UNITED STATES OF AMERICA

OBSERVATIONAL ACTIVITIES

Column Measurements

Ozone

BUV/SBUV/SBUV-2 Satellite Instrument Series (8 Instruments)

The Backscatter Ultraviolet (BUV) and Solar Backscatter Ultraviolet (SBUV) instrument series has produced the longest satellite record for column ozone (April 1970 to the present, with a data gap between 1974 and 1978). NOAA plans to continue the SBUV-2 series on its Polar Orbiting Environmental Satellites (POES) through the end of this decade. Data from the NASA Nimbus-7 satellite and the NOAA POES have been recently reprocessed using the SBUV version 8 algorithm developed at NASA to achieve a cohesive data set standardized to Nimbus-7. The algorithm has been optimized for deriving trends, and for deriving accurate total ozone at large solar zenith angles (75˚ to 88˚), since it does simultaneous retrieval of ozone profile and total ozone. The data set consists of monthly average total ozone in 10° latitude bands from January 1979 to December 2004. (NOAA/CPC, NASA)

Total Ozone Mapping Spectrometer (TOMS) Instrument Series (4 Instruments)

The TOMS series of instruments has produced daily global maps of column ozone at solar zenith angles up to 84º since November 1978, with a data gap between April 1993 and July 1996. Data recently have been reprocessed using the TOMS version 8 algorithm, which minimizes aerosol effects and performs better at large solar zenith angles, though not as well as SBUV V8. Data quality of EP/TOMS has degraded since 2000 because of instrument problems. Corrections are being developed using SBUV-2. (NASA)

Ozone Monitoring Instrument (OMI) on the Aura Satellite

Built with collaboration between the Netherlands and Finland, and operating since August 2004 on the EOS Aura satellite, this hyperspectral imaging spectrometer continues the total column ozone record begun with the Nimbus-7 TOMS instrument. Two different total ozone algorithms are utilized, one based on the TOMS heritage and the other on the GOME/DOAS heritage. The algorithms agree well in cloud-free areas, but vary by up to 10% in cloudy areas and at large solar zenith angles. Lack of sufficient “ground-truth” for conditions where they differ makes the assessment of data quality difficult at the present time. (NASA)

Dobson Network

Dobson total column ozone measurements in the U.S. are done through the NOAA/CMDL Cooperative Network at 16 locations, including 10 national sites in the continental U.S. and Hawaii. Five other sites are collaborative international programmes (South Pole, Perth, Lauder, Samoa, OHP). Data are used for satellite validation and determining ozone trends for the WMO/UNEP Ozone Assessments. NASA also supports Dobson measurements within the U.S. under the auspices of the Network for the Detection of Stratospheric Change (NDSC, see Section 1.1.2.3) (NOAA/CMDL, NASA)

UVB Monitoring and Research Programme (UVMRP)

Direct-sun column ozone is retrieved by UV Multi-Filter Rotating Shadowband Radiometers (UV-MFRSRs) at 32 U.S. sites, 2 Canadian sites, and 1 New Zealand site within the U. S. Department of Agriculture (USDA) UV Monitoring and Research Programme (UVMRP). (USDA)

Ozone-Relevant Gases and Variables

Total Ozone Mapping Spectrometer (TOMS) Instrument Series (4 Instruments)

The TOMS series of instruments has produced daily global maps of column SO_2 from volcanoes at solar zenith angles up to 84° since November 1978 (data gap between April 1993 and July 1996). Aerosol absorption has a large affect on surface radiation and actinic flux. Hence, a technique has been developed to derive aerosol absorption optical thickness (AAOT) in the UV from TOMS. Globally, AAOT in the UV can vary from nearly zero in clean areas to more than 0.5 in biomass-burning regions and in the presence of desert dust. The uncertainty in the TOMS-derived AAOT is about 0.02. Hence, it can capture most large events. (NASA)

Ozone Monitoring Instrument (OMI) on the Aura Satellite

In addition to its primary focus on column ozone, OMI measures tropospheric columns of aerosols, nitrogen dioxide, and sulphur dioxide. (NASA)

Network for the Detection of Stratospheric Change (NDSC)

This international ground-based remote-sensing network, championed in the U.S. by NASA and NOAA, was formed to provide a consistent, standardized set of long-term measurements of atmospheric trace gases, particles, and physical parameters via a suite of globally distributed sites. While the NDSC maintains its original commitment to monitoring changes in the stratosphere, with an emphasis on the long-term evolution of the ozone layer (its decay, likely stabilization, and expected recovery), its priorities have broadened considerably to encompass the detection of trends in overall atmospheric composition and understanding their impacts on the stratosphere and troposphere, establishing links between climate change and atmospheric composition, calibrating and validating space-based measurements of the atmosphere, supporting process-focused scientific field campaigns, and testing and improving theoretical models of the atmosphere. Through collaborative investigations with scientists at U.S. and foreign institutions, column measurements of numerous atmospheric constituents are measured at NDSC Primary and Complementary Stations. NDSC instruments that are particularly suited for such column measurements include UV/Visible spectrometers for ozone, NO_2, BrO, and OClO; FTIR spectrometers for a wide variety of source and reservoir compounds; and Dobson and Brewer spectrometers for ozone. Additional information on the NDSC is available at http://www.ndsc.ws/. (NASA, NOAA/CMDL)

Profile Measurements

Ozone

BUV/SBUV/SBUV-2 Satellite Instrument Series (8 Instruments)

This instrument series has produced the longest satellite record of ozone in the upper stratosphere (1-30 hPa) from April 1970 to the present, with a data gap between 1974 and 1978 (see Section 1.1.1.1). Data recently have been reprocessed using the SBUV version 8 algorithm developed at NASA. They will be used to derive a cohesive ozone-profile data set suitable for trend determinations. Profile ozone data from the SBUV/2 on the NOAA POES are used as input to NOAA/NCEP's Global Forecast System. (NOAA/CPC, NASA)

Stratospheric Aerosol Measurement (SAM) and Stratospheric Aerosol and Gas Experiment (SAGE) Instrument Series (4 Instruments)

The SAM/SAGE series of instruments has provided the longest data set on the vertical profile of ozone in the stratosphere. Near-global coverage has been provided on a near-monthly basis for the periods 1979 to 1981 and 1984 to present. The SAGE ozone data are a benchmark for ozone profile trends. Recent improvements in the processing algorithms have substantially reduced ozone retrieval sensitivity to enhanced aerosols by almost a factor of 10. The SAGE II instrument will complete its mission in late September 2005, after more than 21 years of valuable service. (NASA)

Upper Atmosphere Research Satellite (UARS) Instruments

The UARS HALOE instrument has measured profile ozone since September 1991. UARS measurements are scheduled for termination on 8 December 2005. EOS Aura instruments will continue to make most of these measurements (ozone, H_2O, CH_4, NO_2, HCl, and temperature). (NASA)

Polar Ozone and Aerosol Measurement (POAM) Satellite Instrument Series

The POAM solar occultation instruments (POAM II, 1994 to 1996; POAM III, 1998 to present) continue to provide high-latitude (55°N to 71°N and 63°S to 88°S) measurements of ozone from the upper troposphere to the lower mesosphere. Through most of the POAM measurement period, it has been the only satellite instrument to provide continuous, high-vertical-resolution measurements of stratospheric ozone in the ozone hole region. Recently, this data record has been used to show a significant decrease in the amount of ozone loss at the top of the ozone hole in the past four years (2001 to 2004) relative to that observed during the first six POAM measurement years. (DoD/NRL, NASA)

Aura Satellite Instruments

Aura, the third and last of the NASA Earth Observing System (EOS) observatories, was launched on 15 July 2004, and was designed to make comprehensive stratospheric and tropospheric composition measurements from its four instruments, the High-Resolution Dynamics Limb Sounder (HIRDLS), the Microwave Limb Sounder (MLS), the Ozone Monitoring Instrument (OMI), and the Tropospheric Emission Spectrometer (TES). MLS, HIRDLS, and TES each were designed for measuring ozone profiles. MLS was turned on shortly after launch, and has been delivering ozone-profile data for the upper troposphere and stratosphere since that time. After activation, HIRDLS was found to have a blockage in the optical path. However, even with the 80% blockage, measurements at high vertical resolution still can be made at one scan angle, and ozone profile retrievals recently have been demonstrated. Nevertheless, HIRDLS will not have its designed horizontal coverage, nor will it be able to make measurements over the Antarctic. After launch, the TES translator mechanism began to show signs of bearing wear. The instrument was commanded to skip the limb-sounding modes in May 2005, and will not obtain ozone profiles via this mode of operation; however, some ozone profile information may be derived from the nadir measurements. (NASA)

