, but chemically produced by NO_x, CO, CH_4 and other hydrocarbons. These ozone precursors are emitted in large quantities due to human activities such as traffic and industry. Ozone in the troposphere plays various important roles like the enhanced production of ozone in the summer can cause photochemical smog. Excessive amounts of ozone near the surface are toxic to ecosystems, animals and man. Ozone is a primary source of hydroxyl radicals, which are the detergents of the troposphere, initiating almost all oxidation processes.

Ozone changes in the troposphere have a large impact on the tropospheric composition. The regular information of its concentrations on ground levels is needed for setting ambient air quality objectives and understanding photochemical air pollution in urban areas. In view of the above the regular measurements of surface ozone on round the clock basis are being carried out in NPL since 1997. Seasonal variation in ozone concentrations shows maximum levels in summer and autumn seasons and minimum in monsoon and winter seasons. Diurnal pattern in ozone concentrations shows daytime in situ photochemical build up through out the year. The analysis of data shows that on large number of days the surface ozone values at Delhi exceeds the WHO ambient air quality standard for ozone (hourly average 80 ppb), which is a health hazard and is of serious concern. Number of occurrences of hourly ozone more than 80 ppb was found 83, 39, 113, 158, 112, 111, 173 and 215 during 1997, 1998, 1999, 2001, 2002, 2003, 2004 and 2005, respectively.

The surface ozone measurements were also carried out at other locations in the country including at high altitude stations like Leh / Hanle (one of the highest observatory in the world) in campaign mode. The pattern of diurnal variation at Hanle is altogether different from that observed at urban environment like New Delhi. The nighttime increase of surface ozone has been observed under stable boundary layer conditions in nights and also during thunderstorms. Since NW side of the present site is surrounded by agricultural areas (IARI, PUSA Campus), a preliminary evaluation of possible damage to crop yield by O_3 has been carried out using exposure plant response index (AOT 40) and found O_3 exposures are higher than the critical level of O_3 and suggest that the present level of O_3 may have impact on reduction in crop yields.

Status of Ozone Pollution in India

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Ozone is a secondary pollutant formed by photochemical reactions of NOx and VOCs in the presence of sunlight. Major sources of NOx include vehicles and sources of VOCs include general solvent use, vehicles, surface coating etc. CPCB is monitoring ambient ozone at three continuous stations and one mobile van by Ultraviolet Photometric Instruments in Delhi. In addition various State Pollution Control Boards are monitoring ozone. Results of ozone monitoring shows that ozone levels are within the USEPA standards during most of the year except in few summer days when standards are exceeded. Maximum ozone concentrations are observed in summer months as it is formed by photochemical reactions of NOx and VOCs. NO2 and ozone follow similar trend. Ozone concentrations tend to peak in early to mid afternoon in areas where there is strong photochemical activity. Ozone exposure change as a function of time of day, season and microenvironment. An association between Ozone and temperature has been demonstrated which may be due to increased photolysis rate under meteorological conditions; enhanced thermal decomposition of PAN to release NOx and increased H2O concentration with higher temperature as this will lead to greater OH production.

Monitoring of Ozone over India

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Ozone in the atmosphere is monitored through a network of observatories maintained by India Meteorological Department by means of Dobson Ozone Spectrophotometer manually, Brewer ozone spectrophotometer (continuous recording) and vertical distribution of ozone by ozonesondes released aloft with balloon. Surface ozone measurements using electro-chemical method. In additio, Indian Antarctic station at Maitri also makes ozone profile observations regularly to study the phenomenal depletion of ozone over the south pole region. A Brewer ozone spectrophotometer for measurement of total ozone, SO_2, NO_2 and UV-B radiation on an operational basis has been installed and commissioned for regular observations w.e.f June 1999. The calibration of the instruments are done regularly.

Multi-Year Observation of Early Summer Ozone Pollution Episodes Over Rural Mountain Regions in China

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Based on the multi-year observations at three monitoring sites located in the mountain regions of eastern China, we found the ozone seasonal cycles that show

the late-spring and early-summer maxima. While this kind of early-summer ozone peak does not differ from the ozone seasonal cycles observed at many other places in Northern Hemisphere, the high mixing ratios and the strong temporal variations clearly indicate the "ozone pollution" episodes in East China. Our data from Mt. Tai, (36 15N, 117 06E, 1538 m above sea level) in Shandon Province, Mt. Huang (30 08N, 118 09E, 1841 m asl) in Anhui Province, and Mt. Hua (34 28N, 110 04E, 2065 m asl) in Shaanxi Province show ozone pollution events that could be confirmed by chemical transport model simulation. On a seasonal basis, ozone variations are controlled by air mass climatology and seasonal photochemical activities. However, the influences from large-scale urbanization in China are clearly observed at all of these rural mountain sites. Especially at Mt. Tai during early-summer, the episodic pollution events have been observed for four consecutive years. This large fluctuation of ozone is normally associated with strong variations of carbon monoxide and black carbon as well indicating the strong enhancements by anthropogenic emission from industrialization, urbanization, and periodical biomass burning.

Changing Airspace Environment in eastern Himalayas: A National Facility at Bose Institute, Darjeeling

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The Himalayas has a diverse ecosystem and rich biodiversity. However, the eastern and western parts of Himalayas are very different in nature. The eastern Himalayas is very wet with rich forest cover and lesser population density; the western Himalayas, in contrast, is very dry with scanty forest cover and high population density. Due to its strategic location, Himalayas has been a preferred choice to put up monitoring stations although most of them are in the western Himalayas. Presently, in the eastern Himalayas, only a few stations like Pyramid station and Kathmandu stations are functioning.

Under the Intensification of Research in High Priority Areas (IRHPA) scheme of the Department of Science & Technology, Government of India, Bose Institute has set up, at its Darjeeling Campus, a National Facility for a comprehensive monitoring of the Chemical, Physical and Radiometrical environment of the Eastern Himalayas. The scope of this National Facility will be discussed in the presentation.

