Stratospheric Ozone Observations in Korea

Hi-Ku Cho, Joon Kim and Sung-Rae Chung

Global Environment Laboratory, Dept. of Astronomy & Atmospheric Sciences
Yonsei University, Seoul, Korea

(Manuscript received 18 November 1996)

Abstract

The ozone layer monitoring program of the Global Environment Laboratory at Yonsei University in Seoul, established as one of the Global Ozone Observing System(GO_3OS) of the World Meteorological Organization(WMO), has been carried out daily by measuring total ozone and its vertical distribution using a Dobson Ozone Spectrophotometer(Beck #124) since 1984. In this paper, we review the organization and the historical background of ozone measurements in Korea, describe data acquisition and anaysis systems, and briefly summarize the results from our ozone observations.

1. Introduction

Ozone is the primary absorber of the ultraviolet(UV) radiation and thus, its layer protects the earth's biosphere against the harmful UV radiation from the sun. The absorption of UV radiation by the ozone layer results in increasing temperature, thereby forming the stratosphere. Consequently, the ozone layer plays a significant role in thermal structure, atmospheric circulation and global climate.

Recent concerns regarding anthropogenic depletion of stratospheric ozone have increased the need for precise and accurate measurements to monitor long term trends in this species. The 28th session of the World Meteorological Organization(WMO) Executive Committee approved the Global Ozone Research and Monitoring Project in June 1976. Then, the United Nations Environment Program (UNEP) made recommendations for a worldwide plan of action for the ozone layer research in March 1977. Subsequently, international efforts

to protect global ozone layer resulted in the Vienna Convention in 1985 and the Montreal Protocol in 1987. According to these international protocols and for preservation of the ozone layer, it has been necessary to monitor and study the ozone layer over Korea.

The ozone monitoring program of the Global Environment Laboratory(GEL) at Yonsei University in Seoul (37.6° N, 127.0° E) has begun since May of 1984 using a Dobson ozone spectrophotometer (Beck#124). The Dobson instrument is located on the roof of the Science Building at Yonsei University. The ozone station of the GEL was established as one of the WMO's global ozone observing stations. The observed data have been submitted to the World Ozone Data Center in Toronto, Canada, on a bimonthly basis. Here we review the overall ozone measurement systems in Korea during the period of 1984 through 1996, describe the data acquisition and anaysis systems, and summarize the results from our observed ozone data.

2. Organization, History and Observation

Ozone observation in Korea is carried primarily by the two agencies: Global Environment Laboratory at Yonsei University and Korea Meteorological Administration (KMA). The former is equipped with a Dobson spectrophotometer whereas the latter is equipped with a Brewer spectrophotometer and ozone sonde facilities. Other organizations that have recently involved in ozone monitoring in Korea include: Institute for Laser Engineering (ILE) at Kyung Hee University (using a Light Detection and Range -, LIDAR) and Korea Ocean Research and Development Institute (KORDI) (using a Brewer spectrophotometer).

Yonsei University: Ozone layer observation has been carried by members in the Atmospheric Ozone Research Division of the GEL, which is housed in the Department of Astronomy and Atmospheric Sciences at Yonsei University in Seoul, Korea. The Ozone Research Division has been designated as the station # 252 of the WMO/GO$_3$OS. At least one of the six members in the Division always stays at the station for routine observations and calibrations. Total ozone and its vertical distribution have been measured since May 1984 and February 1986, respectively. Total ozone has been measured at least twice a day when the relative optical air mass(μ) is between 1.5 and 2.5. On clear days, observations of AD-DSGQP (AD - wavelength pairs: A pair λ_1 = 305.5 and λ_2 = 325 nm, D pair λ_1 = 317.5 and λ_2 = 339.9 nm on direct sun using ground quartz plate) and AD-ZB(AD wavelength pairs on zenith blue sky) are used. On cloudy days those of AD-ZC(AD wavelength pairs on zenith cloud) are used. The Umkehr observation of vertical ozone profile has been made on clear days using the wavelength pair C(λ_1 = 311.5 and λ_2 = 332.4 nm), when the solar zenith angle is between 60 and 90 degrees.

A summary of the measurement history is given below:

1. 7 May 1984: The first measurement of total ozone was made with a Dobson ozone spectrophotometer (Beck #124) using the wavelength pair L=AD. This preliminary pilot observation continued until the end of 1984.

2. Jan. 1985 - Mar. 1991: Routine measurements of total ozone were carried out using the wavelength pair L=AD and $\mu=1.5\sim2.5$).

