JAPAN

OBSERVATIONAL ACTIVITIES

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

The Japan Meteorological Agency (JMA) carries out total column ozone and Umkehr measurements at four sites in Japan (Sapporo, Tsukuba, Naha and Minamitorishima) and at Syowa Station, a site in Antarctica, as listed in Table 1. A Brewer spectrophotometer is used for the measurements at Minamitorishima, whereas Dobson spectrophotometers are used at the other observation sites.

Table 1: Location of column ozone and Umkehr measurement sites operated by JMA.

Observation site	Latitude	Longitude	Altitude	WMO station number
Sapporo	43° 04' N	141° 20' E	26.3 m	47412
Tsukuba	36° 03' N	140° 08' E	31.0 m	47646
Naha	26° 12' N	127° 41' E	27.5 m	47936
Minamitorishima	24° 17' N	153° 59' E	8.5 m	47991
Syowa	69° 00' S	39° 35' E	21.8 m	89532

Concentrations of ozone-depleting substances and other constituents are monitored by the Center for Global Environmental Research (CGER) of the National Institute for Environmental Studies (NIES) and by JMA. The locations of the monitoring sites are listed in Table 2. The CGER of NIES monitors halocarbons (CFCs, CCl_4, CH_3CCl_3 and HCFCs), HFCs, surface ozone, CO_2, CH_4, CO, N_2O, NO_x, H_2, the O_2/N_2 ratio, and aerosols at remote sites (Hateruma and Ochiishi). JMA measures the surface concentration 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, a GAW Regional Station in northern Japan. Monitoring of the concentration of surface ozone, CO_2, CH_4 and CO is also carried out at Minamitorishima (a GAW Global Station) and Yonagunijima (a GAW Regional Station in the Ryukyu Islands).

The Ministry of the Environment (MOE) operationally observes the concentration 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).

Table 2: Location of monitoring sites for ozone-depleting substances and other minor constituents.

Monitoring site	Latitude	Longitude	Altitude	Since	Organization
Ochiishi	43° 09' N	145° 09' E	45 m	Oct 1995	CGER/NIES
Hateruma	24° 03' N	123°48' E	10 m	Oct 1993	CGER/NIES
Ryori	39° 02' N	141° 49' E	260 m	Jan 1976	JMA
Minamitorishima	24° 17' N	153° 59' E	8 m	Mar 1993	JMA
Yonagunijima	24° 28' N	123° 01' E	30 m	Jan 1997	JMA
Syowa	69° 00' S	39° 35' E	18 m	Jan 1997	JMA

JMA also observes CFCs, CO_2, N_2O and CH_4 in both the atmosphere and seawater of the western Pacific on board the Ryofu Maru and Keifu Maru research vessels.

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 stratospheric ozone over Tsukuba (where NIES is located) with an ozone laser radar (ozone lidar). This is accepted as a complementary measurement by the Network for the Detection of Atmospheric Composition Change (NDACC). The lidar ozone profiles were assessed by comparison with JMA ozone sonde data and Stratospheric Aerosol and Gas Experiment II (SAGE II) ozone profiles, and

were registered in the NDACC database. The CGER began measuring vertical profiles of ozone with millimeter-wave radiometers in September 1995 at Tsukuba and in March 1999 at Rikubetsu.
JMA has been observing 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 in Antarctica. The KC ozone sonde is an electrochemical instrument that has been used in Japan since it was developed by JMA in the 1960s. Observations are conducted once a week.

Satellite measurements
Ozone layer depletion in high-latitude regions was monitored by the Improved Limb Atmospheric Spectrometer (ILAS), a satellite-borne solar-occultation sensor, from August 1996 to June 1997. ILAS-II, the successor to ILAS, also made measurements of minor constituents associated with polar ozone depletion from April to October 2003. Observed data were processed and analyzed at NIES. The Version 6.1 data of ILAS, which include O_3, HNO_3, NO_2, N_2O, CH_4, H_2O, $ClONO_2$, CFC-12 and aerosol extinction coefficients, were released in 2005. The Version 2 data of ILAS-II, including O_3, HNO_3, N_2O, CH_4, H_2O, $ClONO_2$ and aerosol extinction coefficients, were released in February 2008.

UV measurements

Broadband measurements
The CGER has been monitoring surface UV-A and UV-B radiation using broadband radiometers at 26 observation sites in Japan since 2000. CGER calculates the UV Index using the data observed, and provides it every hour to the public via the Internet from 15 monitoring stations.

Spectroradiometers
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 at Tsukuba and in 1991 at the other sites.

Calibration activities
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 2001–2007 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 was conducted in 2007 at NOAA/CMDL in Boulder, Colorado, USA. The Dobson instruments used for observation at domestic sites are also calibrated against the Regional Standard every three years. As an activity of the RDCC, JMA held a campaign of Dobson Intercomparison at Tsukuba with participation from India, Iran, Pakistan, the Philippines and Thailand in March 2006. As an activity of the QA/SAC, JMA dispatched an expert to the Republic of Korea to install an automated observation system to the Dobson instrument and to instruct operators at Yonsei University, Seoul from July to August 2006.