Some Characteristics of Spring Tropospheric O_3 over China as Observed in the 2004 ,2005 Intensive Ozonesonde Campaigns

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Vertical distributions of atmospheric O_3 over southern and northern China have been detected by the intensive ozonesonde observations respectively in the spring of 2004 and 2005. Measurements were taken in the five sites of southern China: Tengchong (TC, 25.01ºN,98.30°E), Hong Kong (HK, 22.38°N, 114.33°E), Sanya (SY,

18.14ºN,109.31°E), Lin'an （LN,30.30ºN,119.75ºE） and Taipei (TP, 24.98°N, 121.43°E), and in the 4 sites in northern China: Altai (AT,47.73ºN,88.08ºE,) Xining(XN, 36.43ºN,101.45ºE), Beijing(BJ, 39.80ºN,116.18º), Longfengshan(LS, 44.73ºN,127.36ºE). The results reveal that there are complex distributions of vertical O_3 over the landmass of China with a general increase in total O_3 with latitudes and the highest O_3 in northeast China. The characteristics of spring tropospheric O_3 are: i) O_3 laminae in middle or upper troposphere over northern China, including LN are related to stratospheric-tropospheric exchange in middle latitudes. ii) Boundary layer O3 pollutions are indicated in BJ, TP metropolitans and Lin'an located in industrialized Yangtze River Delta. iii) Regional transport of biomass burnings in south-east Asia or in north-east Asia including eastern Russian and the Korea peninsula mainly contributes to O_3 enhancing events in boundary layer in the remote rural sites, such as in TC or LS. iv) Lower tropospheric O_3 in the SY or HK is attributed to the convective transports of marine boundary layer air parcels.

Influence of Biomass Burning in Sumatra, Indonesia, on Surface ozone Concentrations in Tanah Rata: A Preliminary Assessment

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Biomass burning in Sumatra, Indonesia is almost a regular feature during the dry Southwest (SW) Monsoon season which begins in June and ends in September. The prevailing wind flow during these months is mainly southwesterly and Peninsular Malaysia is downwind of Sumatra during the SW Monsoon season. With biomass burning and prevailing winds from the southwest, Peninsular Malaysia is subjected to numerous haze episodes since the early 1980s. These haze episodes has turn into an annual event and it is no different in year 2006.

With the recent installation of a surface ozone analyzer and a TEOM PM10 particulate system at the Regional Global Atmosphere Watch (GAW) in Tanah Rata, Malaysia, hourly surface ozone and PM10 concentrations were measured and analyzed.

Preliminary assessment of the ozone data from the Tanah Rata GAW station showed that when there is large scale biomass burning in Sumatra and with prevailing winds blowing from the south and southwest, ozone concentrations at the station peaks well above the average concentrations.

Characteristics of Surface Ozone Variations at Mt. Abu, India

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Measurements of surface ozone have been made at Mt. Abu (24.6N, 72.7E, 1680m amsl) throughout the year 2000. This location is just above the planetary boundary layer particularly during night and winter season. These measurements are made using a standard ozone analyzer based on UV absorption technique. The average data at every 15 minutes are recorded. These measurements show both diurnal as

well as strong seasonal variations. There is a slight decrease in ozone amount during the midday. This is contrary to the daytime increase observed at Ahmedabad, a urban site. The levels of precursors like CO, NO and NMHCs at this site are very low. The seasonal low is during the monsoon season. This is due to the cleaner air reaching the site as well as cloudy conditions inhibiting any photochemical activity. We have also tried to study transport of ozone to this site using general wind patterns and back trajectories. These results along with other meteorological features will be presented.

Upcoming Observation Facilities at a High Altitude Site near the Himalayan Region

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The Indo-Gangetic plain is the most polluted region in India. Satellite based measurements showed extremely high levels of ozone, NOx, CO, and aerosols over the Indo-Gangetic region and Northeast India. Model simulations show vertical lifting of pollution from these parts of India and its wide spread transport in lower and middle troposphere and influencing radiation budget, chemical composition and air-quality over wide region. Outflow of the southern European pollution also reaches to the Northern India during winter season. Inspite of such importance of this region, systematic and simultaneous observations of trace gases, aerosols, and radiation are severely lacking over the Northern India.

The Aryabhatta Research Institute for Observational Sciences (ARIES), Nainital (29.4° N; 79.5° E, 1951m amsl) is situated in the Shivalik ranges of the central Himalayas. This mountain site is away from the local anthropogenic sources and has the potential to provide a unique opportunity to study regional environment in the Northern Indian region and contributions due to long range transport of pollutants. So far astronomical observations have been major activity at this institute and but now new programs are being initiated here for studies in atmospheric sciences. To begin with, aerosol optical depth (AOD) observations were started in year 2002 using MWR instrument. Extensive aerosol observations have also been initiated for black carbon and aerosol size distribution in 15 size ranges. Recently, surface ozone observations have been started under ISRO-GBP and there is plan to have observations of precursor gases, radiation and other aerosol parameters. Proposals to setup a Lidar and a Stratosphere-Troposphere Radar have been also approved. These will help to study vertical distribution of aerosols and dynamics respectively. Some of the observations made will be discussed during the presentation.

Long-term Variations of Surface Ozone at Lin'an

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Due to its dense population, well-developed industry and agriculture, and prosperous economy, the Yangtze Delta region is one of the most important regions of China. However, the booming economy in and outside the region has been causing some environmental problems, such as the increase of tropospheric ozone, acid deposition, etc. Long-term measurements of surface and tropospheric ozone from the region are urgently needed to evaluate the potential impact of the changes in tropospheric ozone over this region.