Balloonborne Measurements

NOAA routinely conducts ozonesonde measurements at nine locations. These include five domestic sites (Hawaii, California, Colorado, Alabama, Rhode Island) and four international sites (South Pole, Fiji, Samoa, Galapagos). NASA supports the operations of the Southern Hemisphere Additional Ozonesonde (SHADOZ) network of ozonesonde launches from several locations in the tropics and southern subtropics. This network operates in collaboration with NOAA and numerous international partners. NASA also flies ozonesondes and an ozone photometer as components of near-annual, moderate-scale balloon campaigns. Additional ozone profiles are obtained during such campaigns using a submillimeter/millimeter-wave radiometer, an infrared spectrometer, and a far-infrared spectrometer. (NOAA/CMDL, NASA)

Dobson Umkehr

Profiles are obtained from six automated Dobson instruments using the Umkehr technique (Lauder, Perth, Hawaii, Boulder, OHP, Fairbanks). Through collaboration between NASA and NOAA, a new ozone-profile algorithm has been developed to process Dobson Umkehr data. This algorithm is similar to the SBUV V8 algorithm, and has been optimized for deriving trends. (NOAA/CMDL, NASA)

Network for the Detection of Stratospheric Change (NDSC)

Two of the remote sensing instruments designated as primary components of the NDSC are providing long-term profile measurements of ozone. These are the lidars (which measure in both the troposphere and stratosphere) and the microwave radiometers (whose retrievals are limited primarily to the stratosphere). Ozonesondes routinely launched at many NDSC stations also provide ozone-profile data. In addition, several of the high-resolution FTIR spectrometers are beginning to yield ozone-profile information. (NASA, NOAA/CMDL)

Ozone-Relevant Gases and Variables

Stratospheric Aerosol Measurement (SAM) and Stratospheric Aerosol and Gas Experiment (SAGE) Instrument Series (4 Instruments)

The SAM/SAGE series of instruments has provided the longest data set on the vertical profile of aerosols in the stratosphere. Near-global coverage has been provided on a near-monthly basis for the periods 1979 to 1981 and 1984 to present. Recent improvements in the processing algorithms have produced a fully usable water vapour product for the first time. The SAGE II instrument will complete its mission in late September 2005, after more than 21 years of valuable service. (NASA)

Upper Atmosphere Research Satellite (UARS) Instruments

The UARS HALOE instrument has measured profile H_2O, CH_4, NO, NO_2, HCl, HF, and temperature since September 1991. UARS measurements are scheduled for termination on 8 December 2005. EOS Aura instruments will continue to make most of these measurements (ozone, H_2O, CH_4, NO_2, HCl, and temperature). The UARS SOLSTICE and SUSIM instruments measure UV light above the atmosphere between 115 and 410 nm, a wavelength range that impacts both the production and loss of ozone. These measurements started in September 1991, and are scheduled for termination in early August 2005. Instruments on the SORCE satellite will continue these measurements. The UARS PEM instrument measures proton and electron flux into the atmosphere. These measurements started in September 1991, and are scheduled for termination in early August 2005. Instruments on the NOAA GOES and POES satellites will continue these measurements. (NASA)

Polar Ozone and Aerosol Measurement (POAM) Satellite Instrument Series

The POAM instruments continue to provide high-latitude (55^{o}N to 71^{o}N and 63^{o}S to 88^{o}S) measurements of H_2O, NO_2, and aerosol extinction from the upper troposphere to the lower mesosphere. POAM measurements indicate that there were fewer polar stratospheric clouds (PSCs) between 2001 and 2004 at these altitudes, suggesting that the reduced ozone loss also observed is primarily the result of a change in meteorology (toward warmer conditions) in the Antarctic stratosphere over the past four winter seasons. (DoD/NRL, NASA)

Aura Satellite Instruments

In addition to ozone-profile measurements, the four Aura instruments were designed to provide profile measurements of numerous other atmospheric constituents and parameters in the stratosphere and troposphere. MLS has been delivering profiles of temperature, H_2O, ClO, BrO, HCl, OH, HO_2, HNO_3, HCN, N_2O, and CO since the instrument was activated. Despite the optical path blockage, HIRDLS likely will retrieve profiles of temperature, H_2O, CH_4, N_2O, NO_2, HNO_3, N_2O_5, CF_3Cl, CF_2Cl_2, $ClONO_2$, and aerosols. Nevertheless, HIRDLS will not have its designed horizontal coverage, nor will it be able to make measurements over the Antarctic. Because of the issues discussed above for TES, no profile data will be obtained via limb scanning; however, some profile information may be derived from the nadir measurements of temperature, CO, H_2O, and CH_4. (NASA)

Balloonborne Measurements

NOAA monitors upper tropospheric and stratospheric water vapour using cryogenic, chilled-mirror hygrometers that are flown in combination with ozonesondes on a biweekly schedule in Boulder, CO, and at Lauder, New Zealand, in collaboration with NIWA. Water-vapour profiles also are obtained on a campaign basis in Indonesia, the Galapagos, and Hawaii. NASA supports the flights of several balloon instruments (primarily on a campaign basis) capable of providing profile information for numerous atmospheric constituents. *In situ* measuring instruments include a whole-air sampler, gas chromatograph, and TDL and NDIR spectrometers. Over the last decade, near-annual deployments of a NOAA automated gas chromatograph on NASA's Observations of the Middle Stratosphere (OMS) *in situ* balloon gondola have revealed distinct changes in the 0- to 32-km vertical profiles of ozone-depleting substances (ODSs) and other gases. Flights of remote-sensing instruments (a submillimeter/millimeter wave radiometer, an infrared spectrometer, and a far-infrared spectrometer) also have been conducted on an annual basis. It should be noted that the total column abundance for various atmospheric altitude regions can be derived from the profile data for a particular species. (NOAA/CMDL, NASA)

Airborne Measurements

NASA-sponsored airborne campaigns, using both medium- and high-altitude aircraft, have been conducted with NOAA, NSF, and university partnerships, with a focus on satellite validation and scientific study of ozone and climate change. While designed more for process study than for trend determinations, the airborne measurements have provided a unique view of changes in atmospheric composition at various altitudes in response to source forcings. For example, gas chromatographic measurements taken from high-altitude aircraft (ER-2, WB-57F) in the upper troposphere and lower stratosphere since 1991 have established a 14-year record of the amounts of chlorine and bromine entering the stratosphere, and the halogen loading in the lower stratosphere. (NASA, NOAA, NSF)

Network for the Detection of Stratospheric Change (NDSC)

Several of the remote sensing instruments designated as primary components of the NDSC provide profile data for a variety of ozone-relevant gases and variables. These include temperature, water vapour and aerosol measurements by lidars, and water vapour measurements by microwave radiometers. Aerosol-backscatter profiles obtained weekly by NOAA in Colorado, Hawaii, and Samoa are able to detect an increase in stratospheric particle surface area resulting from major volcanic eruptions and capable of affecting heterogeneous chemical ozone loss. The NRL ground-based Water Vapour Millimeterwave Spectrometer (WVMS) instruments measure 40- to 80-km water vapour at Lauder, New Zealand (1992 to present); Table Mountain, California (1993 to 1997, 2003 to present); and Mauna Loa, Hawaii (1996 to present). These measurements confirmed and validated the large increase in water vapour observed by the UARS HALOE instrument in the early 1990s, they show that this trend ceased in the mid-90s, and they demonstrate that there has been (at most) a very small (<0.5%) negative (decreasing) trend in upper stratospheric/lower mesospheric water vapour since late 1996. (NASA, NOAA/CMDL, DoD/NRL)

Ground-Based In Situ Measurement Networks

Weekly to bi-weekly flask samples are collected at 13 globally distributed sites and are analyzed on three instruments at NOAA/CMDL for a total of ~25 gases, most of which are involved in ozone depletion (including all of the gases regulated under the Montreal Protocol). NASA supports a flask sampling effort conducted by the University of California, Irvine (UCI), under which seasonal sampling is conducted at 40 to 50 sites ranging from 71ºN to 47ºS. These flask data provide the basis for determining global, tropospheric trends of these gases and for computation of effective equivalent chlorine (EECl) in the atmosphere. (NOAA/CMDL, NASA)

