USDA UV-B Monitoring and Research Programme (UVMRP)
Thirty-eight YES UVB-1 radiometers are fielded under this programme. (USDA)

USDA UVB Monitoring and Research Programme (UVMRP)
UV-MFRSRs deployed within this 37 station network measure total and diffuse horizontal and direct normal irradiance at nominal 300, 305, 311, 317, 325, 332, and 368 nm with a 2.0 nm bandpass. In addition, vis-MFRSRs are deployed with nominal 415, 500, 610, 665, 862 and 940 nm wavelengths with 10.0 nm bandpass. These 13 measurements are used to create a continuous synthetic spectra model which can then be convolved with specific weighting functions to meet researcher's needs. Access to the synthetic spectra is found on the UVMRP web site at: (http://uvb.nrel.colostate.edu/UVB/uvb_dataaccess.jsf). Direct-sun column ozone is retrieved using the UV Multi-Filter Rotating Shadowband Radiometers (USDA, CSU)

NEUBrew Network
Five NEUBrew stations have a Yankee UV-MFRSR and all stations have a visible MFRSRs collocated with the Brewer spectrophotometer. (NOAA)

NOAA Antarctic UV Monitoring Network
NOAA/GMD has assumed operations of the Antarctic portion of the former NSF UV Monitoring Network. There are Biospherical Instruments (BSI) GUV-511 moderate bandwidth multi-channel radiometers deployed at two of the Antarctic stations, McMurdo and Palmer and a GUV-541 radiometer deployed at the South Pole. (NOAA)

Spectroradiometer Measurements

Central Ultraviolet Calibration Facility
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. The UV spectrograph was removed from operation in August 2009 due to equipment failure. It had been in operation since June 2003 (NOAA)

Network for the Detection of Atmospheric Composition Change (NDACC)
State-of-the-art, high-resolution spectroradiometric UV observations are conducted as a part of the NDACC 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)

NSF (AON Grant to the University of Chicago)UV Monitoring Network
BSI SUV-100 high-resolution scanning spectroradiometers have been deployed at three locations: San Diego, California (sub-tropical location); Barrow, Alaska through June 2016; and a BSI SUV-150B spectroradiometer was deployed at Summit, Greenland through the summer of 2017 ; and a BSI SUV-150B spectroradiometer deployed at Summit, Greenland. (NSF)

NOAA Antarctic UV Monitoring Network
NOAA has assumed operations of the NSF UV Antarctic Network. BSI SUV-100 scanning spectroradiometers are deployed at the three Antarctic stations, McMurdo, Palmer, and South Pole. The scanning range of these instruments is from 290-600 nm.

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. This network ceased operation in 2004 and all 21 Brewers were removed from their network sites. (EPA)

NEUBrew Network
The NOAA Environmental Brewer Spectrophotometer Network (NEUBrew) consists of six stations located in the western, central and eastern United States. Brewer MKIV instruments provide UV irradiance over the range 286.5 nm to 363 nm with 0.5 nm resolution up to 20 times per day. Absolute spectral UV irradiance , instantaneous UV index, and daily erythemal dose time series are available online with a latency of one day.
http://esrl.noaa.gov/gmd/grad/neubrew/. (NOAA)

Satellite-based Estimation
Surface UV radiation can be estimated using satellite-measured total column ozone and top-of-the-atmosphere radiance at a non-ozone absorbing UV wavelength as input to a radiative transfer code. Such methods have been applied to estimate both the spectral irradiance as well as UVB from the TOMS instrument series. Similar data are being produced by the Finnish Meteorological Institute (FMI) using OMI data. Since the cloud effects vary at very short spatial and temporal scales, the satellite derived UVB data are most useful for making estimates of monthly average UVB and spectral irradiance at ~100 km grid scales. An outstanding problem in the estimation of UVB from satellites is the strong UV absorption of most aerosols, most notably dust and secondary organics. An aerosol absorption correction is applied to the TOMS UVB record (but not to the OMI record) using TOMS-derived aerosol index (AI). Though AI can correct for elevated plumes of dust and smoke, it is not sensitive to aerosols near the surface. As a result, the satellites can overestimate UVB by up to 30% in polluted areas. However, this error is largely localized to urban areas and shouldn't significantly affect regional averages. (NASA)

