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MONITORING REPORT ON GLOBAL ENVIRONMENT

- 1994 -

Center for Global Environmental Research

National Institute for Environmental Studies
Environment Agency of Japan

Foreword

Our attitude and perception for our planet have been largely changed since the industrial revolution, and perhaps since the era of geographic discovery in the sixteenth century. Then there appeared to be no limit to physical horizons. Now that limit has become evident from the observation of global changes.

The information regarding the situation of the global environment is necessary to achieve a consensus among nations for environmental policies. To detect global change early, systematic monitoring with coverage of the entire surface of the earth should be implemented under coordination among nations and reseachers from different disciplines. The resulting precise and accurate measurements should be integrated in a timely fashion into an internationally coordinated database which will be available to the decision makers.

The Center for Global Environmental Research was established in 1990 and started working for monitoring, data management, modeling and their integration. CGER's field of monitoring covers the stratosphere, troposphere, marine and fresh water. Groups of researchers are organized to design and conduct the monitoring. This report contains the results of the Ozone Lidar Monitoring Program and the Japan-Korea Marine Biogeochemical Monitoring Program.

The Center for Global Environmental Research very much appreciates both the research staff of these programs for their long-term and patient measurements and the advisory members for their valuable recommendations on the staffs. Researchers who wish to examine and utilize the raw or primary data are strongly encouraged to contact Monitoring Section of the center.

November,1994

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Yosinori Ishii, Dr.
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Preface

The Center for Global Environmental Research coordinates its own monitoring programs. Each program is implemented by an executive group which consists of core researchers, a technical support unit, advisory members. Core researchers are scientists of the National Institute for Environmental Studies. Initially, the programs are proposed by researchers and evaluated by the steering committee for global environmental monitoring. After a proposal is approved, the program is executed in three phases; a feasibility study for one year, a preliminary monitoring stage for next three years, and a long-term monitoring phase continues for 10 years moreover. When the program goes one phase forward and every 3 years during the long-term monitoring, the progress is evaluated by the steering committee for global environmental monitoring. And each core researcher becomes responsible for maintaining the data quality over the long-term phase.

This monitoring report on global environment (1994) summarizes the data of the Ozone Lidar Monitoring Program and the Japan-Korea Marine Biogeochemical Monitoring Program which has been obtained through November 1993. The reliability of the data was endorsed by a subcommittee organized by the core researchers and the secretariat of the CGER's Monitoring Section. The data will be made available to the public in the monitoring report as soon as the data quality is assured.

November,1994

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Ozone Lidar Monitoring

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Abstract:

Since August 1988, vertical profiles of stratospheric ozone have been observed with a lidar at the National Institute for Environmental Studies (NIES), located at 36°N, 140°E. A few improvements have been made to hardware and software, and comparisons were made between the lidar data and SAGE II satellite data. This ozone lidar measurement was accepted as one of the complementary measurements of the Network for the Detection of Stratospheric Change (NDSC). However, aerosols from the Mt. Pinatubo eruption polluted the stratosphere and disturbed lidar measurements. A preliminary correction of the effects of the stratospheric aerosols was applied, and data obtained during the period June 30, 1991 to December 31, 1993 reanalyzed.

1. Background

The rate of increase of chlorofluorocarbons (CFCs) and halons has decreased in recent years and levels of chlorine and bromine in the stratosphere are expected to decrease in the 21st century. Though the ozone layer is expected to recover gradually in the next century, various nonlinearities and feedback processes associated with future emissions of anthropogenic trace gases could result in ozone and climate change. Therefore stratospheric monitoring is important to observe the state of the ozone layer during the period with maximum chlorine and bromine loading, and to assess our understanding of future ozone conditions, especially recovery processes of the ozone layer.

The Network for the Detection of Stratospheric Change (NDSC) in cooperation with satellite sensors and the WMO Global Ozone Observing System will provide better data sets for both monitoring changes in the ozone layer and understanding their causes. The NDSC consists of high-quality, ground-based, remote-sensing research stations that observe ozone, key ozone-related species and such parameters as temperature. The main instruments being installed are lidars, microwave (millimeter wave) radiometers, UV/Visible spectrometers and FTIR spectrometers. The list of the instruments, species and primary stations is given in the Annual Report on Global Environmental Monitoring -1993 (Nakane et al., 1993a). The NIES recognized the important role of the NDSC and its complementary measurements in Japan. Therefore, the NIES is represented by providing a member of the Steering Committee, and the "NDSC Workshop in Japan", in November 1992, and the "NDSC Lidar Workshop", in August 1994, were held. The NIES ozone lidar measurement was accepted as one of the first complementary measurements of the NDSC. Thus, the NIES have been contributing to the

NDSC through various ways.