The NASA Advanced Global Atmospheric Gases Experiment (AGAGE) network conducts high-frequency measurements at five globally distributed sites of many of the halocarbons identified as ODSs, and it has the longest continuous observational record for such species, extending back more than 25 years for some CFCs. New advanced instrumentation now permits the monitoring of many of the CFC replacements, thereby enabling a tracking of such chemicals from their first appearance in the atmosphere. Similar instruments maintained at the four NOAA Baseline Observatories (South Pole, Samoa, Mauna Loa, Pt. Barrow) and at a remote, cooperative research site (Niwot Ridge, Colorado), obtain high-frequency measurements (~hourly) of 10 ozone-depleting gases, including all of the major ozone-depleting gases and most of the Group I and II ozone depleters. Measurement and standards intercomparisons between the AGAGE and

NOAA/CMDL networks and with other international collaborators are leading to an improved long-term database for many ozone- and climate-related gases. These measurements also provide independent records for verifying flask analyses and help to understand the processes that contribute to atmospheric variability of these gases. (NOAA/CMDL, NASA)

UV Irradiance Measurements

Broadband Measurements

SURFRAD Network

Seven Surface Radiation Budget Network (SURFRAD) sites operate Yankee Environmental Systems, Inc. (YES) UVB-1 broadband radiometers. The ISIS network of solar measurements includes broadband Solar Light 501 UVB biometers at each of nine sites. Other instrumentation (located at the Table Mountain test facility near Boulder, Colorado) includes a triad of calibration-reference YES UVB-1 broadband radiometers, and two calibration reference Solar Light 501 UVB biometers. Several other broadband UV radiometers also are operated at the Table Mountain site. These include a Scintec UV radiometer, two types of Kipp & Zonen broadband UV radiometers, an EKO UV radiometer, and a Solar Light 501 UVA biometer. (NOAA/SRRB)

CMDL Network

Supplemental measurements of UV-B using YES UVB-1 instruments continue at Boulder, Colorado and Mauna Loa, Hawaii, where high-resolution UV spectroradiometers also are operated and can be used to interpret accurately the broadband measurements. (NOAA/CMDL)

USDA UVB Monitoring and Research Programme (UVMRP)

Thirty-four YES UVB-1 radiometers are fielded under this programme (see Section 1.1.1.5). (USDA)

Narrowband Filter Measurements

SURFRAD Network

Currently operating at the Table Mountain test facility in Colorado are a Biospherical Instruments GUV-511 UV radiometer, a Smithsonian 18-channel UV narrow-band radiometer, and two YES UV-MFRSRs. A YES UV-MFRSR soon will be deployed at the Central Ultraviolet Calibration Facility's High-Altitude Observatory at Niwot Ridge, Colorado. (NOAA/SRRB)

CMDL Network

Narrowband radiometers (Biospherical Instruments, GUV, 305 nm, 313 nm, 320 nm, and 380 nm) are used at three sites in Alaska. These sites were established in 1998 and operated for about two years with initial funding, but have been operated in a minimal-maintenance mode since. One site was discontinued in 2003 when it was determined that the combination of on-site support and data communications problems were prohibitive. Initial and subsequent calibrations of the instruments have been performed by the manufacturer. Due to reductions in personnel and funding, since 2001 the instrument calibration schedules have been reduced and adequate quality control has not yet been applied to the data. (NOAA/CMDL)

USDA UVB Monitoring and Research Programme (UVMRP)

UV-MFRSRs deployed within this network measure total and diffuse horizontal and direct normal irradiance at 300, 305, 311, 317, 325, 332, and 368 nm with a 2.0-nm bandpass. (USDA)

NSF UV Monitoring Network

Biospherical Instruments (BSI) GUV-511 moderate bandwidth multi-channel radiometers are deployed at five of the seven network sites (McMurdo and Palmer Station in Antarctica, San Diego California, Barrow Alaska, and Summit Greenland). A BSI GUV-514 radiometer is deployed at the South Pole. (NSF)

Spectroradiometer Measurements

Total Ozone Mapping Spectrometer (TOMS) Instrument Series

Data from this series of satellite instruments, originally designed for column ozone retrievals, have been used to produce daily global maps of spectral UVB and UVA since November 1978, with a data gap between April 1993 and July 1996. The data are most useful for tracking weekly and long-term variability of UVB/UVA at ~100-km spatial scales. The data recently have been reprocessed using an improved algorithm. Aerosol absorption (due to soot and mineral dust) and clouds over snow are the largest error sources. The NASA Goddard Space Flight Center (GSFC) and Finnish Meteorological Institute (FMI) are collaborating to develop advanced algorithms that correct these effects. (NASA)

Ozone Monitoring Instrument (OMI) on the Aura Satellite

The space-based UVB measurements begun with the TOMS instruments (see Section 1.3.3.1) will continue with OMI. FMI is responsible for producing the UVB product, and is collaborating with NASA GSFC on the algorithm development. (NASA)

SURFRAD Network

A high-precision UV spectroradiometer and a UV spectrograph are located at the Table Mountain Test Facility in Colorado under the auspices of this programme. (NOAA/SRRB)

Network for the Detection of Stratospheric Change (NDSC)

State-of-the-art, high-resolution spectroradiometric UV observations are conducted as a part of the NDSC at several primary and complementary sites. In particular, U.S. collaboration with NIWA (New Zealand) enables such measurements at Mauna Loa, HI and Boulder, CO. The measurements at Mauna Loa were started in 1995, those in Boulder began in 1998, and they continue to the present. (NOAA/CMDL)

NSF UV Monitoring Network

BSI SUV-100 high-resolution scanning spectroradiometers are deployed at all seven network sites (McMurdo Station, Palmer Station, and South Pole Station in Antarctica; San Diego California; Barrow, Alaska; Summit, Greenland; and Ushuaia, Argentina). A BSI SUV-150B spectroradiometer is also deployed at Summit, Greenland. (NSF)

UV-Net Programme

Brewer Mark IV spectrometers that measure the spectrum between 290 and 325 nm are deployed at all 21 network sites located in 14 U.S. national parks and 7 urban areas around the U.S. (EPA)

Calibration Activities

BUV/SBUV/SBUV-2 Satellite Instrument Series (8 Instruments)

To produce recently released V8 data, instruments were carefully cross-calibrated using internal methods. Derived trends are independent of ground-based network and other satellite data. (NOAA/CPC, NASA)

Total Ozone Mapping Spectrometer (TOMS) Instrument Series (4 Instruments)

The TOMS instruments have been cross-calibrated against the SBUV instrument series. Thus, the SBUV series provides the calibration, while TOMS provides the coverage. (NASA)

Ozone Monitoring Instrument (OMI) on the Aura Satellite

The OMI column ozone dataset released thus far is based on the TOMS V8 algorithm, which has been calibrated against SBUV. Future release, based on the DOAS algorithm, will be independent of SBUV. (NASA)

Dobson Network

World Standard Dobson No. 83 is maintained at NOAA/CMDL as part of the World Dobson Calibration Facility, and regularly participates in international intercomparisons of regional and national standards. (NOAA/CMDL)

Network for the Detection of Stratospheric Change (NDSC)

Several operational protocols have been developed to insure that NDSC data is of the highest long-term quality as possible within the constraints of measurement technology and retrieval theory at the time the data are taken and analyzed. Validation is a continuing process through which instruments and their associated data analysis methods must be validated before they are accepted in the NDSC and must be continuously monitored throughout their use. Several mobile intercomparators within the various NDSC instrument types exist to assist in such validation. (NASA, NOAA/CMDL)

Ground-Based In Situ Measurement Networks

Both the NOAA/CMDL and NASA/AGAGE networks independently develop and maintain highly accurate and precise calibration scales at ppt and ppb levels for the major and minor long-lived ozone-depleting gases. In addition, both networks are developing reliable calibration scales for the short-lived halogen-containing gases that have been introduced as CFC replacements. These new calibration scales support research which addresses the roles of the very short-lived gases that may help explain the apparent imbalance between bromine in the stratosphere and in the troposphere. The International Halocarbons in Air Comparison Experiment (IHALACE) is being supported and should help to form a basis for developing a homogeneous record of halocarbon atmospheric abundances derived from diverse international datasets. (NOAA/CMDL, NASA)