In this talk I will present some results from the analysis of historic and recent data of surface ozone at Lin'an, a background site of the Yangtze Delta region. Historic data of surface ozone are from several scientific projects that had observations of surface ozone at Lin'an. Recent data are from the operational long-term observation of surface ozone. The time series of surface ozone covers the period from 1991 to 2006, with a few large gaps. Since the large gaps in the time series make it difficult to reliably apply sophisticated techniques to extract any trends in the surface ozone data, the rather simple linear fitting has been used in the data analysis. An overall trend of about -0.4 ppbv/a is derived from the surface ozone data, suggesting a long-term decrease. The average diurnal variations of surface ozone for different years show that the daily amplitude relative to daily mean has been increasing. Analysis of extreme values shows that the monthly highest and the lowest 5% concentrations of surface ozone have long-term trends of 0.68 and -0.53 ppbv/a, respectively, implying an increase in the variability of surface ozone.

Impact of Indian Chemical Emissions on the Tropospheric Ozone Level in Asia

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The impact of chemical emissions in the Indian subcontinents on the tropospheric abundance of ozone and its precursors in the surrounding south Asian region has been simulated using the Chemistry-Transport Model (MOZART) forced with dynamical fields provided by meteorological analyses and new emission inventories established for Indian region. Ozone production in this region is dominated by the anthropogenic emissions of carbon monoxide, nitric oxides and non-methane hydrocarbons. The influence of Indian emissions over most of the surrounding South Asian region leads to a 1-5 ppbv increase in the ozone concentration and a 1-10 ppbv increase in the CO concentration in most part of the free troposphere. During the monsoon period of July, the marine winds transport boundary level ozone and CO towards the northeastern region of South Asia as opposed to what is occurring during the pre-monsoon period. However, due to the short residence time of NOx, convective transport of nitrogen oxides is not strong and hence changes in the concentration of this compound are not very large in the free troposphere.

The background level of ozone over the Indian region, (fraction of ozone present in a given area that is not attributed to anthropogenic sources in this area) is approximately 10-30 ppbv and is even larger in the northern part of India during monsoon period as the winds are purely northerly. The contribution of long-range transport of ozone from distance pollution sources in south Asian region towards Indian region is substantial for ozone and CO, but insignificant for NOx.

A Comparison of the TOMS and the Micrtops Ozone Data at IAO, Hanle

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Most of the UV and ozone monitoring stations are located at low altitudes (1-2000 m asl). Consequently, there is limited data reported at high altitude locations (> 3000 m asl). Measurement of total ozone are carried out with the help of Microtops II at Indian Astronomical Observatory (IAO), Hanle, Ladakh (latitude 32°46′N; longitude 78°57′E, 4500 m asl) since several years. Microtops is equipped with five interference filters, centered at 305, 312, 320, 936 and 1020 nm. The first three UV filters are used for ozone measurement and the last two filters are used for the water vapor and the aerosol measurement, respectively. The column ozone amount shows seasonal variation with high values in spring-summer (May-July) and low in winter (December-February). The most frequently occurring overall daily mean ozone value is the range of 250-260 DU. The diurnal variation of ozone indicates that the day time temperature influence the ozone production by photochemical process in the atmosphere. The variability derived from ground-based Microtops measurements compares well with that obtained from the Earth-Probe TOMS data.

Inter-continental Transport and Global Source Attribution of Tropospheric Ozone

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Relevant to the issue of global and regional air pollution, intercontinental transport and hemispherical air pollution are attracting an international concern. For example, Task Force on Hemispherical Transport of Air Pollution (TF HTAP) has been established under Convention on Long Range Transboundary Air Pollution (CLRTAP). Ozone, aerosols, Hg and POPs are the most concerned species in the Task Force in this order. In this talk, intercontinental-transport and its global source attribution of tropospheric ozone pollution will be discussed to give a preliminary view of global source-receptor relationship.

In order to study the global source-receptor relationship of ozone, two methods are conventionally used; one is a zeroing method and another is a tagged method. In the former method, the difference between the calculated ozone at a receptor site with and without the precursor emissions in a specific source area is attributed to the ozone from that area. In the latter method, ozone produced in a specific source area is "tagged", and its contribution to a receptor site is the ozone from that area. There are advantage and disadvantage for the two methods. In the zeroing method, budget closure is not guaranteed due to nonlinearity of ozone formation, but responsible source emissions can clearly be specified. On the other hand, in the tagged method, budget closure is guaranteed, but responsible precursor emissions are not necessarily specified, since the ozone produced in the specified area may be partly due to the precursor emissions from different source area.

An example of global source attribution of tropospheric ozone by using the tagged method will be presented. Our simulation demonstrates that global tropospheric

ozone comes from various source regions as well as remote regions. Ozone transport from the polluted source regions like North America, Europe, and Asia generally accounts for more than 40% of net ozone even in remote locations. Ozone exports from Asian free troposphere are discerned through much of the northern hemisphere, whereas Asia receives substantial effects from Europe, North America and other continents.

Tropospheric Ozone in China - Recent Studies in Urban and Rural Areas

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Urban and industrial areas are the dominant source region for ozone precursors, NOx and VOC. As urban plumes transport to rural areas, they combine with emissions from rural areas (particularly from biogenic sources) producing a significant fraction of ozone in the lower troposphere. It is thus important to understand the sources, chemical and physical processes that influence the budget of ozone in and around the major urban/industrial areas.

In this talk I will give a summary of recent measurements in Beijing, Shanghai, Pearl River delta, and compare these results with those from two mountaintop sites. Data on ozone precursors and pollution tracers, and meteorological and chemical models are used to elucidate the key factors contributing to ozone pollution. Results revealed that very high concentrations of ozone, with hourly value up to 286 ppbv, were produced in urban plumes in major urban centers of China. The formation of ozone appears to have different dependence on NOx and VOC, indicating differences in chemical mix/and meteorology among these regions. Results indicate that ozone pollution has become another regional air-quality issue facing China and may also affect the chemistry and radiative budget of the atmosphere a large spatial scale.

Surface Ozone Studies at NPL, New Delhi during 1997-2006

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Ozone is an important trace gas in the troposphere. It is not directly emitted into the troposphere, but chemically produced by NO_x, CO, CH_4 and other hydrocarbons. These ozone precursors are emitted in large quantities due to human activities such as traffic and industry. Ozone in the troposphere plays various important roles like the enhanced production of ozone in the summer can cause photochemical smog. Excessive amounts of ozone near the surface are toxic to ecosystems, animals and man. Ozone is a primary source of hydroxyl radicals, which are the detergents of the troposphere, initiating almost all oxidation processes.