The NIES installed an ozone lidar system in March 1988 (Sasano et al., 1989) and has been observing the vertical profiles of ozone since August 1988. Since October 1990, observations have been conducted within the framework of the "Ozone Lidar Monitoring Project" of the Center for Global Environmental Research (Nakane, et al, 1993). Comparisons between the lidar data and SAGE II satellite data were made and agreed well (Nakane et al., 1993b). However, after the eruption of Mt. Pinatubo, data below 30 km were affected by stratospheric aerosols. Therefore, preliminary aerosol corrections were applied to the ozone lidar data, using constant aerosol optical parameters (Nakane et al., 1994). A precision and accuracy check of the data was also carried out.

2. The NIES stratospheric ozone lidar system

The NIES stratospheric ozone lidar system (Sugimoto et al., 1989; Sasano et al., 1989) uses an injection-locked XeCl excimer laser (Lambda Physik EMG160TMSC) as the light source for the on-resonant wavelength (308 nm) and an injection-locked excimer laser, XeF laser, as that for the off-resonant wavelength (351 nm). A Raman shifter with deuterium generates another off-resonant 339 nm laser beam from the 308 nm laser beam. The beams from the XeCl and XeF lasers with three wavelengths are expanded 3.3 times and transmitted to the stratosphere.

Table 1 Specification of ozone lidar

Transmitter		
laser	XeF excimer laser	XeCl excimer laser with deuterium Raman shifter
wavelengths	351 nm	308 nm, 339 nm
output energy	75 mJ	140 mJ, adjustable
pulse repetition rate	250 Hz (maximum)	94 Hz (typical)
beam divergence	0.07 mrad	0.07 mrad
Receiver		
telescope diameter	2 m	
field of view	0.6 mrad (typical)	
filter bandwidth	2 nm	2 nm , 2 nm
total optical efficiency	<20%	<10%, <20%
chopper	750 Hz	
Detectors		
photomultipliers	Hamamatsu R3235 (6 channels)	
gate width	1-200 *ms*	
preamplifiers	100 MHz	
Signal processor		
photon counters	1*ms* gate time, 2048 segments (6 channels)	
Data processor	Toshiba AS 475	

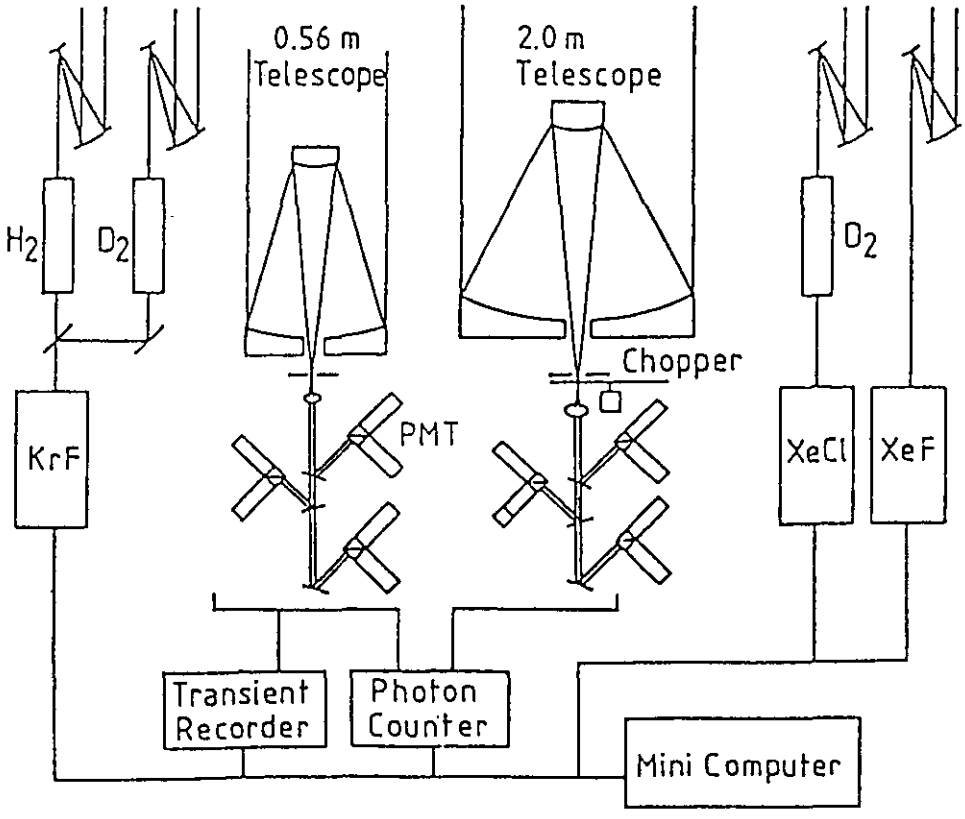


Fig. 1 Block diagram of the ozone lidar (Sugimoto et al., 1989)