SURFRAD Network

The Central Ultraviolet Calibration Facility (CUCF) is located in NOAA's David Skaggs Research Center in Boulder, Colorado. The CUCF calibrates more than 80 UV instruments per year for several U.S. Government agencies and other UV research concerns, both national and international. In addition to laboratory calibrations, the CUCF has developed a portable UV field-calibration system that allows laboratory-grade calibrations to be made at spectroradiometer field sites. The CUCF also produces secondary standards of spectral irradiance that are directly traceable to NIST primary standards. The secondary standards can be calibrated for operation in either the vertical or horizontal orientation. (NOAA/SRRB)

USDA UVB Monitoring and Research Programme (UVMRP)

NOAA CUCF lamp calibrations performed in horizontal and vertical position using NIST traceable 1000-W halogen lamps are used to calibrate 48 USDA UV-MFRSRs and 46 UVB-1 broadbands. A U-1000 1.0-m double Jobin Yvon with 0.1-nm resolution and 10^{-10} out-of-band rejection is used as a reference spectroradiometer to transfer lamp calibration to a broadband triad. The UV-MFRSR radiometer spectral response and its angular response (critical for direct beam retrieval) are measured. The Langley calibration method is employed to provide additional absolute calibration of UV-MFRSRs and to track radiometric stability *in situ*. (USDA)

UV-Net Programme

Collocating ultraviolet radiation (UVR) monitors of different types (e.g., multifilter and broadband instruments) is important for determining changing surface levels and their cause. This supports instrument calibration and data comparison among networks, and allows continuous data collection should an instrument temporarily fail. Currently, only three network Brewers are collocated with other UVR monitors. The Table Mountain Test Facility in Colorado is host to numerous UVR instruments for data intercomparison and calibration. While some instruments remain there for years, others are transported there annually for intercomparison and calibration. The EPA Brewer in Big Bend National Park is 47 kilometres from USDA's climatological station. The instruments at Big Bend have been compared since February 1997. Other UVR monitor collocations operate at Bondville, Illinois and Fort Peck, Montana with SURFRAD and USDA monitors. (EPA)

RESULTS FROM OBSERVATIONS AND ANALYSIS

Ozone

Trend Analyses

Merged Satellite Datasets

Merged total and profile ozone data sets have been created using V8 TOMS and SBUV data adjusted to a common calibration. The V8 data already have been cross-calibrated, so additional adjustments are small (no adjustments to the profile data). These data sets are easily accessible, and convenient for users who do not wish to analyze multiple instrument data sets. (NASA)

Ozonesonde Data

An analysis of Northern Hemisphere ozonesonde data utilizing a statistical model that includes the 1979 to 1996 trend, the trend-change in 1996, plus ancillary variables of solar cycle (f10.7), QBO, and AO/AAO has been completed. (NOAA/CPC)

A comparative analysis of South Pole and Syowa ozonesonde data going back to the 1960s has been completed. (NOAA/AL, NOAA/CMDL)

Ozone Depletion

Statistical analysis of the merged TOMS/SBUV profile ozone data set from 1979 to 1997 shows the largest negative trends in the upper stratosphere at high latitudes (-7% per decade at 47.5˚S and –6% per decade at 47.5˚N), and less negative trends in the tropics and below 30 hPa (-1 to -3% per decade), which is in general agreement with previous profile trend estimates from satellite and ground-based records. This total and profile ozone information also has been used extensively to study the morphology of the anomalous 2002 ozone hole. Further, these data have been used in a correlative study relating the Southern Hemisphere polar vortex to the depletion levels of springtime total ozone at high northern latitudes. An intriguing, though unexplained, connection was found between the strength and interannual variability of these features (correlation coefficient > 0.7). Ultimately, understanding these interactions will improve our ability to predict future ozone changes. (NASA)

Antarctic Ozone Hole

Since approximately 1997, the underlying trend of Antarctic ozone (i.e., the trend after removal of the effect of natural variability in vortex temperatures) has been zero. This cessation of the downward trend in ozone is consistently seen at 60ºS to 70ºS in TOMS total ozone columns, SAGE/HALOE stratospheric columns, ozonesonde ozone columns at Syowa (69ºS), and Dobson total column measurements at 65ºS and 69ºS. The size of the Antarctic ozone hole is primarily controlled by inorganic chlorine and bromine levels (effective equivalent stratospheric chlorine, EESC), and secondarily controlled by the temperature of the Antarctic vortex collar. Fits of the ozone-hole size to temperature and chlorine and bromine levels suggest that the ozone-hole size actually may be decreasing at a very slow rate. This slow decrease is masked by the large natural variability of the Antarctic stratosphere. (NASA)

Ozone Recovery

TOMS/SBUV and Dobson/Brewer total ozone columns and SAGE/HALOE columns above 18 km altitude show that ozone between 60ºN and 70ºS has ceased to decline since approximately 1997. Results derived from the worldwide network of ozonesonde measurements provide similar evidence. Such behaviour appears to be associated with the levelling off and gradual decline in stratospheric halogen loading. In contrast, most of the increase in ozone abundance between the tropopause and 18 km is inferred to be due to transport changes. The increase in this layer can explain approximately half of the post-1997 changes in the total ozone column. (NOAA/CMDL, NOAA/SRRB, NASA).

Ozone Maps

Daily maps of total ozone and monthly total ozone anomalies are being produced, as well as routine updates of the SBUV-2 total ozone change utilizing a statistical model that includes the 1979 to 1996 trend, the trend-change in 1996, plus ancillary variables of solar variation (f10.7), QBO, and AO/AAO. In addition, twice-yearly (Northern and Southern Hemisphere) winter summaries of selected indicators of stratospheric climate are generated. (NOAA/CPC)

Ozone-Related Gases and Variables

Trend Analyses

Upper Atmosphere Research Satellite (UARS) Data

UARS measurements have been used to analyze atmospheric trends in ozone, H_2O, CH_4, NOx ($NO+NO_2$), HCl, HF, and temperature. These measurements also have been used to quantify UV light variations at wavelengths from 115 to 410 nm over the 27-day solar rotation period and an 11-year solar cycle period. (NASA)

Ozone-Related Chemistry

Effects of Large Solar Proton Events (SPEs)

Several satellite instruments (UARS HALOE; NOAA 14 and 16 SBUV-2; POAM III; Aura MLS; Envisat GOMOS, MIPAS, and SCIAMACHY; and Odin OSIRIS) have shown evidence in recent years of solar-particle-caused changes in polar atmospheric constituents. These include large enhancements in mesospheric NO_x (>50 ppbv) as a result of the extremely large SPEs in solar cycle 23, significant stratospheric NO_x enhancements (>20 ppbv) in the winter/fall polar regions after extremely large SPEs in July 2000 and October 2003, and polar mesospheric enhancements of OH (>50%) as a result of the SPE in January 2005. Very large polar mesospheric ozone decreases (>70%) were measured only during the SPEs of July 2000 and October 2003. Modest, but significant, polar upper stratospheric ozone decreases (>10%) persisted after the SPEs of October 2003. Total ozone decreases were computed to be less than 2%. (NASA)

Rate of Ozone Destruction by HO_x

The rate of odd hydrogen production via the reactions of electronically excited oxygen atoms, $O(^1D)$, produced via photolysis of ozone, has been quantified. These data reduce the uncertainty in the computed rates of OH production and ozone destruction via HO_x catalytic cycles. (NOAA/AL)

Chemical Reservoirs

New measurements of the formation rate for HO_2NO_2, a reservoir for HO_x and NO_x species, have been made at temperatures below 250K. The new results have a significant effect on model calculations of HO_2NO_2 formation. (NASA)

The reactivity of HO_2NO_2, has been further elucidated by new measurements of its reaction rate coefficients; absorption cross-sections in the UV, visible, and near-IR; and the quantum yields for the dissociation. These results have led to an improved quantification of the calculated rates of ozone destruction. (NOAA/AL)

Research at the Jet Propulsion Laboratory (JPL) has focused on the rates and mechanisms of several important reactions that control the ozone budget. Rate constants for the OH + NO_2 reaction, which produces the HNO_3 reservoir for odd hydrogen and odd nitrogen radicals in the lower stratosphere, have been remeasured with higher accuracy and sensitivity than previously possible. These new results predict a smaller HNO_3 formation rate. New studies in halogen oxide chemistry related to polar ozone depletion have improved the understanding of the chemistry of the ClO dimer (ClOOCl), a key intermediate in ozone destruction cycles. Finally, the photochemical mechanism for the oxidation of a key bromine-containing compound, bromoform, has been elucidated. Such information will assist in the understanding of the stratospheric bromine budget. (NASA)