Ozone changes in the troposphere have a large impact on the tropospheric composition. The regular information of its concentrations on ground levels is needed for setting ambient air quality objectives and understanding photochemical air pollution in urban areas. In view of the above the regular measurements of surface

ozone on round the clock basis are being carried out in NPL since 1997. Seasonal variation in ozone concentrations shows maximum levels in summer and autumn seasons and minimum in monsoon and winter seasons. Diurnal pattern in ozone concentrations shows daytime in situ photochemical build up through out the year. The analysis of data shows that on large number of days the surface ozone values at Delhi exceeds the WHO ambient air quality standard for ozone (hourly average 80 ppb), which is a health hazard and is of serious concern. Number of occurrences of hourly ozone more than 80 ppb was found 83, 39, 113, 158, 112, 111, 173 and 215 during 1997, 1998, 1999, 2001, 2002, 2003, 2004 and 2005, respectively.

The surface ozone measurements were also carried out at other locations in the country including at high altitude stations like Leh / Hanle (one of the highest observatory in the world) in campaign mode. The pattern of diurnal variation at Hanle is altogether different from that observed at urban environment like New Delhi. The nighttime increase of surface ozone has been observed under stable boundary layer conditions in nights and also during thunderstorms. Since NW side of the present site is surrounded by agricultural areas (IARI, PUSA Campus), a preliminary evaluation of possible damage to crop yield by O_3 has been carried out using exposure plant response index (AOT 40) and found O_3 exposures are higher than the critical level of O_3 and suggest that the present level of O_3 may have impact on reduction in crop yields.

Status of Ozone Pollution in India

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Central Pollution Control Board, East Arjun Nagar, Shahdara, Delhi

Ozone is a secondary pollutant formed by photochemical reactions of NOx and VOCs in the presence of sunlight. Major sources of NOx include vehicles and sources of VOCs include general solvent use, vehicles, surface coating etc. CPCB is monitoring ambient ozone at three continuous stations and one mobile van by Ultraviolet Photometric Instruments in Delhi. In addition various State Pollution Control Boards are monitoring ozone. Results of ozone monitoring shows that ozone levels are within the USEPA standards during most of the year except in few summer days when standards are exceeded. Maximum ozone concentrations are observed in summer months as it is formed by photochemical reactions of NOx and VOCs. NO2 and ozone follow similar trend. Ozone concentrations tend to peak in early to mid afternoon in areas where there is strong photochemical activity. Ozone exposure change as a function of time of day, season and microenvironment. An association between Ozone and temperature has been demonstrated which may be due to increased photolysis rate under meteorological conditions; enhanced thermal decomposition of PAN to release NOx and increased H2O concentration with higher temperature as this will lead to greater OH production.

Monitoring of Ozone over India

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Ozone in the atmosphere is monitored through a network of observatories maintained by India Meteorological Department by means of Dobson Ozone Spectrophotometer manually, Brewer ozone spectrophotometer (continuous recording) and vertical distribution of ozone by ozonesondes released aloft with balloon. Surface ozone measurements using electro-chemical method. In additio, Indian Antarctic station at Maitri also makes ozone profile observations regularly to study the phenomenal depletion of ozone over the south pole region. A Brewer ozone spectrophotometer for measurement of total ozone, SO_2, NO_2 and UV-B radiation on an operational basis has been installed and commissioned for regular observations w.e.f June 1999. The calibration of the instruments are done regularly.

Multi-Year Observation of Early Summer Ozone Pollution Episodes Over Rural Mountain Regions in China

Pakpong Pochanart
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Based on the multi-year observations at three monitoring sites located in the mountain regions of eastern China, we found the ozone seasonal cycles that show the late-spring and early-summer maxima. While this kind of early-summer ozone peak does not differ from the ozone seasonal cycles observed at many other places in Northern Hemisphere, the high mixing ratios and the strong temporal variations clearly indicate the "ozone pollution" episodes in East China. Our data from Mt. Tai, (36 15N, 117 06E, 1538 m above sea level) in Shandon Province, Mt. Huang (30 08N, 118 09E, 1841 m asl) in Anhui Province, and Mt. Hua (34 28N, 110 04E, 2065 m asl) in Shaanxi Province show ozone pollution events that could be confirmed by chemical transport model simulation. On a seasonal basis, ozone variations are controlled by air mass climatology and seasonal photochemical activities. However, the influences from large-scale urbanization in China are clearly observed at all of these rural mountain sites. Especially at Mt. Tai during early-summer, the episodic pollution events have been observed for four consecutive years. This large fluctuation of ozone is normally associated with strong variations of carbon monoxide and black carbon as well indicating the strong enhancements by anthropogenic emission from industrialization, urbanization, and periodical biomass burning.

Changing Airspace Environment in eastern Himalayas:

A National Facility at Bose Institute, Darjeeling

Sibaji Raha
Kolkota, India
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The Himalayas has a diverse ecosystem and rich biodiversity. However, the eastern and western parts of Himalayas are very different in nature. The eastern Himalayas is very wet with rich forest cover and lesser population density; the western Himalayas, in contrast, is very dry with scanty forest cover and high population density. Due to its strategic location, Himalayas has been a preferred choice to put up monitoring stations although most of them are in the western Himalayas. Presently, in the eastern Himalayas, only a few stations like Pyramid

station and Kathmandu stations are functioning.

Under the Intensification of Research in High Priority Areas (IRHPA) scheme of the Department of Science & Technology, Government of India, Bose Institute has set up, at its Darjeeling Campus, a National Facility for a comprehensive monitoring of the Chemical, Physical and Radiometrical environment of the Eastern Himalayas. The scope of this National Facility will be discussed in the presentation.