The backscattered light is collected by the 2 m telescope and then focused on a chopper blade to cut the strong light scattered at lower altitudes. Formerly, single plano-convex lenses were used just before and after the chopper. These were replaced by achromatic lenses, in June 1990. This gives better alignment and higher accuracy, especially in the lower altitude region. Dichroic mirrors, color glass filters and interference filters are used for wavelength separation. Beams separated are then divided by beam splitters (ratio: 95 to 5 %). The signals from the 95% channel and 5% one are called high sensitivity (HS) and low sensitivity (LS) channels, respectively. These are combined to make signals with a larger dynamic range. The split beams are finally focused on the photomultipliers (Hamamatsu R3235) with electrical gates and pre-amplifiers. Signals are processed with the discriminators, photon-counters. Formerly, data processing and system control was done using a minicomputer (PDP 11/53). A Sun-compatible workstation (Toshiba AS475) has been used since February 1994. Signals at 351 nm have been used for measurements of temperature profiles (Nakane et al., 1992).

3. Calculation of the ozone profiles and diagnosis of the data

A real-time data processing system using a workstation was installed in March 1993

and a software system for further processing in March 1994. Data-checking, aerosol corrections and comparisons with other ozone data can be done interactively using the latter system. The software was developed partly to correct the effects of the aerosols from the Mt. Pinatubo eruption and partly to simplify data-handling.

The vertical profiles of ozone were calculated based on the conventional DIAL equation from the lidar signals;

$$N(z) = \frac{1}{2\{\sigma_{on}(T) - \sigma_{off}(T)\}}\left[\frac{d}{dz}\left\{-\ln\frac{n_{on}(z)}{n_{off}(z)}\right\}+B+E\right]$$

$$B = \frac{d}{dz}\ln\frac{\beta_{on}(z)}{\beta_{off}(z)}$$

$$E = -2\{\alpha_{on}(z) - \alpha_{off}(z)\}$$

where n(z) is the photoelectron number, $\beta(z)$ and $\alpha(z)$ the backscattering coefficient and extinction coefficient owing to aerosols and air molecules at the altitude of z, $\sigma(T)$ the temperature dependent absorption cross section of ozone (Bass and Pauer, 1985; Pauer and Bass, 1985; Cacciani et al., 1989), T the temperature, and N(z) the number density of ozone molecules.

When aerosol effects are negligible in the range of interest, terms B indicates negligible and E is estimated from the air molecule profile. However, the contribution of aerosols to B and E should be accounted for after major volcanic eruptions like Mt. Pinatubo. We assume the power law for the aerosol extinction coefficient $\alpha_1(z,\lambda)$ and the aerosol backscatter coefficient $\beta_1(z,\lambda)$. That is:

$$\alpha_1(z,\lambda) = \alpha_1^0(z,\lambda^0)(\lambda/\lambda^0)^{-\gamma}$$

$$\beta_1(z,\lambda) = \beta_1^0(z,\lambda^0)(\lambda/\lambda^0)^{-\sigma}$$

$$s_1(\lambda^0) = \alpha_1(z,\lambda^0)/\beta_1(z,\lambda^0) .$$

When s_1=10, γ =0, σ=1.0 are used, substantial reduction of systematic errors owing to aerosols is obtained. The sensitivities of ozone profiles with the values of s_1, γ and σ were examined. Only slight changes were found within the range of parameters, s_1=5 - 20, γ=-1 - 1 and σ=0.5 - 1.5. We assumed the value of these parameters as above, and calculated the vertical profiles of the ozone concentration for the data after the eruption of Mt. Pinatubo. Despite the usefulness of this aerosol correction, residual systematic errors remain when there are large amounts of aerosols. Therefore in those case, we set the minimum altitudes of the ozone profiles above the aerosol layers.

Data with statistical errors less than 10 % without systematic errors are archived. Statistical errors for ozone number densities calculated are estimated by assuming that the statistical errors are determined only by the shot noise of the received signals. Usually the

maximum height is limited by the statistical noise. Data with an unusual oscillation larger than 10 % are eliminated. The minimum height is determined by the signal distortion from the effect of the chopper or dead time of the photon counter, which is detected by the ratio between HS and LS signals.

The vertical profiles of ozone after the eruption of Mt. Pinatubo until the end of 1992 are shown in Fig.2.