RESULTS FROM OBSERVATIONS AND ANALYSIS

The ozone mixing ratios measured with the millimeter radiometer at Rikubetsu Station during the period from November 1999 to June 2002 were compared with the Sapporo ozone sonde data and satellite data from the Halogen Occultation Experiment (HALOE), and showed good agreement.

Trend analyses were carried out 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 mainly decreased in the 1980s and no significant trends or slight increasing trends have appeared since the mid-1990s, although total ozone varies year by year. Trends for vertical profiles were examined using Umkehr and ozone sonde measurements. At all sites in Japan, reduced ozone levels are seen in two ranges at altitudes of about 20 and 40 km. On the other hand, an increasing trend is seen at altitudes of less than 15 km at Naha.

Increasing trends are seen in erythemal UV measurements at three sites in Japan since the beginning of JMA's UV radiation observation in the early 1990s. As the total ozone was at its lowest level around the early 1990s and no significant trends or slight increasing trends are seen in the total ozone after the mid-1990s, the cause of the above increasing trends in erythemal UV radiation since 1990 cannot be attributed to ozone changes.

THEORY, MODELLING AND OTHER RESEARCH

The Centre for Climate System Research (CCSR), the University of Tokyo and NIES developed a chemistry-climate model (CCSR/NIES CCM). JMA's Meteorological Research Institute (MRI) also independently developed another chemistry-climate model (MRI-CCM). Both the CCSR/NIES and the MRI groups participate in the Chemistry-Climate Model Validation Activity (CCMVal) of Stratospheric Processes and their Role in Climate (SPARC) programme, and contribute to model intercomparison for the improvement of CCMs and a better understanding of the ability of such models.

CCSR/NIES CCM is based on a spectral atmospheric general circulation model (CCSR/NIES AGCM). A new version of this CCM with T42 horizontal resolution has been developed that includes bromine chemistry and atmospheric sphericity effects. It was used to simulate global distribution and time evolution of the stratospheric ozone layer for the recent past and future under a future scenario with the concentration of greenhouse gases and ozone depletion substances recommended by CCMVal for the simulation. The results were published in the WMO Ozone Assessment Report 2006 and scientific journals. 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 using a nudging method. The model was used to investigate the effects of atmospheric sphericity on stratospheric chemistry and dynamics in the Antarctic, ozone destruction outside the Arctic polar vortex due to polar vortex processing, and N_2O distributions in the Northern Hemisphere in early and late Arctic polar vortex breakup years. The results were published in scientific journals.

JMA's Meteorological Research Institute (MRI) has developed a CTM and CCM for the study of stratospheric ozone. One of the prominent features of MRI-CCM is that quasi-biennial oscillation (QBO), which plays a crucial role in interannual variations in the stratosphere, is spontaneously reproduced for wind and ozone in the tropical stratosphere by a T42L68 version that has about 300 km of horizontal resolution and 500 m of vertical resolution in the stratosphere. MRI-CCM has been operationally used at JMA to produce assimilated ozone distributions by incorporating total ozone data from Total Ozone Mapping Spectrometers (TOMS) and Ozone Monitoring Instruments (OMI) and ozone forecasts for several days. The ozone distributions calculated are utilized to monitor variations in the total ozone and in the stratospheric ozone, as well as for the operational UV forecast service. MRI-CCM is also used in research for the study of interaction between the ozone layer and the climate, as well as for future predictions of the ozone layer.

As an extension of MRI-CCM, a new CCM (MRI-CCM2) has been developed by incorporating tropospheric chemistry, resulting in a seamless chemistry module from the Earth's surface up to the model lid at about 80 km. MRI-CCM2 is an important component of the MRI climate system model, which includes the ocean, atmosphere, cryosphere and biosphere.

ILAS and ILAS-II data have been used extensively to elucidate the detailed chemical and physical processes related to ozone layer depletion in polar regions, such as polar stratospheric cloud (PSC) formation, denitrification, chemical ozone loss rates and partitioning among chlorine species.

The effects of enhanced UV-B radiation on terrestrial plants are being studied by NIES, which has developed a novel method of detecting plant UV-B stresses based on the detection of mRNA expression changes by cDNA macroarray analysis. This method illustrates shifts in gene expression in response to stressors such as drought, salinity, UV-B, low temperature, high temperature, acid rain and photochemical oxidants. NIES has also made a mini-scale macroarray with 12 ESTs for diagnosis of the above environmental stresses in plants.

DISSEMINATION OF RESULTS

Data reporting

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

Observation data acquired by JMA are submitted monthly to the World Ozone and UV Data Centre (WOUDC) in Toronto, Canada. Provisional total ozone data are also posted daily on the Character Form for the Representation and Exchange of Data (CREX) of the WMO Global Telecommunication System (GTS), and used accordingly at 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 at Syowa are submitted weekly to the WMO Secretariat for the preparation of Antarctic Ozone Bulletins.

