JAPAN

In Japan, the Ministry of the Environment (MOE) and the Japan Meteorological Agency (JMA) play principal roles in monitoring atmospheric ozone, atmospheric constituents related to the depletion of the ozone layer, and surface UV-A and UV-B ultraviolet radiation. The MOE has been promoting coordination and cooperation among national institutes and universities through the Global Environment Research Fund (GERF) since 1990. The MOE also supports a programme to monitor global environmental changes on a long-term basis at the Center for Global Environmental Research (CGER) of the National Institute for Environmental Studies (NIES). The Ozone Layer Monitoring Office of the JMA coordinates observations, monitoring, and data processing of atmospheric ozone and surface UV-B radiation.

OBSERVATIONAL ACTIVITIES

Column measurements of ozone and other gases/variables relevant to ozone loss

The JMA carries out total column ozone and Umkehr measurements with Dobson spectrophotometers at three sites in Japan (Sapporo, Tsukuba, and Naha) and at Syowa Station, a site in Antarctica. Most of these measurements were initiated during the International Geophysical Year (1957–8). The JMA also began total column ozone and Umkehr measurements with a Brewer spectrophotometer at Minamitorishima (Global Atmosphere Watch, GAW, Global Station, a remote isolated island in the western North Pacific) in 1994.

The MOE observes concentrations of halocarbons (CFCs, CCl_4, CH_3CCl_3, halons, HCFCs, and CH_3Br) and HFCs at remote sites (around Wakkanai and Nemuro) and at an urban site (Kawasaki). The CGER of NIES observes halocarbons (CFCs, CCl_4, CH_3CCl_3, and HCFCs), HFCs, surface ozone, CO_2, CH_4, N_2O, NO_x, H_2, the O_2/N_2 ratio, and aerosols at remote sites (Hateruma and Ochiishi).

The JMA observes surface concentrations of ozone depleting substances (CFCs, CCl_4, and CH_3CCl_3) and other constituents (surface ozone, CO_2, N_2O, CH_4, and CO) at Ryori (GAW Regional Station in northern Japan). Concentrations of surface ozone, CO_2, CH_4, and CO are also observed at Minamitorishima and Yonagunijima (GAW Regional Station in the Ryukyu Islands). The JMA also observes CFCs, CO_2, N_2O, and CH_4 in both the atmosphere and seawater of the western Pacific on board the research vessel *Ryofu Maru*.

Profile measurements of ozone and other gases/variables relevant to ozone loss

Ground-based and sonde measurements

Since October 1990, the CGER of NIES has been measuring the vertical profiles of the stratospheric ozone over Tsukuba (where NIES is located) with an ozone laser radar (ozone lidar), which is accepted as a complementary measurement by the Network for the Detection of Stratospheric Change (NDSC). Recently, the lidar data were reprocessed using a newly developed algorithm (version 2). The lidar ozone profiles were assessed by comparison with the JMA ozone sonde data and Stratospheric Aerosol and Gas Experiment II (SAGE II) ozone profiles, and were registered in the NDSC database. The CGER began measurements of vertical profiles of ozone with millimeter-wave radiometers in September 1995 at Tsukuba and in March 1999 at Rikubetsu.
The JMA carries out observation of the vertical ozone distribution by KC (KI solution and carbon electrode) ozone sonde at three sites in Japan (Sapporo, Tsukuba, and Naha) and at Syowa Station, Antarctica. The KC ozone sonde is an electrochemical-type ozone sonde that has been used in Japan since it was developed by the JMA in the 1960's. Observations are conducted once a week.

Satellite measurements

The Improved Limb Atmospheric Spectrometer (ILAS) and its successor ILAS-II were developed by the MOE to observe profiles of ozone and other atmospheric species related to ozone layer depletion in high-latitude regions. The ILAS was flown on the Advanced Earth Observing Satellite (ADEOS) from August 1996 to June 1997. The ILAS-II was put into space on board the ADEOS-II in December 2002 and made measurements from January to October in 2003. Data obtained with the ILAS instrument have been processed and analyzed at NIES and the version 5.2 data, which include O_3, HNO_3, H_2O, N_2O, CH_4, and aerosol extinction coefficients, have already been distributed to the scientific community for further research. The version 6.1 data, which include $ClONO_2$ and CFC-12 in addition to the version 5.2 species, are to be released in 2005. Data obtained with the ILAS-II instrument have been processed with the version 1.4 retrieval algorithm and are to be released to the public in 2005.

UV measurements

Broadband measurements

The CGER has been monitoring surface UV-A and UV-B radiation using broadband radiometers at 21 observation sites in Japan since 2000.

Spectroradiometers

The JMA observes surface UV-B radiation with Brewer spectrophotometers at Sapporo, Tsukuba, and Naha in Japan and at Syowa Station in Antarctica. The observations were started in 1990–1.