3. Feb. 1986 - Mar. 1991: Routine measurements of vertical ozone distribution were carried out using the Umkehr method with the wavelength pair L=C.

4. Apr. 1991 - Aug. 1991: Calibration of the Dobson spectrophotometer (Beck #124) was made against the world standard (Beck #65) at NOAA, ERL in Boulder Colorado, USA. (During this period, the phototube system of the Beck #124 was changed with an electronically controlled system).

5. Sep. 1991 - present: Routine observations of total ozone and the vertical distribution were resumed. Every two months, the observed data have been sent to the World Ozone an UV Data Center (WOUDC) in Toronto, Canada.

6. August 1993 - present: Measurement of UV-B (280-320 nm) radiation has been added to the monitoring program.

7. January 1996 - present: Measurement of UV-A (320-400 nm) radiation has started.

8. 27 February - 26 March 1996: Intercomparison and calibration of the Dobson spectrophotometer (Beck #124) were made against the regional standard (Beck #116) at the Aerological Observatory of Meteorological Research Institute in Tsukuba, Japan during the WMO Regional Comparison Campaign of the Dobson Ozone Spectrophotometers.

Korea Meteorological Administration (KMA): Total ozone and the vertical ozone distribution have been measured using a Brewer spectrophotometer at the Pohang Upper-Air Observatory (36.0° N, 129.4° E) since January of 1994. Also, Electrochemical Concentration Cell (ECC) ozone sonde measurement has been initiated since January of 1995 on a weekly basis. The ozone sonde data are important in validating other data such as Brewer umkehr data and satellite observed data. These ozone data will be reported to WOUDC regularily.

Other Institutes: Korea Ocean Research and Development Institute (KORDI) recently initiated ozone observation with a Brewer spectrophotometer at Ansan, Korea. Total ozone and the vertical distribution have been monitored since August in 1996. This Brewer spectrophotometer will be installed at the King Sejong station (62.2° S, 58.8° W) located at the South Pole in 1997 to monitor antarctic ozone variations. Institute for Laser Engineering (ILE) at Kyung Hee University has been operating the prototype DIAL-LIDAR for ozone profile measurements at Kyung Hee Suwon campus since 1992. Vertical ozone profile is measured over the altitude of 5~35 km with an altitude resolution of 250 m.

3. Brief Results on Ozone Observations with Dobson Spectrophotometer

Recently, the Global Environment Laboratory at Yonsei University published a report - Ozone Layer Monitoring over Korea: 1985-1994 [*Cho*, 1996] . The following is the brief summary of the statistical results from this report. The data collected from January 1985 through December 1994 are shown in Fig. 1. Monthly average of the total ozone during this 10-year period (1985~1994) averaged about 319 Dobson Unit (DU). The maximum monthly averaged value was found in March (353 DU) and the minimum in October (288 DU) (see Fig. 2). These results are in good agreement with those obtained from the Tsukuba ozone station (which is located in similar latitudes) in Japan during the similar period [*Japan Meteorological Agency*, 1996] .

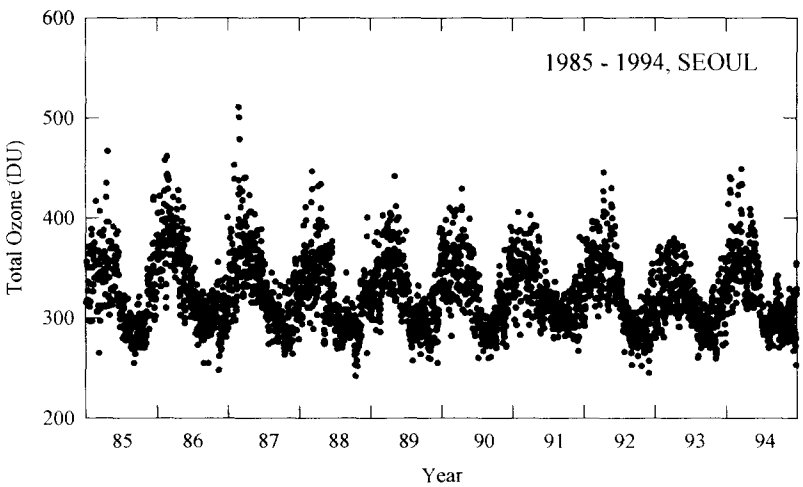

Fig.1. Temporal variation of daily total ozone.