Some Characteristics of Spring Tropospheric O_3 over China as Observed in the 2004 ,2005 Intensive Ozonesonde Campaigns

C.Y. Chan[1], X.D. Zheng[2], C.S Zhao[3], S.C. Liu[4], L.Y. Chan[1], and Y.S. Lee[1]
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[3] *Department of Atmospheric Science, Peking University Beijing, China*
[4] *Research Center for Environmental Changes, Academia Sinica, Taipei, Taiwan* .

Vertical distributions of atmospheric O_3 over southern and northern China have been detected by the intensive ozonesonde observations respectively in the spring of 2004 and 2005. Measurements were taken in the five sites of southern China: Tengchong (TC, 25.01ºN,98.30°E), Hong Kong (HK, 22.38°N, 114.33°E), Sanya (SY, 18.14ºN,109.31°E), Lin'an （LN,30.30ºN,119.75ºE） and Taipei (TP, 24.98°N, 121.43°E), and in the 4 sites in northern China: Altai (AT,47.73ºN,88.08ºE,) Xining(XN, 36.43ºN,101.45ºE), Beijing(BJ, 39.80ºN,116.18º), Longfengshan(LS, 44.73ºN,127.36ºE). The results reveal that there are complex distributions of vertical O_3 over the landmass of China with a general increase in total O_3 with latitudes and the highest O_3 in northeast China. The characteristics of spring tropospheric O_3 are: i) O_3 laminae in middle or upper troposphere over northern China, including LN are related to stratospheric-tropospheric exchange in middle latitudes. ii) Boundary layer O3 pollutions are indicated in BJ, TP metropolitans and Lin'an located in industrialized Yangtze River Delta. iii) Regional transport of biomass burnings in south-east Asia or in north-east Asia including eastern Russian and the Korea peninsula mainly contributes to O_3 enhancing events in boundary layer in the remote rural sites, such as in TC or LS. iv) Lower tropospheric O_3 in the SY or HK is attributed to the convective transports of marine boundary layer air parcels.

Influence of Biomass Burning in Sumatra, Indonesia, on Surface ozone Concentrations in Tanah Rata: A Preliminary Assessment

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Biomass burning in Sumatra, Indonesia is almost a regular feature during the dry Southwest (SW) Monsoon season which begins in June and ends in September. The prevailing wind flow during these months is mainly southwesterly and Peninsular Malaysia is downwind of Sumatra during the SW Monsoon season. With biomass burning and prevailing winds from the southwest, Peninsular Malaysia is subjected to numerous haze episodes since the early 1980s. These haze episodes has turn into an annual event and it is no different in year 2006.

With the recent installation of a surface ozone analyzer and a TEOM PM10 particulate system at the Regional Global Atmosphere Watch (GAW) in Tanah Rata, Malaysia, hourly surface ozone and PM10 concentrations were measured and analyzed.

Preliminary assessment of the ozone data from the Tanah Rata GAW station showed that when there is large scale biomass burning in Sumatra and with prevailing winds blowing from the south and southwest, ozone concentrations at the station peaks well above the average concentrations.

Characteristics of Surface Ozone Variations at Mt. Abu, India

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** University of Washington, Bothell, USA*
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Northern Indian region and contributions due to long range transport of pollutants. So far astronomical observations have been major activity at this institute and but now new programs are being initiated here for studies in atmospheric sciences. To begin with, aerosol optical depth (AOD) observations were started in year 2002 using MWR instrument. Extensive aerosol observations have also been initiated for black carbon and aerosol size distribution in 15 size ranges. Recently, surface ozone observations have been started under ISRO-GBP and there is plan to have observations of precursor gases, radiation and other aerosol parameters. Proposals to setup a Lidar and a Stratosphere-Troposphere Radar have been also approved. These will help to study vertical distribution of aerosols and dynamics respectively. Some of the observations made will be discussed during the presentation.

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- The APN Project (ARCP2006-05CMY) -

The 3rd Symposium
on
Asian Ozone Pollution in Eurasian Perspective

April 16, 2006
Frontier Research Center for Global Change
Japan Age3ncy for Merine -Earth Science and Technology
Yokohama, Japan

Overview of ground-level stations, observational and modeling evidence for ozone pollution in Asia

Hajime Akimoto
Frontier Research Center for Global Change (FRCGC)
Japan Agency for Marine-Earth Science and Technology (JAMSTEC)

There has been an increased concern on tropospheric ozone in Asia due to its climate sensitivity and toxicity on human health and vegetation. However, observational data of ozone in Asia is rather limited: among the WMO GAW and EANET stations the number of stations reporting surface ozone concentration is only a few outside of Japan. Most of other observations has been carried out on a project base and not necessarily continuous. Nevertheless, many important features of the spatial and temporal variability of ozone has been extracted from such research-based observational data.

The characteristic features of seasonal variation of surface ozone in Asia obtained by previous studies may be summarized as follows:

1. East Siberia (Mondy): Spring (April) maximum, shallow summer minimum
2. North East Asian outflow region (Japan) : Spring (March-April) maximum, autumn second maximum and summer minimum
3. Eastern China (Mt. Tai, Mt. Hua): Summer (June) maximum, autumn second maximum, winter minimum, summer second minimum
4. Central China (Waliguan): Summer (June) maximum, winter minimum
5. Central Asia (Isskykul): Summer maximum, winter minimum
4. South China (Hong Kong): Autumn Maximum, spring second maximum, summer minimum
5. Continental Southeast Asia (Thailand): Early spring (February-March) maximum, deep summer minimum
6. South India (Gadanki): Early spring (February-March) maximum, summer minimum

Much regional representative data is necessary particularly for India and other part of China and Central Asia. Some comparison with model output will be presented.

APN ozone dataset: what we know about ozone characteristics in Asia based on 15 regional sites

Pakpong Pochanart
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Scientific evidences from observation, global and regional CTM studies, and satellite data analysis, revealed that the large-scale anthropogenic emissions and the ozone pollutions over East Asia are rivals to Europe and North America, and will be much larger from now on. At the same time, there are still remote regions in Asia where the anthropogenic emissions appear not to be significant. To gain insight on Asian ozone characteristics, this APN- Akimoto project was initiated.