Calibration Activities

Satellite BUV instruments
The UV instruments have very high susceptibility to degradation in the space environment with unpredictable variability from one instrument to another. In addition, some instruments have had non-linear detector response as well as hysteresis and spectral stray light problems. The EP/TOMS instrument developed a complex cross-track dependent response after several years. NASA has for several decades supported the calibration of NOAA SBUV/2 instruments both before and after launch. The post launch activities include both hard calibration (by monitoring on-board calibration data and the solar irradiance), as well as soft calibration. Soft calibration techniques include analysis of spectral and spatial patterns in measured radiances to separate geophysical effects from instrumental effects. NASA flew the SSBUV instrument 8 times on the Space Shuttle to provide calibration of NOAA SBUV/2 instruments. Other satellite instruments such as SAGE, and currently the MLS instrument on Aura, are also providing useful calibration information. However, ground-based data have not been used for satellite calibration, except for the BUV instrument that operated on the Nimbus-4 satellite from 1970 to 1974. However, NASA uses Dobson/Brewer ozone network and ozone soundings to verify SBUV/2 and TOMS data after applying soft and hard calibrations. (NOAA)

Dobson Network
World Standard Dobson No. 83 is maintained at NOAA/ESRLGMD as part of the World Dobson Calibration Facility, and regularly participates in international intercomparisons of regional and national standards. Since 2014, intercomparisons have been held in Melbourne, Australia; Tsukuba, Japan; Hohenpeissenberg, Germany; and Izana, Spain. Investigations into the correct characterization of Dobson instruments were performed in collaboration with the PTB laboratory in Braunschwei, Germany, The laser equipment was used to test optical parameters of the spectral response of the Dobson band-pass. This work was done per agreement with the European Joint Research Project Consortium in line with the ATMOZ (Traceability for atmospheric total column ozone) project under the European Metrology Research Program that focuses on assessment of the accuracy in total column ozone measurements. Optical characterization of the instruments allows the development of schemes to compare and reconcile differences in ozone column data derived from different instruments, including applications related to satellite validation. NOAA conducts calibration verification of the Dobson 83 instrument by conducting campaigns every two years at the Manua Loa site, with the last campaign held in the summer of 2016. (NOAA)

Ozone Soundings
NOAA prepares ozonesonde instruments and follows pre-flight checks according to WMO standard operating procedures. It participates in international intercomparisons of ozonesonde measurements (environmental simulation chamber tests) and develops methods to resolve instrument related differences. The intercomparisons and dual ozonesonde flights at NOAA provide key information on developing a homogenized time series of balloon measurements at each NOAA site. WMO Global Atmospheric Watch sponsors the ozonesonde calibrations where various international groups are invited to the World Calibration Centre for Ozonesondes at the Juelich Research Centre. The Juelich OzoneSonde Intercomparison Experiments (JOSIE) were held in 1996 and 2000. The last calibration campaign was a field (balloon) project at Laramie Wyoming called BESOS in 2004: http://croc.gsfc.nasa.gov/besos/. The next JOSIE test will be held in October/November, 2017. (NASA, NOAA)

Network for the Detection of Atmospheric Composition Change (NDACC)
Several operational protocols have been developed to insure that NDACC 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 NDACC and must be continuously monitored throughout their use. Several mobile intercomparators within the various NDACC instrument types exist to assist in such validation. (NASA, NOAA)

Ground-Based In Situ Measurement Networks
Both the NOAA 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. (NOAA, NASA)

Central Ultraviolet Calibration Facility
The Central Ultraviolet Calibration Facility (CUCF) is located in NOAA's David Skaggs Research Center in Boulder, Colorado. The CUCF calibrates UV instruments for several U.S. Government agencies and other UV research concerns, both national and international. The CUCF also measured spectral response and angular response (critical for direct beam retrieval) for broadband and narrowband instruments. 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 transfer standards. The secondary standards can be calibrated for operation in either the vertical or horizontal orientation. (NOAA)