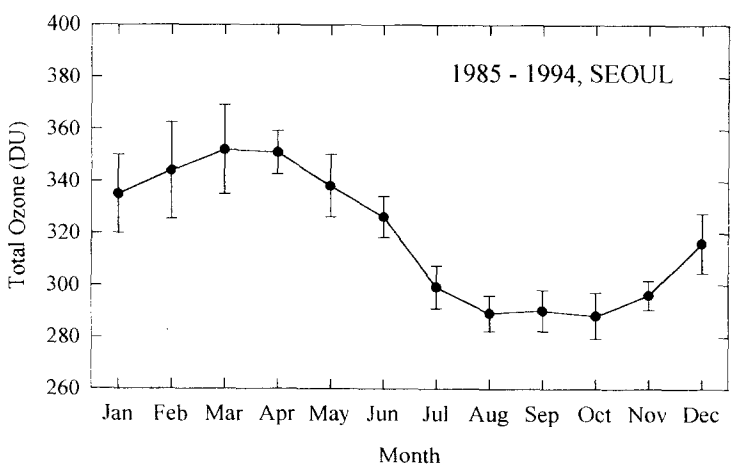

Fig.2. Annual variation of monthly mean total ozone.(Bar means standard deviation.)

The vertical distribution of atmospheric ozone over Seoul has been analyzed using the Umkehr observations for the same period. The maximum ozone concentration occured at the altitude of 22km with an average of 17 DU/km (Fig. 3). The altitude of maximum concentration appears to vary with season and the total ozone tended to decrease with increasing altitude.

Variations in the total ozone over Seoul area were also examined from 1978 to 1992. When the Dobson measurements were not available, we used the data from the Nimbus 7 satellite/Total Ozone Mapping Spectrometer(TOMS) based on the strong correlation found between the two measurements [*Cho et al.*, 1994]. On a long term basis, the total ozone showed approximately 3.8% decrease per decade. On a seasonal basis, the rate of decrease per decade was greatest (4.9%) in winter and least (1.7%) in fall [*Cho et al.*, 1994]. The power spectrum analysis indicated that the annual and quisi-biennial (QB) and 4 month oscillations explained about 50%, 0.5% and 0.3% of the data variance, respectively.

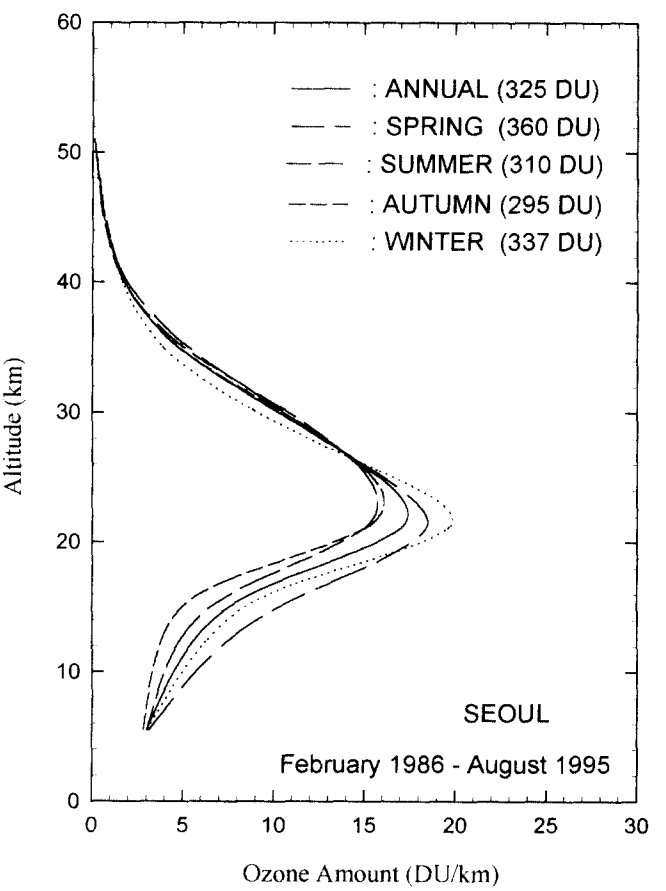

Fig.3. Annual and seasonal distributions of vertical ozone at Seoul.

4. Quality Assurance: Instrument Calibration and Intercomparison

As indicated above, the Dobson spectrophotometer(Beck #124) at Yonsei University was calibrated in 1991 against the world standard instrument (Beck #65) at NOAA/ERL in Boulder, Colorado, USA. Traveling standard lamp tests were made twice during November-December in 1985 and during the period from November in 1991 to February in 1992. Result of 1985-1987 calibration checks on Dobson instrument (Beck #124) using traveling standard lamp was +1.17 [*NOAA/ERL*, 1987] . Also, on a regular basis, we have been performing primarily two kinds of calibration: (1) mercury lamp test and (2) standard lamp test. The mercury lamp test has been made once a month and the standard lamp test has been made twice a month. We have followed the instructions given in the WMO Operations Handbook [*Komhyr*, 1980] and, therefore, the detailed information on these calibration procedures are not presented here.