Polar Stratospheric Clouds (PSCs)

Michelson Interferometer for Passive Atmospheric Sounding (MIPAS) Validation

SAGE III PSC data for the 2002-2003 Arctic winter have been used by to validate PSC sightings and thermodynamic-type classifications of the PSCs observed for that season by the MIPAS instrument on the Envisat platform. (NASA)

Coupling of Satellite and Aircraft Data

An analysis of SAGE III 1022-nm extinction versus the 1022-nm/449-nm extinction ratio has enabled the discrimination of PSCs in mixtures of background aerosol with very few large NAT particles, such as the NAT “rocks” observed *in situ* during the SAGE III Ozone Loss and Validation Experiment (SOLVE) airborne campaign. Thus, SAGE III can provide systematic observations of these clouds, which would greatly improve current understanding of how they form and lead to stratospheric denitrification and prolonged ozone destruction. (NASA)

SPARC PSC Assessment

SAGE III data will be a focus of the recently initiated SPARC PSC Assessment, which aims to bridge significant gaps that still exist in our knowledge of PSCs. These gaps are primarily in our understanding of solid PSC particle formation, limiting our ability to represent PSCs and their chemical effects in global models and to predict how these might differ in the stratosphere of the future. (NASA)

Stratospheric Ozone - Climate Connection

Antarctic Ozone and Climate

Recent observational analyses have added to our understanding of the ways stratospheric ozone depletion and tropospheric climate are linked. Specifically, an examination of the Antarctic stratospheric ozone and tropospheric climate during the period from 1979 through 2002 has been used to show that stratospheric variability is an important driver of surface climate variability. (NOAA/AL)

Aerosol Effects

Biomass-burning aerosol particles have been observed in the lower stratosphere. The ability of such species to be transported to the stratosphere can impact the chemistry and climate of this region. (NOAA/AL)

Ozone-Relevant Gases

A new precise and accurate method for measuring HCl and $ClONO_2$ in the upper troposphere and lower stratosphere from aircraft platforms using chemical ionization mass spectrometry has been demonstrated. Use of this methodology in the winter polar stratospheric vortices during periods of rapid ozone destruction will help better quantify and understand ozone destruction processes. The measurements of HCl, in particular, have been used to quantify the amount of stratospheric ozone in the upper troposphere. Expanded use of this method will lead to improved quantification of ozone transport from the stratosphere to the troposphere and the budget of stratospheric ozone. (NOAA/AL)

Oceanic Gas Fluxes

Data from seven research cruises in the past decade have allowed refinement of the atmospheric lifetime of methyl bromide and an improved understanding of the budget of this gas. The cruises provided the only widespread, combined atmospheric and ocean surface measurements of very short-lived gases to date. The most recent cruises took place in 2001 and 2004. (NOAA/CMDL)

UV

UV Trends

SURFRAD Network

Work has been initiated with the Colorado State University (CSU) UVB group to analyze some of the stations in their network for trends in solar UV irradiance. Three radiative transfer models in the UV are being run to compare to spectral direct normal and diffuse horizontal irradiance measurements made with the State University of New York (SUNY) at Albany UV rotating shadowband spectroradiometer on clear days. (NOAA/SRRB)

USDA UVB Monitoring and Research Programme (UVMRP)

Analysis of nine years of broadband data indicates no statistically significant trend in UVB. The difficulty in detecting the expected upward trend in UVB is due to calibration uncertainties, radiometric sensitivity drift, year-to-year variability due to changes in cloud cover, ozone, aerosols, albedo, etc. Improved quantification of these variables is essential for any trends analysis. (USDA)

The variation of ground-level UV irradiance with latitude, season, and elevation revealed by the UVB-1 broadband meter is broadly consistent with theoretical expectations. The large annual cycle in monthly integrated broadband UV irradiance usually peaks in July. During summer, lengthening duration of daylight with latitude poleward counteracts the increase in solar zenith angle at a fixed local time, providing a weaker latitudinal gradient in UV irradiance than at other times of the year. Under this circumstance, localized atmospheric conditions such as cloudiness and limited visibility can have a substantial influence on the differences in radiation levels between sites. (USDA)

UV Forecasts and Exposure

UV Alert System

NOAA/CPC is producing UV forecasts for the U.S., and is developing a UV Alert system with the EPA. The UV Alert system is designed to advise the public when UV levels are unusually high and represent an elevated risk to human health. The UV Alert system consists of a graphical map displaying the daily UV Alert areas, as well as additional information included in the EPA's UV Index ZIP Code look-up web page and via the EPA's AIRNow EnviroFlash e-mail notification system. The criteria for a UV Alert are that the noontime UV Index must be at least a 6 and must be 2 standard deviations above the daily climatology. (NOAA/CPC, EPA)

Effects of UVB Exposure

A major limitation in predicting the impacts of UVB irradiance on humans, plant leaves and flowers, and aquatic organisms is the difficulty in estimating exposure. An analysis of the spatial variability in the daily exposure to narrowband 300- and 368-nm and broadband 290- to 315-nm

(UVB) solar radiation between 12 paired locations in the USDA UVB Climate Network over two summer growing seasons has been completed. The spatial correlation of the UVB, 300- and 368-nm daily exposures between locations was approximately 0.7 to 0.8 for spacing distances of 100 km. The 300-nm daily exposure was typically more highly correlated between locations than the 368-nm daily exposure. (USDA)

THEORY, MODELING, AND OTHER RESEARCH

Ozone

Theory, Modelling, and Analysis

Model Comparisons

SBUV-2 total ozone data have been compared with 2-D Chemical Transport Models (CTMs) from the University of Illinois and GSFC. In addition, mechanisms to improve the ozone data assimilation within the NWS Global Forecast System are being developed. This includes the SBUV-2 data, as well as the data that may be available operationally from the NASA Aura satellite (e.g., OMI and HIRDLS) and the GOME2 instrument from METOP. (NOAA/CPC)

Multi-Fractal Analysis

Statistical multi-fractal analysis was used to produce a correlation between the rate of ozone photodissociation and the intermittency of temperature in the Arctic lower stratosphere, with potential implications for radiative transfer, turbulent dynamics, and chemistry. (NOAA/AL)

Photochemical Ozone Loss

The Match technique has been applied to five years of Antarctic data from POAM III, using trajectories obtained from the ECMWF, UKMO, and NCEP meteorological analyses for studying photochemical ozone loss. The results show that the Match ozone loss rates are sensitive to the choice of meteorological analysis. In late August and early September, when ozone loss rates peak near the South Pole, the ECMWF trajectories generally yield lower loss rates than those obtained with the UKMO and NCEP analyses. These differences are important because the NCEP- and UKMO-derived POAM loss rates are significantly higher than model results (using upper limit values for BrO_x and ClO_x and *JPL 2002* kinetics), while ECMWF results show no significant measurement/model deficit. Because of its higher temporal and spatial resolution, it is reasonable to conclude that the ECMWF results may be more accurate. (DoD/NRL)

A recent modelling analysis suggests that the underestimation of the chemical loss of polar ozone by past photochemical model simulations may be due to two factors: 1) the presence in the atmosphere of much higher levels of bromine then is commonly assumed, due to a significant stratospheric influence of the decomposition products from very short-lived biogenic bromocarbons; and 2) the significantly faster photolysis of the ClO dimer than calculated using recommended cross-sections. It appears that models may provide more accurate simulations of seasonal and long-term ozone depletion due to a greater influence of chemical reactions involving bromine, and that the Montreal Protocol and its amendments are having the desired effect on ozone levels throughout the world. (NASA)

Ozone Forecasts

The Navy Operational Global Atmospheric Prediction System (NOGAPS) is being extended into the stratosphere and mesosphere for the development of an ozone forecast capability. The extended model (NOGAPS-ALPHA) was shown to provide reliable short-range stratospheric ozone forecasts during the second SAGE III Ozone Loss and Validation Experiment (SOLVE-II) campaign. (DoD/NRL)

Interannual Variability

In a study of ozone interannual variability, the GSFC 2-D model was forced with observed wind fields from NCEP and ECMWF global analyses over the period from 1970 to the present. By including the dynamical forcing, the 2-D model resolved most of the observed total ozone variability in time and latitude. Long-term 2-D model simulations with realistic dynamics will enhance understanding of past and predicted ozone change, and can be run using minimal computer resources and time. (NASA)