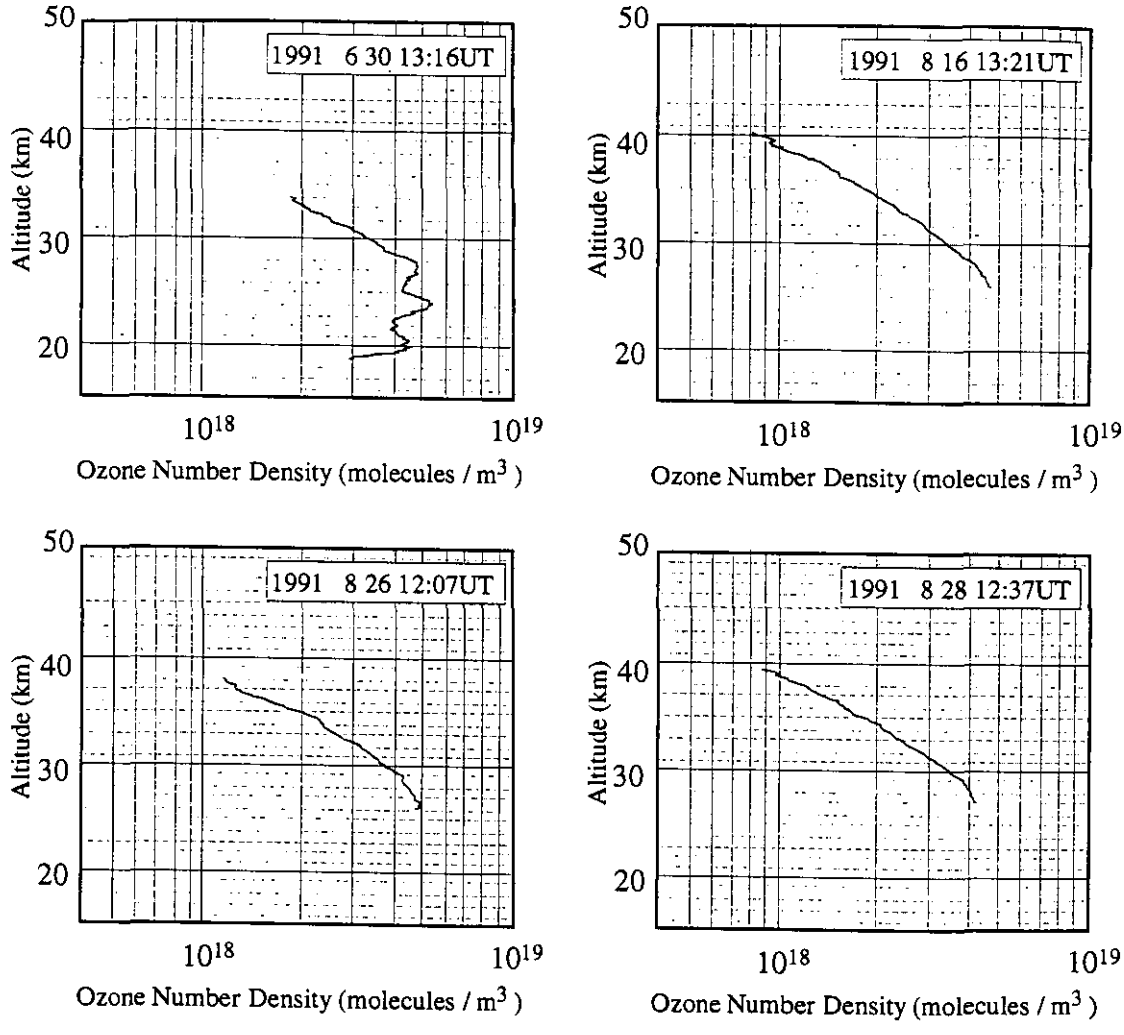


Fig. 2 Vertical profiles of ozone measured with the NIES Ozone Lidar.