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 51 USDA UV-MFRSRs and 52 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)

NEUBrew network
The NOAA Environmental Brewer spectrophotometer network (NEUBrew) consists of six stations located in the western, central, and eastern United States. Each Brewer Mark IV spectrophotometer is calibrated for absolute spectral UV irradiance at least one per calendar year. (EPA, NOAA) All six of the network Brewers were originally calibrated by International Ozone Services by comparing to the WMO Brewer transfer standard #017. Brewer 017 is directly traceable to the WMO Brewer Ozone Triad located at Environment Canada in Toronto, Ontario, Canada. In 2015 Brewer 017 traveled to Boulder to calibrate several Brewers after

filter changes. Data quality evaluation with regards to measurement stability is ongoing after the filter changes.

In the summer of 2014 all NEUBrew Brewers were removed from their monitoring sites and returned to Boulder, Colorado for refurbishment and ozone calibration. For the refurbishment many of the NEUBrew Brewer's had a new solar-blind filter installed. The original NiSO4 filter was replaced by INRAD's new UVC-7 filter, a chemical variant of the original. The new filter is more thermally stable than the original and less hygroscopic. Eight out of 10 of the network Brewers received the new UVC-7 filter while two instruments kept the original NiSO4 filters. Two of the Brewers are operating side by side at Table Mountain, USA, one with the original $NiSO_4$ filter and the other with the UVC-7 filter. During October 2014 while all ten network Brewers were operating side by side they were calibrated against the WMO transfer standard, Brewer 017, by International Ozone Services.

Two methods of tracking any drift from those original calibrations are employed by NEUBrew. The first is to adjust the extra-terrestrial constant (ETC) calibration constant by using the internally generated R6 value and the second is by performing Langley regressions on the ozone data to derive the ETC. Data quality evaluation is ongoing after the filter changes regarding instrumental drift and measurement stability (NOAA)

RESULTS FROM OBSERVATIONS AND ANALYSIS

Ozone

Merged Satellite Datasets

Since there are often biases between different satellite instruments it is necessary to create consistent long-term data sets by cross-calibration of different records when they overlap and by using ground-based data (including NOAA ground based networks) when they do not. Such data sets have been produced using TOMS and SBUV total column ozone and profile records. Several new efforts to provide long term merged data sets of ozone columns and stratospheric profiles of ozone and other trace gases are ongoing. Many of these activities are part of the SI2N intercomparison efforts. (NASA, NOAA)

Ozone Depletion & Recovery

Statistical analysis of the Umkehr ground based data, FTIR, merged SBUV, SAGE, GOMOS, SAGE-MLS, and SAGE-OSIRIS profile ozone data from 1979 to June 1997 shows the largest negative trends in the upper stratosphere (35-45 km) at middle latitudes at -10 % per decade at both Southern and Northern Hemispheres. The middle stratosphere (20-25 km) trends are derived from ozonesonde, satellite and FTIR records indicate -7 % per decade decline at both Southern and Northern middle latitudes and less negative trends are found at lower stratosphere (12-15 km) at -9% per decade in the Northern Hemisphere (no information for Southern hemisphere)These trends are in general agreement with previous profile trend estimates from satellite and ground-based records. Since 1997, ozone between 12 and 15 km (lower stratosphere) in the Northern middle latitudes has increased at a larger rate than is expected based on the decline in the ODS abundances. The middle and upper stratospheric ozone has been increasing at the Northern middle latitudes, tropics, and Southern middle latitudes since 1997. Published analyses of Antarctic ozonesonde records at South Pole and Syowa stations show statistically significant increases in the middle- and lower-stratospheric ozone in September. Ground-based and satellite ozone measurements made in the upper stratosphere since 1997 also indicate positive trends that are consistent with a leveling off and initial decrease of stratospheric halogen concentrations. However, the derived ozone trends in the middle and lower stratosphere are not always statistically significant, since the natural ozone variability, stratospheric cooling and measurement uncertainties make analyses less certain.