Calibration activities

The JMA began operation of the Quality Assurance/Science Activity Centre (QA/SAC) in Tokyo and the Regional Dobson Calibration Centre (RDCC) in Tsukuba in accordance with the GAW strategic plan 2001–7 to contribute to the assessment and improvement of the quality of ozone observations in Regional Associations II (Asia) and V (South-West Pacific) of the World Meteorological Organization (WMO). The Regional Standard Dobson instrument (D116) is calibrated against the World Standard instrument (D083) every three years. Recent intercomparison with the World Standard occurred in 2004 at NOAA/CMDL in Boulder, Colorado, USA. The Dobson instruments used for observation at domestic sites are calibrated against the Regional Standard every three years. As an activity of the RDCC, the JMA held two campaigns of Dobson Intercomparison, one in 2003 (at Tsukuba with participation from China) and the other in 2004 (at Seoul for Korea). As an activity of the QA/SAC, the JMA dispatched an expert to the Philippines to adjust the Dobson instrument and to instruct the operators in Manila.

RESULTS FROM OBSERVATIONS AND ANALYSIS

Continuous observation of vertical ozone profiles with a millimeter-wave radiometer in Tsukuba demonstrates that semiannual variations between 56 and 76 km are present and that the phase of the semiannual variation inverts suddenly at around 68 km.
Trend analyses were done for total ozone at three sites (Sapporo, Tsukuba, and Naha) eliminating the variation component of solar activity and quasi-biennial oscillation (QBO). The results show that total ozone has decreased over the last 20 to 30 years except at Naha, which is located on a lower latitude. Trends for vertical profiles were examined by using Umkehr and ozone sonde measurements. At all sites in Japan, ozone decreases are seen in two ranges, i.e., at about 20 and 40 km altitudes.

Because spectral UV measurements by the JMA have been recorded for fewer than 15 years, the general UV trend is uncertain. However, an apparent negative relation between UV intensity and total ozone amount was found in the data collected under clear sky conditions. It was also found that UV intensity varies depending on the weather conditions. Using the statistical relation between sunshine duration and precipitation and fine resolution weather data, an estimated UV intensity map (for every cell in a 20-km horizontal grid) was made and published for reference by the public.

THEORY, MODELLING, AND OTHER RESEARCH

A chemical climate model (CCSR/NIES CCM) based on a spectral atmospheric general circulation model (CCSR/NIES AGCM) was developed by the Centre for Climate System Research (CCSR), the University of Tokyo, and NIES and used for estimating the future development of the stratospheric ozone layer. A new version of CCSR/NIES CCM with T42 horizontal resolution has been developed that includes bromine chemistry. NIES has also developed a three-dimensional chemical transport model (CTM) in which temperature and wind velocity data are assimilated into the calculated fields in CCSR/NIES AGCM by using a nudging method. The CTM is being used to simulate the variability of ozone in the stratosphere.

The Meteorological Research Institute (MRI) of the JMA has developed a stratospheric CTM that can be run in interactive or non-interactive mode between chemistry and radiation. MRI-CTM is now operationally integrated at the JMA to produce assimilated ozone distributions by incorporating total ozone data from Total Ozone Mapping Spectrometer (TOMS) and several-day forecasts. The calculated ozone distributions are used to monitor ozone variation and for the UV forecast service. MRI-CTM is also used for research for making future predictions of the ozone layer.

The MRI, the National Institute of Information and Communications Technology (NICT), and some universities have measured O_3, HCl, HF, and other stratospheric constituents with NDSC instruments at NDSC primary stations such as Eureka (Canadian Arctic), Lauder (New Zealand), and other mid-latitude and tropical sites in cooperation with foreign research organizations.

The MRI has measured ozone, aerosols, and other species relevant to stratospheric ozone depletion using lidars and Fourier transform infrared (FTIR) spectrometers to understand the stratospheric processes over the Canadian Arctic, and it made analytical studies of ozone depletion in the Northern Hemisphere.

In spite of the short observation periods of ILAS (November 1996–June 1997) and ILAS-II (January–October 2003), their data have been used extensively to evaluate quantitatively the extent of the polar ozone destruction, for example, the determination of chemical ozone loss rates in the polar regions. Their data have also been used to elucidate the detailed chemical and physical processes related to ozone layer depletion, for example, polar stratospheric cloud (PSC) formation and denitrification mechanisms in the polar regions.

The effects of the increase in ultraviolet radiation on human health have been studied under the GERF. These studies include an exposure assessment of UV radiation, molecular epidemiological studies of UV exposure on skin cancer, epidemiological studies on ocular diseases due to increased UV radiation, and UV-B-induced immuno-suppression resulting in increases in viral infections (NIES, National Cancer Center Research Institute, National Institute of Health, National Institute of Industrial Health, Kobe University, Osaka City University, and Kagoshima University).