Information to the public

An 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 acquired by JMA on total ozone, ozone sonde and UV-B measurements are summarized monthly and published on the Internet for the media and the public. An annual report that includes detailed trend analyses of ozone over Japan and the globe is also published for the government and the public. Based on UV-B observation results and newly developed ozone forecast techniques, JMA has been providing an Internet UV forecast service (in the form of an hourly UV-index map) for the public since 2005. In addition to forecast information, this service also provides an analytical UV map and quasi-real-time UV observation results 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 Annual Summary Reports.

PROJECTS AND COLLABORATION

As a GERF-funded activity, a project named *Studies on the Variability of Stratospheric Processes and Uncertainties in the Future Projection of Stratospheric Ozone* is being carried out by NIES, CCSR, Hokkaido University and Miyagi University of Education. In this project, the following investigations are being conducted: (i) evaluation of the reproducibility of chemical and meteorological fields in the stratosphere as calculated using CCSR/NIES CCM, (ii) detection of the variation of water vapor in the tropical tropopause layer, (iii) determination of the mean age of stratospheric air over Japan, and (iv) understanding of the impact of solar activity change on stratospheric ozone distribution.

JMA's Aerological Observatory has developed an automated Dobson measuring system that reduces the burden on the operator and improves the data quality as described on the JMA/GAW web site (http://gaw.kishou.go.jp/wcc/dobson/windobson.html). Some foreign organizations are interested in introducing this automated Dobson system, and JMA is ready to provide technical support to them.

FUTURE PLANS

NIES millimeter-wave radiometers are used for continuous measurement of the vertical profile of ozone over Rikubetsu and Tsukuba. There are also plans to continuously measure the vertical profiles of ozone from the lower stratosphere to the mesosphere as an NDACC activity.

In 2008, JMA's KC-type ozone sonde, which has been used for measurement of the vertical profile of ozone at Naha, will be changed to the ECC (Electrochemical Concentration Cell)-type ozone sonde that is widely used internationally.

The observation of ozone, water vapour and other species near the tropical tropopause will be continued to aid understanding of the role of the tropical transition layer. Precise measurements of trace gases in the stratosphere will be continued to provide key information on physical, chemical and dynamical processes. As an example, precise monitoring of trace gases in the middle atmosphere enables detection of the variability in the mean age of air and evaluation of how well current models can reproduce changes in dynamical processes.

Development and improvement of the CCM and CTM numerical models will continue, which will allow better prediction of future changes in the ozone layer and better understanding of the mechanisms of chemistry–climate interaction.

A Superconductive Submillimeter-Wave Limb-Emission Sounder (SMILES) is being designed for installation in the Japanese Experiment Module (JEM) on the International Space Station (ISS) as a collaborative project between the Japan Aerospace Exploration Agency (JAXA) and the National Institute of Information and Communications Technology (NICT). The system's detailed design and manufacturing of the proto-flight model (PFM) for JEM/SMILES are complete, and a launch scheduled in 2009 by the H-II Transfer Vehicle (HTV) is aimed at. The mission objectives are: i) space demonstration of a superconductive mixer and a 4-K mechanical cooler for submillimeter limb-emission sounding, and ii) global observations of atmospheric minor constituents in the stratosphere (O_3, HCl, ClO, HO_2, HOCl, BrO, O_3 isotopes, HNO_3, CH_3CN, etc), contributing to the atmospheric sciences. The SMILES observation is characterized by its focus on the variation of radical species in the stratosphere and the impact of such variations. Based on its high sensitivity in detecting atmospheric limb emission in the submillimeter wave range, JEM/SMILES will make measurements on several radical species crucial to ozone chemistry (normal O_3, isotope O_3, ClO, HCl, HOCl, BrO, HO_2 and H_2O_2). The SMILES will also try to observe the isotopic composition of ozone.

NEEDS AND RECOMMENDATIONS

To evaluate the changing state of the ozone layer including detection of ozone layer recovery, systematic observations with the cooperation of international monitoring networks, such as the NDACC and the WMO GAW Programme, should be continued. A high-quality ozone-monitoring network is also required. However, some regions do not have a satisfactory systematic calibration program. Each government that conducts ozone observation should recognize the importance of periodic Dobson Intercomparisons to ensure high-quality ozone data, and promote activities relevant to the detection of ozone recovery.

To predict future changes in the ozone layer more precisely, integration between stratospheric and climate models is desirable. The interactions between climate change and ozone layer depletion and changes in the ozone layer in the post-CFC period due to emissions of CH_4, H_2 and N_2O need to be assessed. Studies on chemical and dynamical processes including the formation of PSCs and denitrification mechanisms, cross-tropopause transport and the ozone budget near the tropopause region should also be continued. Reevaluation of chemical reaction data including photochemical data for stratospheric modeling is urgently required to resolve discrepancies between observations and model calculations.

To detect the variations and long-term trends in ground-level UV radiation, a systematic calibration program and a well-coordinated monitoring network should be established.

Studies on the effects of increased UV radiation on human health, ecosystems, air quality and biogeochemical cycles are strongly recommended, especially the effects of increased UV radiation under rising temperature conditions.

****