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 showing slight

signs of improvement. The stratospheric ozone seasonal decline within the Polar vortex is measured by NOAA ozonesondes at South Pole since 1986. The loss rates in 14-21 km layer during the month of September in 2015 and 2016 were slightly less severe (at 3.2 and 2.9 Dobson Units per day respectively) as compared to the 1992-2011 average linear decline of 3.4 ± 0.03 DU/day (NOAA).

Antarctic ozone depletion is primarily controlled by inorganic chlorine and bromine concentrations (effective equivalent stratospheric chlorine, EESC), and secondarily controlled by Antarctic stratospheric temperatures and dynamics. Slightly warmer temperatures in 2016 lessened the severity of the ozone hole while it remains difficult to attribute ozone hole improvement with the slowly decreasing levels of stratospheric chlorine. Fits of various ozone hole diagnostics to temperature and chlorine and bromine levels suggest that the ozone hole is very slowly improving, and the observations in 2016 add confidence to this trend. However, detection of this slow improvement is masked by the large natural variability of the Antarctic stratosphere. (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. Similar maps are created with the total column observations from the OMI instrument on Aura and the nadir looking OMPS instruments on Soumi-NPP. (NOAA/CPC, NASA)

Ozone depleting gases

Multiple global measurement networks continue to show that tropospheric concentrations of most long-lived ozone-depleting gases continue to decrease, and this has led to a fairly steady decline in total atmospheric chlorine, total atmospheric bromine, and EESC. Chlorine from some short-lived gases is increasing (from CH_2Cl_2), but not by an amount that offsets the overall chlorine decline from longer-lived gases. (NASA, NOAA)

UV

UV and Health

NOAA/GRAD and NOAA/NWS/NCEP/CPC in collaboration with Klein Buendel, Inc a health research company developed a prototype for a smart-phone application that utilizes NOAA's UV forecast. The application is a tool for managing and providing information on sun-burning potential and vitamin D production. The project was funded by the National institute of Health.

UV Trends

SURFRAD Network

Work by Colorado State University (CSU) UVB researchers continued for analyzing trends in solar UV irradiance at eight stations in the CSU-USDA network stations. Both positive and negative tendencies were detected ranging from –5% to +2% per decade. However, inter-annual variability was between 2 and 5%. (NOAA)

Scientists analyzing UV-B flux over the continental USA using NASA TOMS data and UVMRP network data found that "ground-based in-situ measurements, like those from the UVMRP network, are indispensible in monitoring atmospheric status and not totally replaceable by space-based remote sensing retrievals". The incorporation of these ground-based measurements with current satellite algorithms has improved UV retrievals for the latest satellite package (OMI). (Xu et al., 2010) (USDA)

UV Forecasts and Exposure

UV Forecasts and Alert System

NOAA/CPC is producing UV forecasts and has developed a UV Alert system with the EPA. The UV Index forecasts are on a gridded field covering the entire globe. Forecast fields are generated at one hour frequency out to five days. The UV Index forecasts include the effects

of Earth-Sun distance, total ozone, solar zenith angle, surface albedo (inclusive of snow/ice), cloud attenuation, and climatological aerosol conditions. The gridded fields are freely available on the NCEP ftp site. 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 UV-B Climatological 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:

Antarctic and Arctic Ozone Loss
Recent analyses of Arctic and Antarctic ozone loss using observed concentrations of ozone and trace species in the stratosphere, in combination with advanced chemical/transport models show that much of the variability in ozone loss can be well explained by a combination of variations in transport that drive the distribution of ozone and the photochemical loss of ozone. (NASA)