Ozone dataset from 15 monitoring stations in Asia have been compiled, mainly based on year 2004. These data have been collected from measurements at representative sites made by APN collaborators, and from selected sets of representative data available from Acid Deposition Monitoring Network in East Asia (EANET) and World Data Center for Greenhouse Gases (WDCGG). Our APN ozone dataset and can be classified as regional and rural categories, and are critical for the identification of the Asian ozone characteristics in Eurasian perspective. In this work, these data are investigated. I will report the details, coverage, and the availability of the APN ozone data focusing on the seasonal cycles, diurnal variations, and long term trend of ozone for the available sites.

Impact of urban pollution on ozone and PAN concentrations on the background atmosphere of western China: Preliminary results from the 2006 summer field campaign at urban Lanzhou and remote Mount Wualiguan

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Ozone (O3), PAN, and other trace gases were measured during summer 2006 at Lanzhou (June 19-July 17) and Mt Wualiguan (July 21-August 16). The objectives were to study urban photochemical pollution in an interior city, Lanzhou which was once the most polluted city in China, and the impact of urban/regional pollution on the remote atmosphere of western China. Another objective of the Mt Wualiguan study was to confirm the 2003 result and to better understand the budget and source of reactive oxidized nitrogen.

The measurements in a suburban area of Lanzhou indicate a strong influence of the boundary-layer development on the levels of various air pollutants in this valley-situated city. Urban emissions were frequently sampled during morning while regional air masses were often measured during late afternoon after changes in wind directions. There were four days with 1-hr O3 exceeding 120 ppbv, with highest PAN level of ~ 9 ppbv.

The 2006 data at Mt Wualiguan appeared to be different from those obtained in summer 2003. There was clear evidence in transport of anthropogenic pollution (from Lanzhou) to Mt Wualigan in 2006 while no such evidence was indicated in the previous study. The PAN concentrations (mean=0.44 ppbv) at Mt Waliguan were similar to those measured during afternoon and nighttime at Lanzhou.

Transformation of gaseous and particulate nitrogen oxides during the transport of air from China to Okinawa, Japan

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A new station (Cape Hedo Atmosphere and Aerosol Monitoring Station: CHAAMS) has been established in Okinawa at the northern tip of the main island. We have carried out the aerosol measurement in order to understand the chemical composition and the chemical transformation of aerosol in East Asia. In this presentation the results of NO3- measurements made at Cape Hedo in the year of 2006 are shown.

Observations were all carried out at CHAAMS which is situated at the north end of Okinawa Island (128.25E, 26.87N, 60 m asl). There is no large industrial area near the observation site. The average temperature is 21 °C and the relative humidity is about 75 %. The station was renewed and expanded in June, 2005 and in January, 2007.

Measurements of aerosol chemical composition were made by use of an aerosol mass spectrometer (AMS, Aerodyne). By use of AMS aerosols of PM1 size range can be measured. PM10 NO3- was measured with a nitrate monitor (R & P 8400) equipped with a PM10 impactor for removal of particles larger than 10 _m. The data taken simultaneously at Cape Hedo such as total NOy and gaseous HNO3 concentrations (data provided by Prof. Bandow of OPU) and NOx concentrations (data provided by MoE, Japan) were also used for analyses.

Figure 1 shows the variation of total NOy, gaseous nitrogen (NOx + HNO3g) and particulate nitrate (PM10 NO3-) measured in March-November, 2006 at CHAAMS. High concentration peaks of NOy were seen in spring. Concentration of NO3- also showed peaks simultaneously. Back trajectories clearly suggested that those high concentrations of pollutants were transported mainly from China.

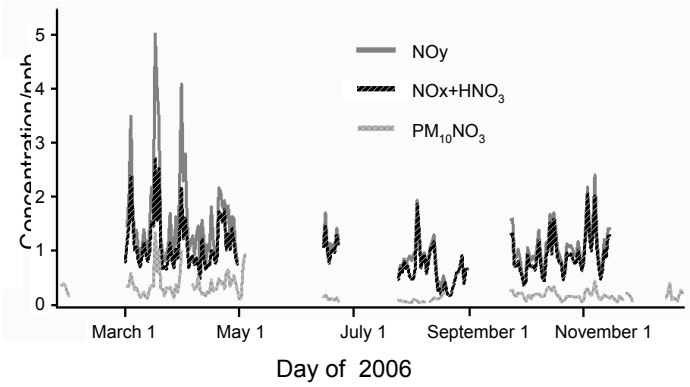

Figure 1. variation of NOy, NOx + HNO_3g, and NO_3 (PM_{10}).

As shown in Fig. 1 NOy and NO3 are relatively high in March and April, whereas they are low in summer. This is also due to the difference of air mass origin. Back trajectory analyses showed that air masses come from the Pacific Ocean in summer, while they come from the continent in spring. Origins of pollutants are clearly different in two seasons.

Oxygenated nitrogen is distributed between gases (NOx (= NO + NO2) and gaseous HNO3) and particles. Changes of the fraction of gases and particles depend on the temperature following the thermal equilibrium, i.e., NH4NO3 ⇔ NH3 + HNO3. The fraction of particles is relatively high in spring. In summer the fraction of particles is low possibly due to the decomposition of NH4NO3 during the long range transport.

When NH4NO3 decomposes, resulting HNO3 gas can be adsorbed on coarse

particles such as sea salts and dust particles. Therefore, the longer the transport at relatively high temperature the larger the fraction of particulate NO3- becomes and the larger the fraction of NO3- contained in coarse particles becomes. Accordingly, the smaller the fraction of gaseous nitrogen oxides and the smaller the fraction of NO3- contained in fine particles becomes. Such situation was clearly observed at Hedo, Okinawa.