Decadal Analyses and Simulations

Several multi-decadal integrations of the GSFC 3-D CTM from 1975 to 2025 have been completed. The model includes observed and predicted changes in chlorine and bromine source gases, solar UV radiation, and volcanic aerosols (past only). Model transport is driven by winds from a general circulation model (GCM). To assess the influence of various factors on ozone, the model has been run with chlorine source gas fixed at 1979 levels and without volcanic aerosols. The model output is analyzed using the same statistical approach applied to observations. The ozone response to chlorine is found to be insensitive to interannual variability in time series longer than 25 years. Analysis of the simulations with and without volcanic aerosols suggests that current statistical techniques are unable to accurately separate the volcanic signal from interannual variability in ozone. (NASA)

A chemistry-climate coupled model has been developed and is currently being tested at GSFC. This model is being used to produce 20-year 'time slice' simulations with fixed trace-gas boundary conditions and a 150-year integration to study interactions between ozone, water vapour, other greenhouse gases, and climate. (NASA)

Total and profile ozone data from the NOAA 16 SBUV/2 satellite are used in a near-real-time ozone assimilation system at the GSFC GMAO. Data are combined with CTM ozone forecasts to produce global 3-D ozone estimates. Because of its coverage and longevity, SBUV data are commonly used in ozone and meteorological assimilation systems. Tests using MLS and OMI data from Aura in the assimilation system indicate better representation of total and stratospheric ozone using these data. (NASA)

TOMS total ozone is commonly used with a source of stratospheric profile ozone to estimate total column tropospheric ozone. Various methods have been used to construct long-term records of tropospheric ozone, particularly in the tropics. These records have been used in a series of variability and transport studies. (NASA)

Ozone-Related Gases and Variables

Validation Studies

Ground-Based Measurements

A ground-based programme for aerosols and trace gases has produced new results related to NO_2 daily and diurnal variation and aerosol UV absorption. The results will be used for OMI validation and for climate studies. (NASA)

Actinic Flux Measurements

The National Center for Atmospheric Research (NCAR) CCD actinic flux spectroradiometer (CAFS) is being deployed on NASA airborne field experiments. The measurements are being used to determine ozone-column abundances above and below the aircraft for the validation of OMI data. (NSF, NOAA/SRRB)

Environmental Properties of Atmospheric Gases

CFC Substitutes

Laboratory studies of the atmospheric lifetimes and environmental fates of many CFC substitutes have been conducted, thereby permitting an evaluation of their "ozone friendliness." These results provide important input parameters for model calculations of the future vulnerability of the ozone layer, and are used together with industrial production-and-use information to analyze the growth of such chemicals in the atmosphere. (NOAA/AL, NASA)

Oceanic Gas Lifetimes

The partial lifetimes with respect to oceanic loss for more than 90 halogenated gases have been determined using a simple, coupled, ocean-atmosphere box model and the COADS data set for sea-surface temperature and wind speed. (NOAA/CMDL)

UV

UV Instrumentation

The temperature dependence of the Brewer UV spectrometer has been studied in order to improve the quality of data for UV trends. (NOAA/SRRB)

UV Effects

The UVMRP supports research studying UVB effects on plants and ecosystems. Numerous publications document the results of these studies. (USDA)

DISSEMINATION OF RESULTS

Data Reporting

Ozone

TOMS and SBUV Series

In June 2004, a 2-DVD set containing the entire TOMS V8 data set was released. The data cover the period from November 1978 through August 2003. Similarly, a DVD containing SBUV V8 ozone profile data was released. Data are from Nimbus 7 (1978 to 1993), NOAA 9 (1985 to 1998), NOAA 11 (1988 to 2001) and NOAA 16 (2000 to 2003). The Goddard Earth Sciences (GES) Data and Information Services Center (DISC) routinely distributes the data. (NASA)

POAM Data

Data from the POAM instrument is available via ftp at ftp://poamb.nrl.navy.mil/pub/poam3/ and also is submitted to the NASA Langley Distributed Active Archive Center (DAAC). (DoD/NRL)

OMI Data

TOMS-compatible total ozone data produced from OMI since September 2004 are available from the GSFC DAAC at http://daac.gsfc.nasa.gov/. Total ozone data produced using a DOAS algorithm will be available by the end of 2005. (NASA)

Umkehr Data

Dobson Umkehr data processed using an SBUV-like algorithm are available at http://www.srrb.noaa.gov/research/umkehr/. (NOAA/SRRB, NASA)

World Ozone and Ultraviolet Radiation Data Center (WOUDC)

Total ozone, Umkehr, and ozonesonde data are reported to the WOUDC from U.S. Government agencies and institutions. Ozone data from sites that are part of the NDSC and the SHADOZ network are available from the programme web sites (http://www.ndsc.ws/ and http://croc.gsfc.nasa.gov/shadoz/, respectively), and also are imported to WOUDC. (NOAA, NASA).

Maps

All daily SBUV/2 total ozone map analyses are available as images in png format on the Internet. The raw data from the SBUV/2 are available from NESDIS. Additionally, the total ozone analysis and forecast fields out to five days from the NCEP GFS are presented via a web page. (NOAA/CPC)

Assessments

2006 WMO/UNEP Scientific Assessment of Ozone Depletion

The latest assessment, mandated under the provisions of the Montreal Protocol, is underway and is expected to provide the Parties with the information in support of future decision-making. (NOAA, NASA)

Arctic Climate Impacts Assessment (ACIA)

Chapter 3: Ozone and Ultraviolet Radiation was completed for the latest ACIA. (NOAA/SRRB)

Ozone-Related Gases and Variables

TOMS Aerosol Data

A preliminary dataset of AAOT in the UV derived from TOMS data can be obtained from torres@tparty.gsfc.nasa.gov. Public release of the data is planned for June 2006. (NASA)

Ozone-Depleting Substance Data

Long-term data from the NOAA/CMDL network are updated every six months on the NOAA/CMDL website (http://www.cmdl.noaa.gov/) and submitted annually to the World Data Centre and to the World Data Center for Atmospheric Trace Gases at the Carbon Dioxide Information Analysis Data Center (CDIAC). Data from field missions (firn-air studies, ocean flux studies), previously posted only upon publication, now are posted shortly after the field missions. Data on very short-lived gases from seven research cruises over the world's oceans are posted and available for use on the NOAA/CMDL website. (NOAA/CMDL)

Long-term data from the NASA/AGAGE network are reviewed on a semi-annual basis by the Science Team, and are archived every six months with CDIAC. Data from the UCI flask-sampling network are archived similarly. (NASA)

UV Data

SURFRAD Network Data

UV data from the SURFRAD Network are available on the NOAA/SRRB website (http://www.srrb.noaa.gov/). (NOAA/SRRB)

USDA UVB Monitoring and Research Programme (UVMRP)

UVB-1 broadband data and UV-MFRSR data from this network are regularly submitted to the WOUDC. (USDA)

Information to the Public

Ozone

TOMS and OMI Data

Near-real-time ozone data from Earth Probe TOMS and from the OMI instrument on Aura are routinely distributed via the TOMS web site (http://toms.gsfc.nasa.gov/). Data from TOMS are usually available with 12 hours; data from OMI within 2 days. The site provides online access to TOMS data back to 1978. While used mostly by scientists, educators and students also use the site extensively. An Ozone Hole Watch web site is being developed to provide a single site for anyone interested in the Antarctic ozone hole. (NASA)

Merged TOMS/SBUV Total and Profile Ozone Data

Merged TOMS/SBUV total and profile ozone data sets are available on the Internet (http://hyperion.gsfc.nasa.gov/Data_services/merged/index.html). (NASA)

UV

Forecasts

Noontime UV forecasts are made available to the public via several formats. One is a text bulletin for 58 cities for the U.S. The other is a gridded field that is made available via the NOAA/CPC and NOAA/NCEP ftp sites. (NOAA/CPC)

Advisories

The primary UVR advisory in the United States is the UV Index, operated jointly by NOAA and EPA. Currently, the UV Index computer model processes total global ozone satellite measurements, a rough cloud correction factor, and elevation to predict daily UVR levels on the ground and the resulting danger to human health. This model assumes zero pollution levels. UV Index reports are available in local newspapers and on television weather reports. The EPA also issues a UV Alert when the UV Index is predicted to have a high sun-exposure level and is unusually intense for the time of year. UV Alert notices can be found at EPA's SunWise web site (http://www.epa.gov/sunwise/uvindex.html), in local newspapers, and on television weather reports. (EPA)

Ozone-Depleting Gas Index

An ozone-depleting gas index (ODGI), based on Effective Equivalent Chlorine (EECl) measured globally in the NOAA/CMDL network, is being implemented. EECl is indexed to 1 on 1 January 1994, when it reached its maximum value. (NOAA/CMDL)

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PROJECTS AND COLLABORATION

NOAA/CMDL

The Dobson and ozonesonde measurements are included in the WMO Global Atmosphere Watch (GAW) and in the NDSC. Significant collaboration with federal agencies (NASA, DoE) and universities (University of Colorado, Harvard, Princeton, Humboldt State University, etc.) is maintained through both global monitoring and field missions.