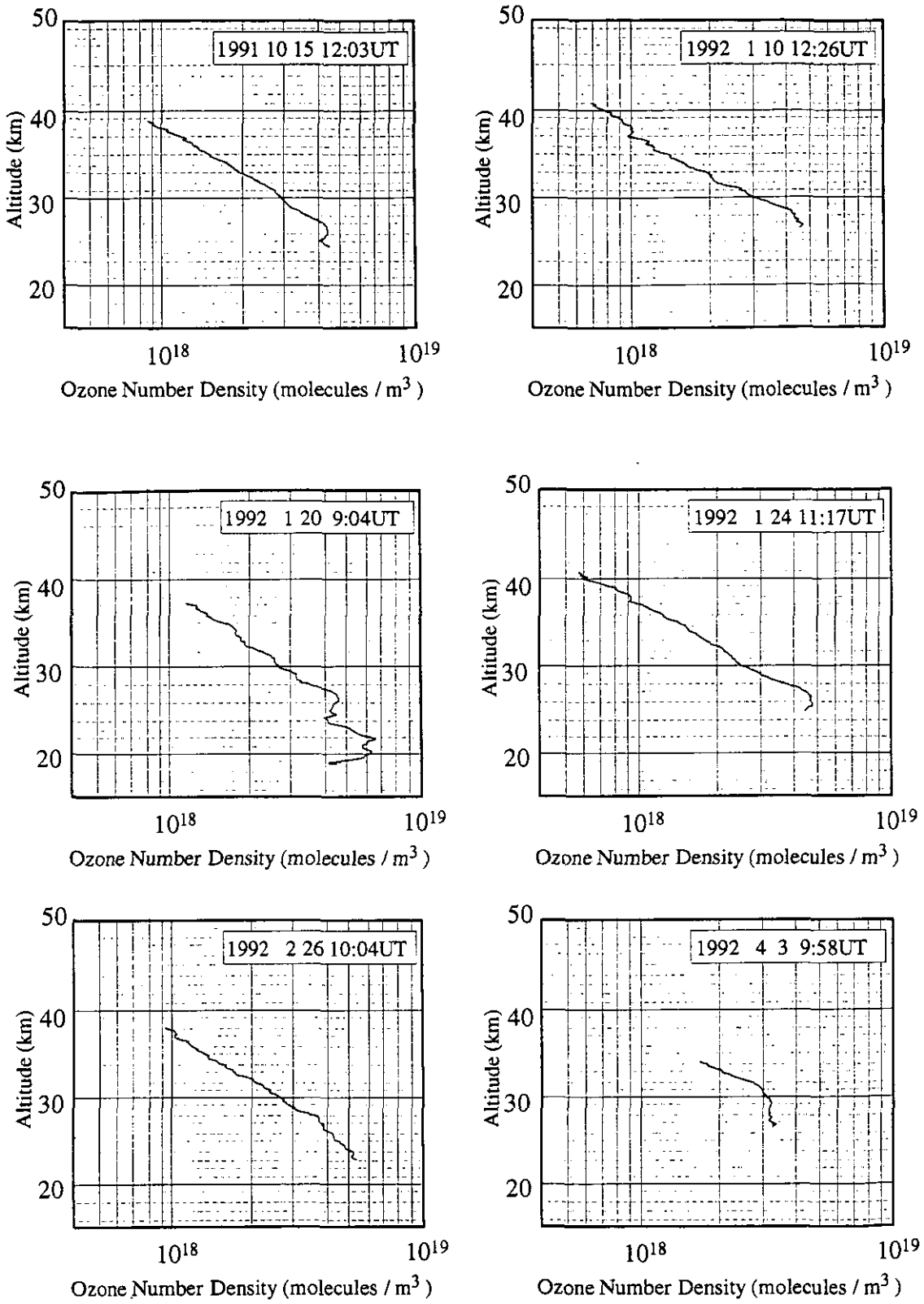
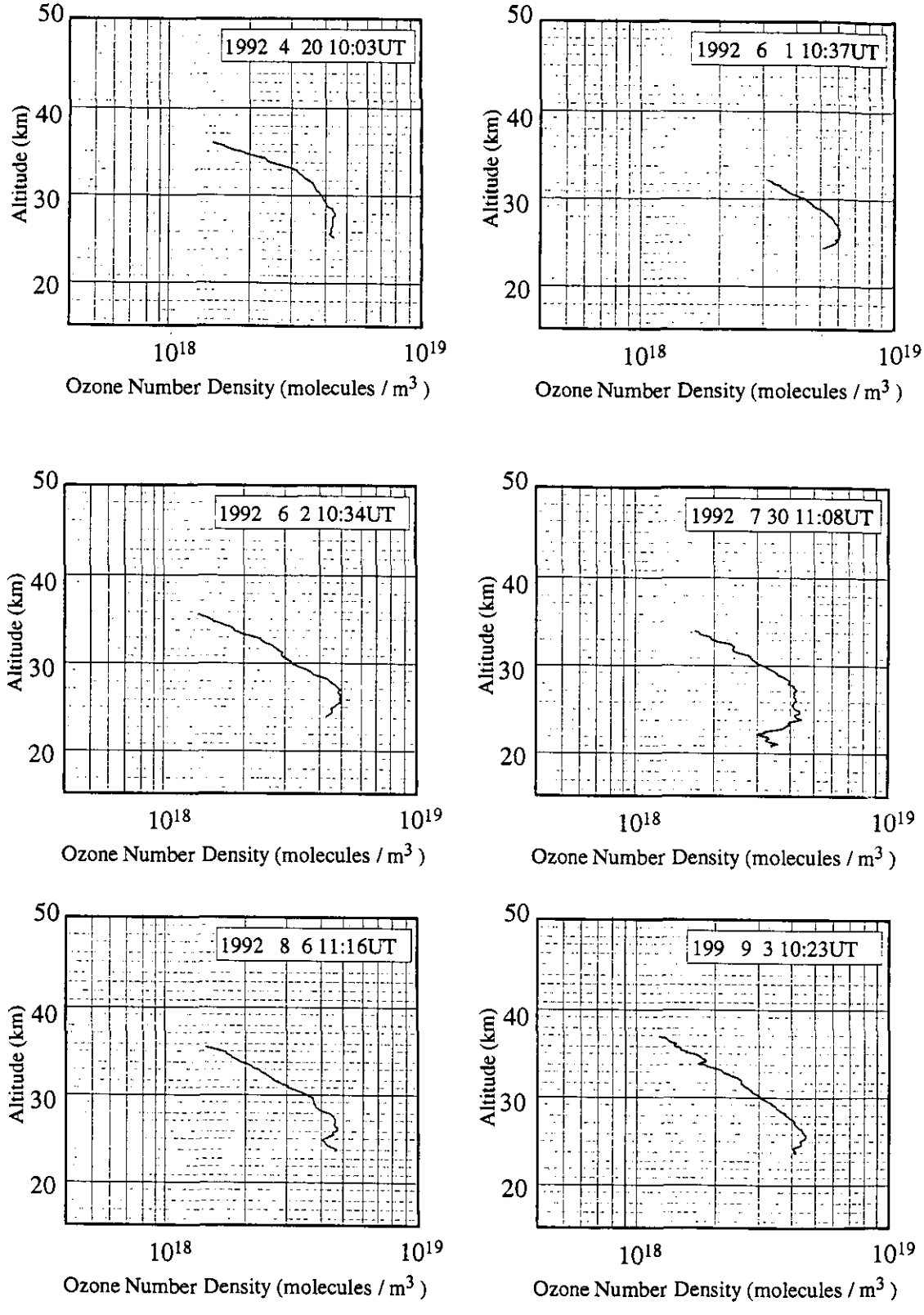