Variability in surface ozone and related trace gases at Mt. Abu in India

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Measurements of surface ozone have been made at Mt. Abu (24.6N, 72.7E, 1680m amsl) throughout the year 2000. This location is just above the planetary boundary layer particularly during night and winter season. Ozone levels at such a high altitude site are mainly maintained by horizontal as well as vertical transport. These measurements were made using a standard ozone analyzer based on UV absorption technique. These measurements show both diurnal as well as strong seasonal variations. There is a slight decrease in ozone amount during the midday. This is contrary to the daytime increase observed at Ahmedabad, a urban site. The levels of precursors like CO, NO and NMHCs at this site are very low.

Highest average ozone (about 54 ppbv) is observed in the month of October. Monsoon season (June, July and August) shows the lowest ozone of about. This is due to the cleaner south-west winds from the Arabian Sea. Higher O3 levels in October and November are as a result of its production by photochemistry at local scale under sluggish wind conditions. Long range transport of air from West Asia, North Africa and Europe are observed in winter months (December, January and February) at this site. The O3 levels at Mt Abu in winter are not significantly different than the O3 levels at high altitude tropical station at Mauna Loa and mid-latitude station at Mt Fuji. The difference in O3 levels due to transport of air at local scale (October) and regional scale (winter) is about 12 ppbv. The O3 variations in different seasons and its transport in different wind conditions will be presented and discussed during the meeting.

Role of Chemistry/Transport on surface ozone at Darjeeling

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The characteristics of surface ozone monitored continuously at Darjeeling (27.01N, 88.25E, msl: 2196 meter) in the Eastern Himalayas for the period of 2004-2006 are reported. The relative importance of long range transport and conventional photochemistry in controlling surface ozone concentration is discussed. Averaged surface ozone concentration at Darjeeling is 45 ppbv with a range from 20 to 130 ppbv. Such high surface ozone concentrations are rarely observed at other sites in India.

Surface ozone in the surroundings of Darjeeling is also of the order of the 45 ppbv, which indicates that horizontal advection is not the primary source of ozone at the observing site. The possibility of long range transport of surface ozone and precursor gases is also examined by calculating seven days backward trajectories using the HYSPLIT4 model. The surface ozone concentration computed by the MATCH-MPIC model is higher than the observed mean value, but within the variability of observed ozone concentrations, reproducing the basic photochemistry and key features in the O3 distribution in this region.

Ozone Monitoring and Research Activities in Malaysia

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Ozone monitoring and research activities in the Malaysian Meteorological Department (MMD), Ministry of Science, Technology and Innovation began in the year 1991 with the establishment of vertical ozone profile measurements at the Petaling Jaya Meteorological Station using ozone sondes launched twice a month. The following year, monitoring activities were expanded to include measuring total column ozone and UV radiation with the installation of a Brewer Spectrophotometer at the same station. To complete the whole range of ozone measurements, a surface ozone analyzer was installed at the Tanah Rata Regional Global Atmosphere Watch (GAW) Station in 1997. This instrument was later upgraded to a multi-gas analyzer system in 2004 which not only monitors surface ozone but other critical air pollutants such as oxides of nitrogen, sulphur dioxide and carbon monoxide. With the establishment of a new Baseline GAW station in Danum Valley in 2004 by the MMD, surface ozone measurements were initiated at this specialized station in December 2006.

The main objectives of the ozone monitoring activities of the MMD are to detect long term changes to support the Montreal Protocol Scientific agenda and regional and global research activities. As a member of the World Meteorological Organization, ozone and UV data from the measurements made by the Brewer Spectrophotometer and the ozone sonde since 1992 are submitted to the Ozone World Data Centre in Toronto, Canada.

With the current available ozone and UV monitoring systems in Malaysia, the MMD is involved in a number of research projects and among them are the Asian Ozone Pollution in Eurasian Perspective project and the Southern Hemisphere Additional Ozone Sondes (SHADOZ) project. The former project examines the spatial distribution and temporal variability of ozone, an important atmospheric constituent in the troposphere, which is an effective greenhouse gas and a toxic substance for human health and vegetation. It aims to get a perspective of surface ozone in Asia and to discuss how it is affected by human activity by clarifying both intra- and inter-continental long-range transport over the Eurasian continent. While SHADOZ is designed to remedy data discrepancy of a number of stations that are operating in the southern hemisphere tropics and subtropics which has differing frequency and reporting procedures. SHADOZ achieves its aims by coordinating launches, supplying additional sondes in some cases, and by providing a central archive location. Data will be collected in a timely manner and will be available through its website to the SHADOZ and TOMS Science Teams, as well as to the scientific community as a whole.

Going forward, plans are being made to encourage local scientists and

researchers to actively participate in the atmospheric environment programs of the MMD. The MMD is also seeking partnership with interested parties and organizations to further improve and develop ozone measurements at its monitoring sites and to participate actively in research activities.

Future Prediction of Surface Ozone over East Asia using the Models-3 Community Multi-scale Air Quality Modeling System (CMAQ) and the Regional Emission Inventory in Asia (REAS)

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Tropospheric ozone (O_3) over East Asia in the present and future has been simulated by the Models-3 Community Multi-scale Air Quality Modeling System (CMAQ) coupled with Regional Emission inventory in Asia (REAS) to predict the surface O_3 variations caused by future anthropogenic emission changes. REAS is available at http://www.jamstec.go.jp/frcgc/research/p3/emission.htm. For future predictions, REAS provides three emission scenarios for China, the reference (REF), the policy succeed (PSC), and the policy failure (PFC) cases and one emission scenario, the REF for other countries. The monthly-averaged O_3 concentration in summer was relatively high (70-80 ppbv in June and 65-75 in August) over the North China Plain in the year 2000. The projected REF emissions for the year 2020 enhance the O_3 concentration to 75-90 ppbv in June and 75-85 in August. The projected PSC emissions for the year 2020 with a little NOx reduction and a large NMVOC increase during the period, 2000-2020, caused O_3 concentrations to decrease in northeastern and central China. Meanwhile, the projected PFC emissions for the year 2020 bring about significant increases in the monthly-averaged O_3 concentration of more than 20 ppbv (1 ppbv yr-1 growth) in the North China Plain. Surface O_3 concentration under the PFC scenario is increased by 6-8 ppbv over the Korean peninsula and by 2-6 in Japan during 2000-2020 in spite of a reduction of NOx in Japan. At midday in June over central eastern China (CEC), these model experiments show that O_3 concentration is largely affected by NOx emission increases but is not sensitive to NMVOC emission increases.