Some of the recent calibration results are presented in Figs. 4 and 5. The differences in Q (or wavelength) value between the table and the mercury lamp test are shown in Fig. 5 for the period of 1993-1996. The bulk of the data were distributed within the acceptable range (±0.3 degree). When the difference in Q larger than ±0.3 occurred, the Table of Settings of Q was corrected appropriately. For the same period, the calibration results on the standard lamp test for the three different wavelengths are shown in Fig. 5. The distribution of the data suggests that the level of the calibration of the spectrophotometer has been remained relatively constant during this period.

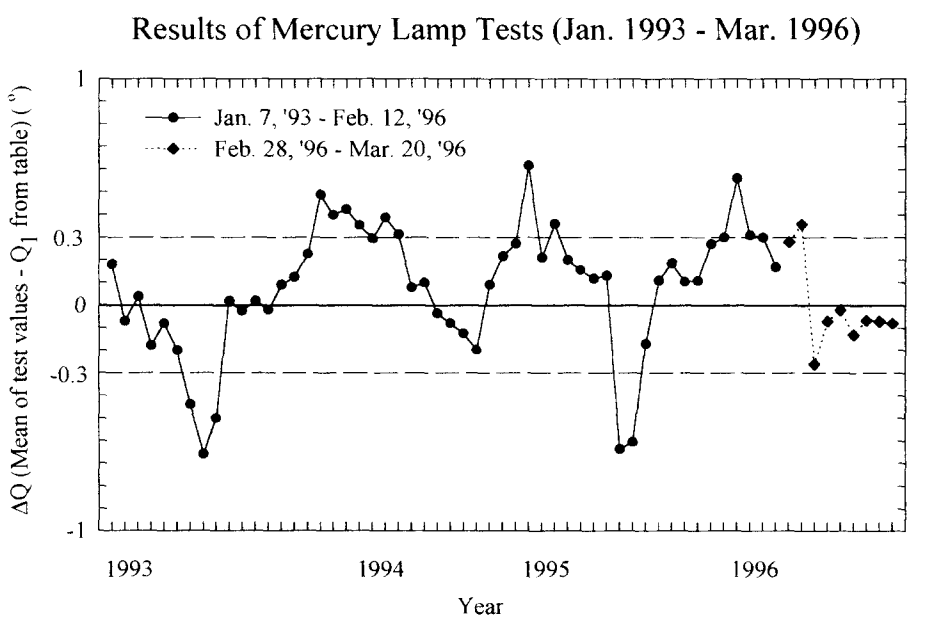

Fig.4. Calibration results of the Dobson Ozone spectrophotometer(#124)from the mercury lamp tests during Jan. 1993 - Mar. 1996.

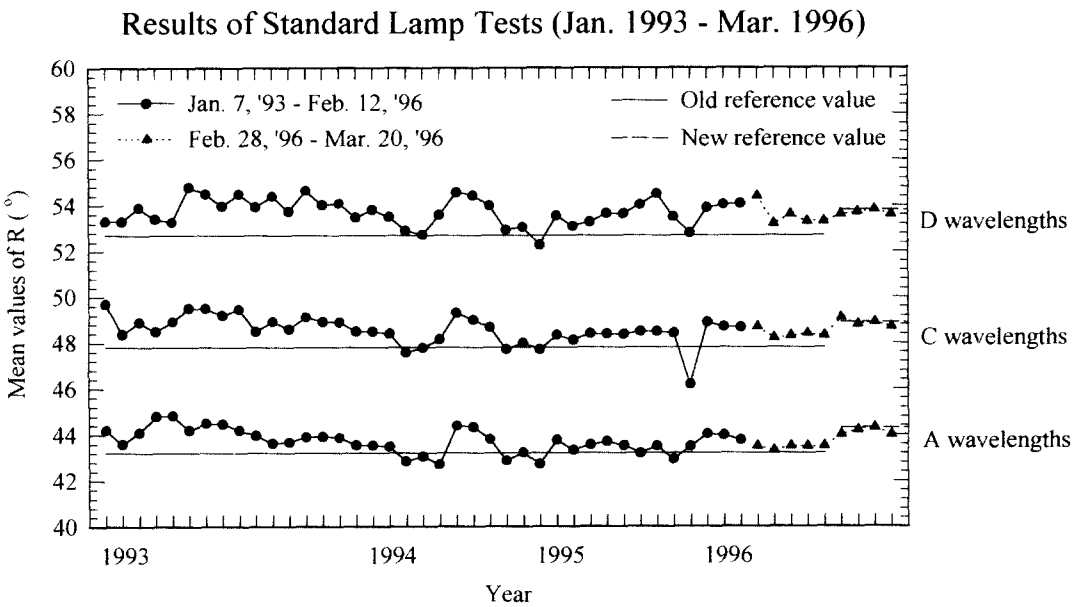

Fig.5. Same as Fig.4 except for the standard lamp tests.