The effects of enhanced UV-B radiation on terrestrial plants are being studied by NIES. NIES developed a novel method of detecting plant UV-B stresses. This method is based on the detection of mRNA expression changes by cDNA macroarray analysis.

DISSEMINATION OF RESULTS

Data reporting

NIES and the Solar-Terrestrial Environment Laboratory (STEL) of Nagoya University have established stations with NDSC instruments including lidars, millimeter-wave radiometers, and FTIR spectrometers. Some of the activities conducted by these organizations have been incorporated into the NDSC complementary measurements in Japan. The reanalyzed NIES ozone lidar data were recently registered in the NDSC database, and the NIES millimeter-wave ozone data at Rikubetsu are ready for registration in the NDSC.

Observation data acquired by the JMA are submitted monthly to the World Ozone and UV Data Centre (WOUDC) in Toronto. Provisional total ozone data are also posted daily on Character Form for the Representation and Exchange of Data (CREX) of the WMO global telecommunication system (GTS), and used accordingly in the WMO Ozone Mapping Centre in Thessaloniki. In the Antarctic winter and spring seasons, total ozone and ozone sonde data acquired at the Japanese Antarctic station, Syowa, are submitted weekly to the WMO Secretariat for the preparation of Antarctic Ozone Bulletins.

Information to the public

The Annual Report on the state of the ozone layer, surface UV-B radiation, and atmospheric concentrations of ozone-depleting substances is published for the public by the MOE. Data on total ozone, ozone sonde, and UV-B measurements acquired by the JMA are summarized monthly and published for the media and the public through a website. The Annual Report of Ozone Layer Monitoring, which includes detailed trend analyses of ozone over Japan and the globe, is also published for the government and the public by the JMA. Based on UV-B observation results and newly developed ozone forecast techniques, the JMA started a UV forecast service (hourly UV-index map) through a website for the public in 2005. This service not only provides forecast information, but an analytical UV map and quasi-real-time UV observation results are posted hourly on the website.

Relevant scientific papers

The MOE supports research on global environmental changes, including ozone layer depletion, through the GERF and their results are published in the Annual Summary Reports.

PROJECTS AND COLLABORATION

Through the GERF, the MOE supports the projects “Research on explanation of long-term trend and prediction of future change of ozone layer” and “A study on elucidating mechanisms of polar ozone depletion using satellite measurement data”.

The Aerological Observatory of the JMA has developed an automated Dobson measuring system. This system reduces the operator’s burden and improves the data quality. Some foreign organizations are interested in introducing this automated Dobson system. The JMA is ready to provide technical support, and plans for collaboration with various organizations are now in preparation.

FUTURE PLANS

The NIES millimeter-wave radiometers, which have been used for the continuous measurement of the vertical profile of ozone over Japan, have been improved to extend the altitude range of the observation. It is planned to measure continuously the vertical profiles of ozone from the lower stratosphere to the mesosphere as an NDSC activity.

The calibration of Dobson instruments from all over the world to the World Standard is essential to precisely monitor global ozone change. However, most Dobson instruments in Asian countries, except in China, Korea, and Japan, have not been calibrated since 1996. The JMA is now planning to hold a Dobson Intercomparison with the participation of four countries in the spring of 2006.

The observation of ozone, water vapour, and other species will be performed near the tropical tropopause to understand the role of the tropical transition layer. Developing and improving the numerical models, CCM and CTM, will continue, which will enable better prediction of future changes of the ozone layer and better understanding of the mechanisms of the chemistry–climate interaction.

Studies using ILAS and ILAS-II data will be continued to better understand the mechanisms of polar ozone destruction.

NEEDS AND RECOMMENDATIONS

To evaluate the changing state of the ozone layer and ground-level UV radiation, including detection of ozone layer recovery, systematic observations with the cooperation of international monitoring networks, such as the NDSC and the WMO GAW Programme, should be continued.
To detect recovery of the ozone layer, a fine and high-quality ozone-monitoring network is required. However, some regions do not have a well-functioning systematic calibration system. Each government that conducts ozone observation should recognize the importance of periodic Dobson Intercomparisons that ensure high-quality ozone data, and promote activities relevant to the detection of ozone recovery.

To more precisely predict future changes in the ozone layer, numerical models need to be improved; especially desirable is integration between stratospheric and climate models. The interactions between climate change and ozone layer depletion and changes in the ozone layer in the post-CFC period due to the emissions of CH_4, H_2, and N_2O need to be assessed. Chemical and dynamical processes including the formation of PSCs and denitrification mechanisms, cross-tropopause transport, and the ozone budget near the tropopause region need to be studied.

The effects of increased UV radiation on human health and ecosystems need to be studied, especially the effects of possible longer exposure to increased UV radiation under rising temperature conditions.

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