Fig. 2 (continued)



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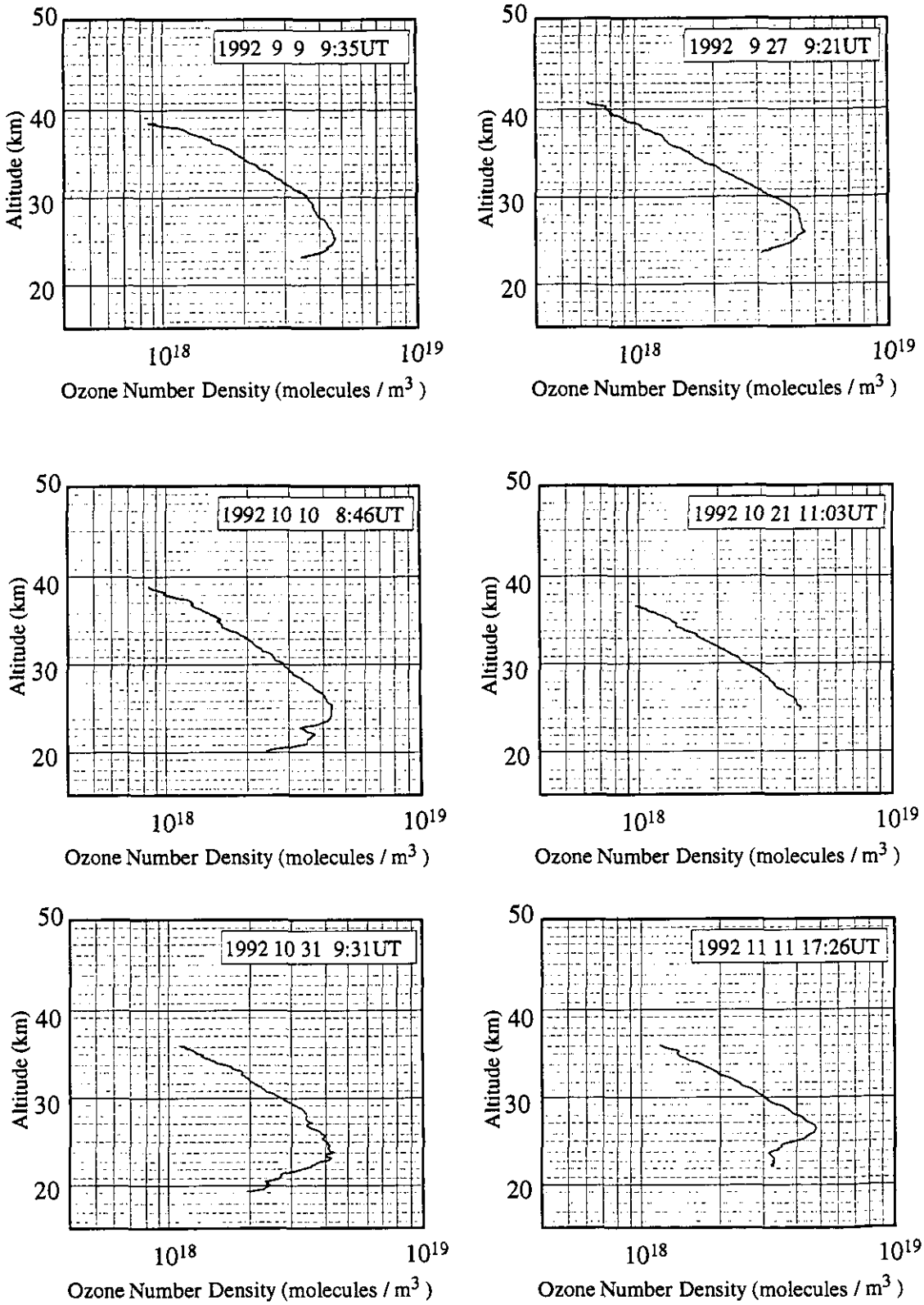