It is worth mentioning about the results from the WMO's international campaign of intercomparison and calibration of Dobson spectrophotometers in Asia and the Pacific region (held in Tsukuba, Japan during 27 February-26 March 1996). The results of the initial intercomparison indicated that the ozone values from the Beck #124 were 2.5% higher than the regional standard (Beck #116). After a series of calibrations and tests such as mercury lamp test, standard lamp test, 2-lamp test, discharge lamp test, the comparison between the Beck #124 with the regional standard resulted in better agreement. The result of the final intercomparison showed that the difference between the two for AD-DSGQP observations was within 0.1% with μ values of 1.15-2.5, and 0.9% for μ values of 2.5-3.2 [*Chung*, 1996].

5. Data Management and Analysis System

At Yonsei University two types of field logbooks are maintained: one for total ozone observation and the other for the Umkehr observation. Typically, the total ozone is measured twice a day when the solar zenith angle is around 60 degrees ($1.5<\mu<2.5$). For each observation, we usually obtain two values: one from the AD-DSGQP and the other from AD-ZB. When the station is cloud-covered, the data are obtained from the AD-ZC measurement. Observed data are recorded on the form provided by the WMO for ozone

observation on a daily basis. Both of these data are summarized and bound at the end of the year. The data are also stored in the archive using the computerized system which is consisted of several microcomputers connected through the local network. Several researchers including faculty members, post-doctoral research associate and many graduate-level research assistants are using this system for various analyses. As has been indicated above, the summary of 10-year observation has been compiled and published as a progress report of the GEL at Yonsei University [*Cho*, 1996] . These data are available for public use based upon the request. All the data are submitted to WOUDC every two months and are published in the bimonthly report, "Ozone Data for the World".

6. Concluding Remarks

The high quality data have been produced through the ozone monitoring system using a Dobson spectrophotometer at Yonsei University in Korea since 1984. So far, university has been playing a leading role in ozone measurements. The major difficulty in ozone observation in an academic environment has been the lack of continuous supports from the permanent technical staffs such as professional technicians in electronics, computer system analysis, and data management. For example, ozone research at Yonsei University has been heavily relying on the dedications from a few faculty members and the graduate research assistants supported by external fundings. Rapid increase in interest and strong supports in ozone research by the Korean Government is very promising and will ensure continuous monitoring of quality ozone data in the future.

Acknowledgements

Our thanks go to our graduate students and colleagues in the Department of Astronomy and Atmospheric Sciences for their invaluable contributions to the ozone monitoring. Stratospheric ozone observation using a Dobson spectrophotometer was made possible through the financial supports from the Korean Science and Engineering Foundation, the Ministry of Science and Technology, and the Ministry of Environment of Korea (G-7 Project).

References

Cho, H. K., H. K. Kim, and K. T. Lee, Variability and Trend of Total Ozone over Seoul, *J. of the Korean Meteo. Soc.*, **30**, 219, 1994.

Cho, Hi-Ku, Ozone layer monitoring over Korea: 1985-1994. Global Environment Laboratory, Report 96-1, Yonsei University, Seoul, Korea, 224pp. 1996.

Chung, Sung-Rae, Effects of Lamp Tests and Intercomparison of Dobson Ozone Spectrophotometer on the Accuracy of Observed Total Ozone. M.S. Thesis, Yonsei University, Seoul, Korea, 91 pp. 1996.

Japan Meteorological Agency, International Workshop on Ozone Observation in Asia and the Pacific Region (IWOAP) Proceeding, 27 February-26 March 1996, Tokyo, Japan, 1996.

Komhyr, W. D., Operations Handbook - Ozone Observations with a Dobson Spectrophotometer. *WMO Global Ozone Research and Monitoring Project Report*, 6, Geneva, 125pp. 1980.

National Oceanic and Atmospheric Administration, Geophysical Monitoring for Climate Change, *Summary Report*, 16, NOAA/ERL, Boulder, Colorado, 1987.