NOAA/CPC

Activities include participation in several initiatives of Stratospheric Processes and their Relation to Climate (SPARC), i.e., stratospheric temperatures, ozone, UV, climate change; collaboration with the EPA on the UV Index and, recently, the UV Alert system; collaboration with NASA in ozone monitoring, calibration of the SBUV/2 instruments, and dynamical processes influencing ozone changes; collaboration with the surface radiation monitoring efforts of NOAA/OAR and USDA-CSU for the validation of UV forecasts and NCEP GFS surface radiation products, and the NDSC Data Host Facility.

NOAA/SRRB

The CUCF is designated by a Memorandum of Understanding to be the national UV calibration facility by agreement among the following organizations: NOAA, USDA, EPA, NASA, National Institute of Standards and Technology (NIST), NSF, National Biological Service, and the Smithsonian Institution. The CUCF compared secondary standards of irradiance with the Joint Research Centre's European Union UV Calibration Centre's (ECUV) ultraviolet spectral irradiance scale in Ispra, Italy. The CUCF's irradiance scale is directly traceable to the NIST spectral irradiance scale, while the ECUV's irradiance scale is traceable to that of the German national standards laboratory, Physikalisch-Technische Bundesanstalt (PTB).

NASA

NASA collaborates extensively with several NOAA laboratories (AL, CMDL, CPC, SRRB) in all areas of ozone and UV research, including space-based, airborne, balloonborne, and ground-based measurements, as well as in various modelling and analysis activities. NASA often supports research activities within these laboratories in the aforementioned areas. The NDSC, which is championed by NASA and NOAA within the U.S., is a major contributor to WMO's Global Ozone Observing System (GO_3OS) within the frame of its Global Atmosphere Watch (GAW) Programme.

NASA is closely collaborating with KNMI (Netherlands) and FMI (Finland) on processing data from the Aura OMI instrument. Though NASA and KNMI are developing independent algorithms using TOMS and GOME heritage, respectively, the results are being compared carefully to assess the strengths and weaknesses of each algorithm.

USDA

USDA is actively collaborating with the NASA TOMS and AERONET groups on aerosol absorption using UV-MFRSR and Cimel instruments. USDA researchers are funded for participation in the NSF MIRAGE Mexico City air quality study scheduled for February/March 2006. Collaborations also exist with DoE for providing aerosol optical depths and column ozone data. Agency personnel participated in the Norwegian filter radiometer intercomparison held in Oslo in May 2005.

FUTURE PLANS

Ozone

Column Ozone from Dobson/ Brewer Zenith-Sky Measurements

The operational zenith-sky total ozone algorithm for Dobson and Brewer instruments is based on empirically derived tables. NASA has developed a TOMS-like algorithm to process these data, which has the potential to substantially improve data quality. There are plans, subject to availability of funds, to process all historical zenith-sky data using this algorithm. (NASA)

Brewer Umkehr Retrievals

An Umkehr retrieval capability similar to that developed for the Dobson instrument is being developed for the Brewer spectrometer. (NOAA/SRRB, NASA)

TOMS Data Reprocessing

TOMS data likely will be reprocessed before the 2008 Quadrennial Ozone Symposium, based on lessons learned by comparing TOMS with SBUV, GOME, SCIAMACHY, and OMI. (NASA)

Ozonesondes

A new ozonesonde programme has been established under the auspices of the NASA/SHADOZ programme in Costa Rica. Ozonesonde launches at Summit, Greenland will begin in collaboration with the NSF in late 2005. (NOAA/CMDL)

Dynamical Forcings

An examination of the statistical relationship of tropospheric forcings (e.g., AO/AAO, tropopause pressure, etc.) to changes in total ozone and layer ozone will be undertaken. (NOAA/CPC)

Ozone-Relevant Gases/Variables

Improvements in sampling and analysis efficiency have enabled weekly vertical profiles of ~25 trace gases at numerous sites in the lower troposphere. Expansion of this network across North America will aid considerably in source attribution of new and old, short- and long-lived ODSs. Current and future measurement campaigns include multiple deployments of a new gas chromatograph (GC) aboard the Altair uninhabited aerial vehicle (UAV) and the operation of this same instrument onboard a Learjet in Brazil. Plans also include continued monitoring of ODSs from the NASA WB-57F high-altitude aircraft and the NASA OMS balloon gondola. Additional sampling of firn air is scheduled for Greenland as part of an overall firn and ice sampling effort to take place during the International Polar Year. These records continue to improve our understanding of the natural contributions of ODSs. Development and operation of an airborne 6-channel GCMS/ECD that measures approximately 20 important atmospheric trace gases whose changing burdens impact air quality, climate change, and stratospheric/tropospheric ozone will continue. (NOAA/CMDL)

Several aircraft, balloon, and ground-based measurement campaigns are in the planning and near-implementation stages. These campaigns, planned for bases within the U.S. and the subtropics, will provide important validation data for ozone and ozone- and climate-related trace gases and parameters for Aura and other satellite sensors. They also will address high-priority science questions associated with atmospheric ozone chemistry and transport. (NASA)

UV

UV Index Forecast

An algorithm enhancement will be operational beginning Fall 2005. Features of this enhancement are global coverage, hourly forecasts up to and beyond 72 hours, better cloud transmission estimates, more realistic aerosol depictions, and realistic increases over snow-covered surfaces. Forecasts will be generated on 0.5-degree grids and made available on NCEP's ftp site. (NOAA/CPC)

Brewer Network

An interagency agreement is being negotiated for CUCF to operate a six-station network of Brewer spectroradiometers using instruments from the EPA network that closed in 2004. The primary emphasis will be on the effects of aerosols and clouds on UV radiation, but routine retrievals of ozone, ozone profiles from Umkehr, aerosol optical depth, and nitrogen dioxide also will be attempted. It is expected that the collaboration with the CSU UVB group will lead to further work with the data in their network. It also should be possible to improve on the current methods used to retrieve column ozone, which could lead to improvements in aerosol UV optical-depth retrievals below 368 nm. (NOAA/SRRB, EPA)

USDA UVB Monitoring and Research Programme (UVMRP)

A new site planned for Houston, TX, and the development of real-time data streams will be attempted within the network. New interagency collaborations will include participation in the NSF MIRAGE air-quality study in Mexico City (February/March 2006), and the generation of aerosol atmospheric corrections for a NASA/USGS invasive-species study. (UDSA)

NEEDS AND RECOMMENDATIONS

Ozone

Column Ozone

Column ozone data produced by satellite and ground-based instruments agree well in cloud-free conditions and at solar zenith angles less than 70º. However, the data quality of all measuring systems degrade under cloudy conditions and at large solar zenith angles, with differences of 10% or larger. Given the need for accurate ozone trends in the polar regions, it is important to improve the quality of ground-based data in these regions, and to focus future calibration and data intercomparison efforts accordingly. (NASA)

Profile Ozone

There is a vast amount of unprocessed Brewer Umkehr data residing in the archives. A concerted effort should be made to process these data using a common Dobson/Brewer algorithm, which is necessary for trend studies. (NASA)

The only currently planned U.S. space-based ozone-monitoring instrument in the post-Aura era will be the NPOESS OMPS instrument, a limb scattering measurement with very little heritage. In order to provide a calibration source for OMPS so that the data will be of sufficient quality for scientific studies and trend analysis, consideration should be given to adding a simple solar occultation instrument to NPOESS. (DoD/NRL)

Ozone-Relevant Gases and Variables

Aerosol Absorption Optical Thickness (AAOT)

There are currently no operational ground-based instruments that provide AAOT in UV. AAOT from the AERONET network is limited to wavelengths longer than 440 nm. NASA has improved a long-standing technique to derive AAOT in UV by combining measurements from AERONET and UV Shadowband radiometers. Efforts to utilize this methodology for deriving AAOT in the UV should be implemented. (NASA)