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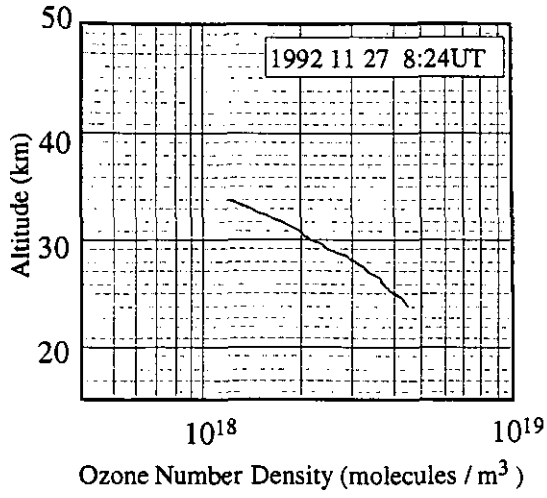

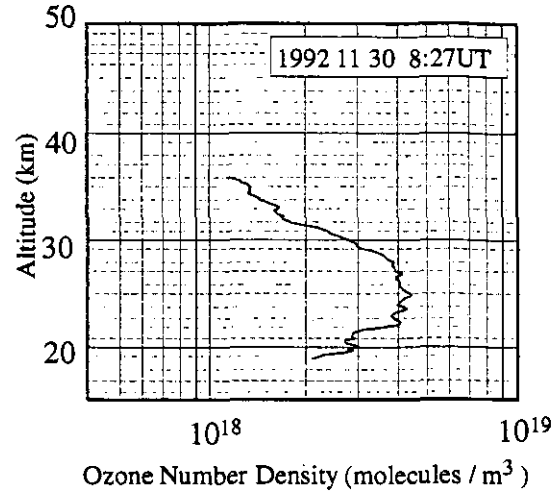

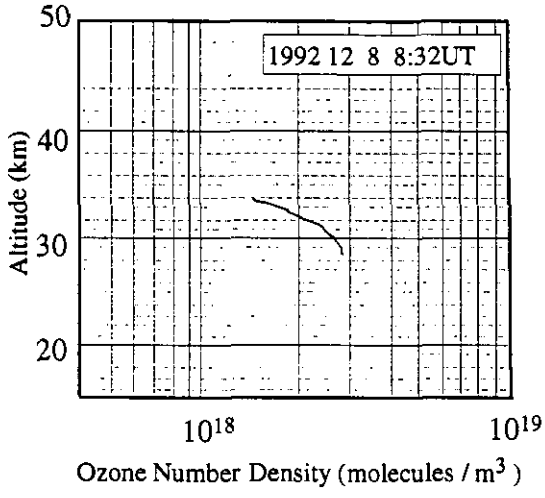

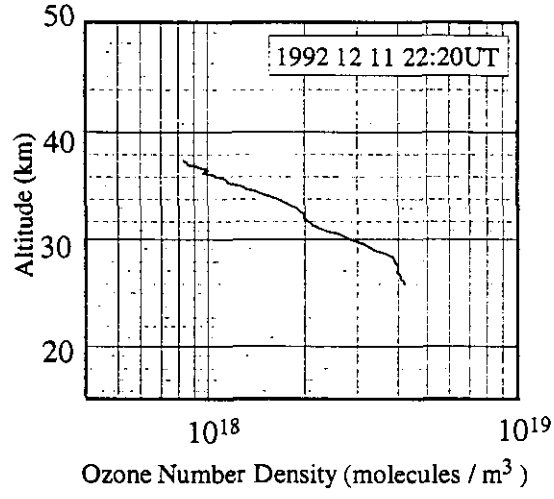

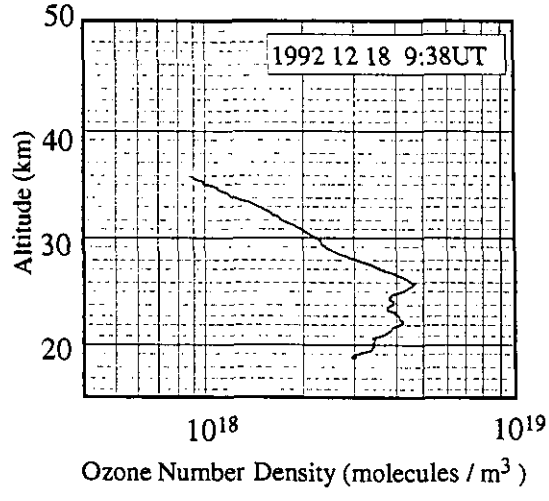

Fig. 2 (continued)

4. Variations of ozone

Temporal variations of ozone at 20, 25, 30, 35, and 40 km from September 1988 are depicted in Fig.3. Seasonal variations differ with altitude. Ozone density is high in winter and low in summer at 20 km; high in summer and low in winter at 30 and 35 km. This seasonal variation with altitude is consistent with known mechanism of seasonal variations in the lower and upper stratosphere: Transport effects are dominant in the lower stratosphere and photochemical effects in the upper stratosphere. The aerosol correction was applied after the arrival of the stratospheric aerosols owing to the eruption of Mt. Pinatubo. However, many data at 20 km should have been eliminated, because the effects of the stratospheric aerosols were sometimes too large to correct properly. The optical parameters of the Pinatubo volcanic aerosols should depend on time and altitude. Time and altitude depending optical parameters could improve the aerosol corrections. Despite these difficulties, a decrease of ozone at 25 km in 1992 and 1993 is discernible. Trends of ozone number densities at 25, 30, 35, and 40 km are negligible. Longer term monitoring is necessary to detect trends in the vertical profile of ozone.