Development of the urban-scale chemical weather forecasting system

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We present an evaluation of the distribution of ozone over Kanto region, calculated by using a one–way nested global/regional air quality forecasting (AQF) system. This AQF system consists of the global chemistry–transport model (CTM) part and the regional CTM part. The global CTM part is based on CHASER (chemical atmospheric general circulation model for study of atmospheric environment and radiative forcing), and the regional CTM part is based on WRF (weather research and forecasting) / Chem. An experimental phase of this model system began operation in July of 2006 and has been providing 15–hour forecasts of the distribution of ozone concentrations over Kanto region four times in a day. The time-evolution and horizontal distribution of chemical species calculated by this AQF system were compared to ground–based observations. About 83% of stations in

Kanto region (251 stations) showed 0.70 or higher for the correlation coefficient between forecasted and observed ozone.

Diagnosis of Urban Air Quality by OH Ractivity Measurement

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Measurements of OH reactivity provide very important information to verify our knowledge of atmospheric photochemistry. To realize this we developed an instrument to measure a lifetime of OH radical in ambient air by laser-induced pump and probe technique. OH radicals are generated in the photolysis of ozone by 266 nm laser. Decay of resultant OH is monitored by LIF-FAGE technique using 308 nm laser. Total OH reactivity which is inverse of lifetime was measured in the ambient air in Tokyo using the developed instrument in order to test the utility of the instrument. It demonstrated that the instrument is practically running well and we succeeded to observe OH reactivity through the year in Tokyo.

To test our knowledge we have measured OH reaction partners as many as possible simultaneously. Calculated OH reactivity was obtained by the concentrations of NO_x, CO, O_3, NMHCs (non-methane hydrocarbons) and OVOCs (oxygenated volatile organic compounds) measured. In wintertime we found very nice agreement of OH reactivity between observed and calculated one. However, other seasons usually observed OH reactivities are higher than calculated during spring, summer, and fall. These suggest that the secondary products by the photochemical reactions in the atmosphere would be a missing sink for the OH loss process.

The yield of peroxy radicals per an initially produced (ex. ozone photolysis) OH radical by the chain reactions is a very effective parameter to discuss ozone production in the urban atmosphere in terms of the air quality (i.e. the pollutant concentrations such as NO*x*, CO and VOCs). We defined this yield as the oxidant potential, Y. Since the oxidant potential is the yield of peroxy radicals per one OH radical by the chain reactions, Pozone, production rate of ozone is expressed as a product of initial concentration of OH and Y. We calculated Y values by simple box model in the case of including the unknown species as VOCs and excluding the missing sink, respectively. When the unknown species were included as VOCs, the potential increases from 32 % to 88 %. This result indicates the photochemical production rates of ozone in the urban air are substantially greater than expected. Finally we demonstrate that the measurement of OH reactivity in the urban atmosphere provides very useful information in order to diagnose comprehensively the urban air quality in terms oxidant formation.

Urban photochemistry in central Tokyo:
Rates and regimes of oxidant production in winter and summer

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Net photochemical production rates of oxidant (O_x = O_3 + NO_2), *F-D*(O_x), were determined in Tokyo during the winter and summer of 2004 using observed and calculated HO_2 radical concentrations. The rates calculated using the two datasets

are similar. In summer, morning *F-D*(O_x) values on smog days (those with midday O_3 concentrations exceeding 100 ppbv) were higher than those on smog-free days (with typical midday O_3 concentrations of 30 ppbv); however, the amount of ozone produced in a single day, as estimated by integrating *F-D*(O_x) over the daytime, was not significantly different for the two periods. This analysis suggests that the occurrence of smog events in the city center cannot readily be explained by day-to-day variations in the strength of *in situ* photochemistry. On smog days, the coupling of photochemistry and meteorology appears to be important, as air masses in which oxidants accumulated over successive days arrive at the city center at approximately midday, transported by land–sea breeze circulation.

The average maximum daytime *F-D*(O_x) in summer, 11–13 ppbv h^{-1}, was only < 2.5 times higher than that in winter (6–8 ppbv h^{-1}). In winter, an underestimation of HO_2 levels at high NO concentrations resulted in an underestimation of *F-D*(O_x) when calculated using modeled HO_2. While the model predicted a volatile-organic compounds (VOC)-limited regime for O_x production in winter, *F-D*(O_x) based on observed HO_2 did not show features of the VOC-limited regime and only steadily increased with increasing NO mixing ratio, even when it exceeded 20 ppbv. In summer, the dependence of *F-D*(O_x) on non-methane hydrocarbons (NMHCs) and NO_x concentrations was similar in the two cases, in which observed and calculated HO_2 levels were used. A VOC-limited regime, predicted on smog-free days, changed to a NO_x-limited regime on smog days.

MAX-DOAS: the new ground-based measurements of NO_2 and aerosols

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Recently, satellite observations revealed that a highly significant increase in the tropospheric nitrogen dioxide (NO_2) column abundance has occurred over the industrial areas of China since 1996. However, an important question remains to be addressed as to the validity of satellite tropospheric NO_2 data in East Asia, including China, owing to the lack of satellite-independent measurements in polluted regions. We have performed such satellite-independent observations of the tropospheric NO_2 using a ground-based Multi-Axis Differential Optical Absorption Spectroscopy (MAX-DOAS) instrument at several sites in Japan and China since January 2005. Our MAX-DOAS measurements were found to have the capability of measuring not only NO_2, but also aerosols in the lower troposphere. We highlight some results obtained so far, focusing on the temporal variation of NO_2 and aerosols and the satellite validation.