Ozone- and Climate-Related Trace-Gas Measurements

There is a need to maintain and expand the existing *in situ* networks, both geographically and with improved instrumentation. Current workforce limitations prevent the development and propagation of gas standards on as rapid a schedule as required by these networks to keep up with the increasing number of new chemicals of scientific interest. In addition, expanded efforts are needed for data analysis as more and more chemicals are being measured. (NASA, NOAA/CMDL)

UV

Geographical Measurement Coverage

UV monitoring in the tropics is very limited. Relatively inexpensive broadband UV instruments could be set up easily at installations launching ozonesondes (e.g., SHADOZ) in the tropical region. Such efforts should be coordinated with the NDSC. In this way, UV at the surface under aerosols/pollution can be linked with the ozone profiles measured by the ozonesondes and ground-based profiling instruments. (NOAA/CPC)

Only seven of the EPA Brewers are currently deployed in or near densely populated areas. Satellite-derived UVR is less reliable for urban locations, because satellite instruments do not adequately characterize pollutants at ground level. Because of the deficiency of current urban UVR data, health researchers conducting local studies are sometimes making their own UVR measurements as needed, with instruments that are often not easily compared with those from any of the existing UVR networks. Thus, better ground-level measurements collected in locations close to air-quality monitors are required. Finally, many sites have data gaps and inconsistencies. Only a limited number of ground-based sites provide historically continuous UV records. More analyses of available data and improved calibration could fill gaps in coverage. (EPA)

Calibration and Validation

The WMO has requested that the CUCF become the WMO centre for UV calibrations. However, funding for this within and outside NOAA has yet to be identified. Efforts to accomplish this should continue. (NOAA/SRRB)

It is now well established that the ratio of UVB and UVA can be predicted accurately under both clear and cloudy conditions wherever quality column ozone data exist. Since total ozone measurements currently are being made globally with very high accuracy and precision by satellite and ground-based instruments, UVB levels can be ascertained, often more accurately than they can be directly measured, if UVA levels are known. However, the causes of UVA variability are poorly understood (clouds, NO_2, aerosols), and satellite and ground-based estimates of UVA show poor correlation in the absence of ancillary data. Future measurements and intercomparisons should focus on this issue. (NASA)

Effects Research

Although the effects of UV exposure drive UV monitoring activities, only limited resources historically have been targeted towards UVB effects research. Expansion of UVMRP activities in this critical area is needed at a multi-agency level. (USDA)

Acronyms and Abbreviations

AAOT	aerosol absorption optical thickness
ACIA	Arctic Climate Impacts Assessment
AERONET	Aerosol Robotic Network
AGAGE	Advanced Global Atmospheric Gases Experiment
AL	Aeronomy Laboratory (NOAA, U.S.)
AO/AAO	Arctic/Antarctic oscillation
BSI	Biospherical Instruments
BUV	Backscatter Ultraviolet
CAFS	CCD Actinic Flux Spectroradiometer
CCD	charge-coupled device
CDIAC	Carbon Dioxide Information Analysis Data Center
CFC	chlorofluorocarbon
CMDL	Climate Monitoring and Diagnostics Laboratory (NOAA, U.S.)
COADS	Comprehensive Ocean-Atmosphere Data Set
CPC	Climate Prediction Center (NOAA, U.S.)
CSU	Colorado State University (United States)
CTMs	chemical transport models
CUCF	Central Ultraviolet Calibration Facility
DAAC	Distributed Active Archive Center (NASA Langley, U.S.)
DISC	Data and Information Services Center (NASA Goddard, U.S.)
DoD	Department of Defense (United States)
DoE	Department of Energy (United States)
DOAS	Differential Optical Absorption Spectroscopy
ECD	electron capture detector
ECMWF	European Centre for Medium-Range Weather Forecasts (United Kingdom)
ECUV	European UV Calibration Center
EECl	effective equivalent chlorine
EESC	effective equivalent stratospheric chlorine
EOS	Earth Observing System
EP	Earth Probe
EPA	Environmental Protection Agency (United States)
FMI	Finnish Meteorological Institute (Finland)

FTIR	Fourier transform infrared
GAW	Global Atmosphere Watch
GC	Gas Chromatograph
GCM	general circulation model
GCMS	Gas Chromatography Mass Spectrometry
GES	Goddard Earth Sciences
GFS	Global Forecast System
GMAO	Global Modeling Assimilation Office (NASA Goddard, U.S.)
GOES	Geostationary Operational Environmental Satellite
GO_3OS	Global Ozone Observing System (WMO)
GOME	Global Ozone Monitoring Experiment
GOMOS	Global Ozone Monitoring by Occultation of Stars
GSFC	Goddard Space Flight Center (NASA, U.S.)
HALOE	Halogen Occultation Experiment
HIRDLS	High-Resolution Dynamics Limb Sounder
IHALACE	International Halocarbons in Air Comparison Experiment
JPL	Jet Propulsion Laboratory (United States)
KNMI	Koninklijk Nederlands Meteorologisch Institut (The Netherlands)
MFRSRs	Multi-Filter Rotating Shadowband Radiometers
MIPAS	Michelson Interferometer for Passive Atmospheric Sounding
MIRAGE	Megacity Impacts on Regional and Global Environments
MLS	Microwave Limb Sounder
NASA	National Aeronautics and Space Administration (United States)
NAT	nitric acid trihydrate
NCAR	National Center for Atmospheric Research (United States)
NCEP	National Centers for Environmental Prediction (NOAA, U.S.)
NDIR	non-dispersive infrared
NDSC	Network for the Detection of Stratospheric Change
NESDIS	National Environmental Satellite, Data, and Information Service (NOAA, U.S.)
NIST	National Institute of Standards and Technology (United States)
NIWA	National Institute of Water and Atmospheric Research (New Zealand)
NOAA	National Oceanic and Atmospheric Administration (United States)
NOGAPS	Navy Operational Global Atmospheric Prediction System
NPOESS	National Polar-Orbiting Operational Environmental Satellite System
NRL	Naval Research Laboratory (United States)
NSF	National Science Foundation (United States)
NWS	National Weather Service (NOAA, U.S.)
ODGI	ozone-depleting gas index
ODSs	ozone-depleting substances
OHP	Observatoire de Haute-Provence (France)
OMI	Ozone Monitoring Instrument
OMPS	Ozone Mapping and Profiler Suite (NPOESS)
OMS	Observations of the Middle Stratosphere
OSIRIS	Optical Spectrograph and Infrared Imaging System
PEM	Particle Environment Monitor
POAM	Polar Ozone and Aerosol Measurement
POES	Polar Orbiting Environmental Satellites
PSCs	polar stratospheric clouds
PTB	Physikalisch-Technische Bundesanstalt (Germany)
QBO	quasi-biennial oscillation
SAGE	Stratospheric Aerosol and Gas Experiment
SAM	Stratospheric Aerosol Measurement
SBUV	Solar Backscatter Ultraviolet
SCIAMACHY	Scanning Imaging Absorption Spectrometer for Atmospheric Cartography
SHADOZ	Southern Hemisphere Additional Ozonesonde (Network)
SOLSTICE	Solar Stellar Irradiance Comparison Experiment
SOLVE	SAGE III Ozone Loss and Validation Experiment
SORCE	Solar Radiation and Climate Experiment
SPARC	Stratospheric Processes and Their Role in Climate

SPEs	solar proton events
SRRB	Surface Radiation Research Branch (NOAA, U.S.)
SUNY	State University of New York (United States)
SURFRAD	Surface Radiation Budget Network (NOAA, U.S.)
SUSIM	Solar Ultraviolet Spectral Irradiance Monitor
TDL	tunable diode laser
TES	Tropospheric Emission Spectrometer
TOMS	Total Ozone Mapping Spectrometer
UARS	Upper Atmosphere Research Satellite
UAV	uninhabited aerial vehicle
UCI	University of California, Irvine (United States)
UKMO	United Kingdom Meteorological Office
UNEP	United Nations Environment Programme
USDA	U. S. Department of Agriculture (United States)
USGS	U. S. Geological Survey (United States)
UV	ultraviolet
UVMRP	UV Monitoring and Research Programme
UVR	ultraviolet radiation
WMO	World Meteorological Organization
WOUDC	World Ozone and Ultraviolet Radiation Data Centre (Canada)
WVMS	Water Vapor Millimeterwave Spectrometer
YES	Yankee Environmental Services, Inc.

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