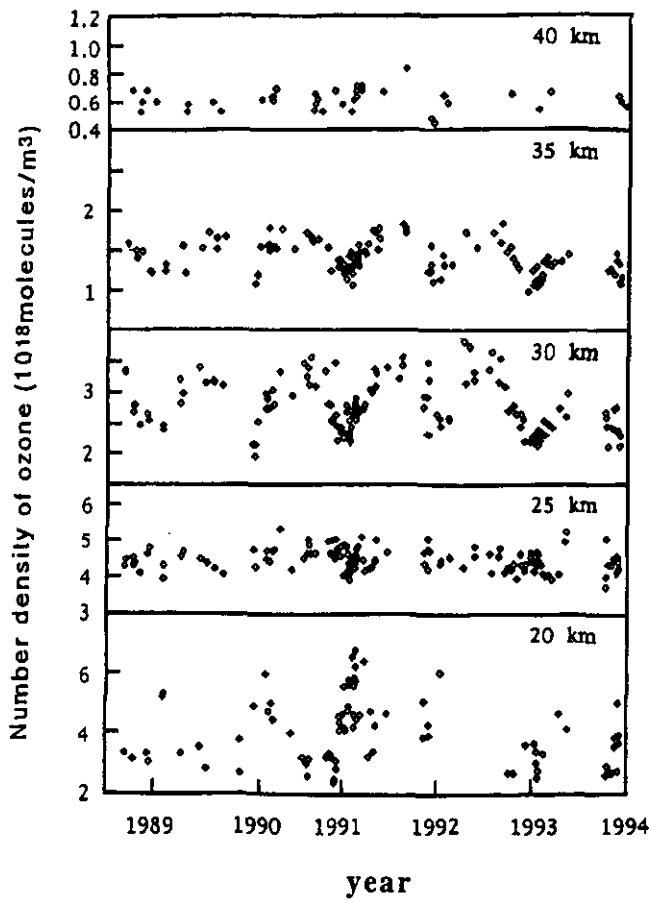

Fig. 3 Variations of ozone at an altitude of 20, 25, 30, 35, and 40 km (Nakane et al, 1994) .

5. Conclusion

The preliminary aerosol corrections and data quality check were performed successfully and ozone profiles below 30 km were obtained, even after the eruption of Mt. Pinatubo. The time series of the ozone number densities at each altitude are consistent with our understanding of ozone variations based on the photochemistry of the ozone layer, transport processes of ozone, and knowledge on the state of the atmosphere after the eruption of Mt. Pinatubo. However, the optical parameters used were constant with time and altitude, and the air density profiles used are based on the US standard atmosphere (1976). Aerosol corrections using the optical parameters of aerosols and the air density profiles based on the observations will improve the accuracy of the data in the lower stratosphere.

6. Acknowledgements

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The project has been managed based on discussions among the members of the subcommittee for Ozone Lidar Monitoring, organized by the NIES-CGER.

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