Ozone-Related Gases and Variables

Environmental Properties of Atmospheric Gases

The abundance and atmospheric lifetime of carbon tetrachloride (CCl_4) is important to understanding stratospheric ozone recovery and climate change as well as the linkage between these issues. Laboratory work has determined updated values for the UV absorption cross sections and atmospheric lifetime for CCl_4. This information was used in a new international assessment of CCl_4 coordinated by the WCRP's SPARC program in 2016 with NOAA and NASA contributions (NOAA, NASA). This up-to-date analysis, closes the gap in the CCl_4 budget discrepancies, although imbalance remains in our understanding of CCl_4 sources and sinks that suggest additional sources of CCl_4 to the atmosphere of unknown origin. (NOAA, NASA)

Chemistry of Potential ODS Replacements

Laboratory and theoretical work has provided information about the ozone-layer friendliness and climate friendliness of candidate replacements for ozone-depleting substances used for a variety of societal applications such as refrigeration, air conditioning, electronics manufacture, and fire protections. Early information about the suitability of a proposed substance is needed by industry before costly development investments are made. 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. Recent studies have focused on reassessing the UV photolysis and $O(^1D)$ kinetics of several long-lived CFCs, HCFCs, and greenhouse gases. Model calculations of past and future ozone abundance and its trends rely on accurate measurements of the UV absorption spectra (and temperature dependence) and kinetic parameters to

minimize uncertainty. Laboratory measurements were made to reduce the model input uncertainty for key species to <5%, in some cases. Recent studies measured the UV absorption spectrum of NF_3 to better define its atmospheric lifetime, ~570 years. Kinetic studies were conducted for $CHF=CF_2$, HFO-1438ezy(E), and (E)-$CF_3CH=CHCF_3$. It was determined that these chemicals have short atmospheric lifetimes, 5-90 days and relatively low GWP_{100} values (<20). These studies have shown that there are substantially different lifetimes for fluoroinated stereoisomers. (NOAA)

Chemistry of Persistent Greenhouse Gases

Fundamental laboratory studies of the atmospheric formation and loss processes of persistent greenhouse gases, i.e., substances with atmospheric lifetimes greater than 500 years, are used to evaluate their environmental impact, e.g. global warming potential. Laboratory studies found that perfluoroamines, which are used as heat transfer compounds, are primarily removed in the upper atmosphere, which results in atmospheric lifetimes greater than 2000 years. Perfluoroamines were also found to have large radiative efficiencies (>0.6 W m^{-2} ppb^{-1}), which results in this class of compound having large global warming potentials (GWP_{100} values greater than 20,000). $CF_3C(O)F$ is formed in the atmosphere in the degradation of several HFCs currently present in the atmosphere. Laboratory studies showed that the short-wavelength UV photolysis of $CF_3C(O)F$ leads to a small yield (<1%) of CF_4, an extremely potent persistent greenhouse gas. (NOAA)

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)

UV Effects
The UVMRP supports research studying UVB effects on plants and ecosystems. Numerous publications document the results of these on-going studies, and are listed on the program's web site at (http://uvb.nrel.colostate.edu/UVB/uvb_pubs.jsf). (USDA)

UV Model Comparisons
The UVMRP's modeling group, "The Center of Remote Sensing and Modeling for Agricultural Sustainability" has published preliminary results of their coupled climate-crop modeling system. Validation and system refinement is underway and has shown promising results. Corn yields for the 16-state USA corn belt over the 27 year span (1979-2005) agree to within +/-10% of the actual yields. This modeling effort is being expanded to evaluate precipitation, temperature and UV effects on the yields, with the ultimate goal of developing a system that will be capable of both achieving credible and quantitative assessments of key stress factors, and evaluating alternative cultural practices for sustainable agriculture production. (USDA)

DISSEMINATION OF RESULTS

Data Reporting

Ozone
Ozone data from Aura instruments (OMI, MLS, and HIRDLS)), past TOMS instruments, the OMPS nadir and Limb instruments on Suomi-NPP, and the AIRS instrument are routinely distributed by the Goddard Earth Sciences (GES) Data and Information Services Center (DISC) at http://disc.sci.gsfc.nasa.gov/acdisc. Both level 2 (measured) data and level 3 (grid averaged) data are distributed in HDF format. OMI level 3 data are distributed in ASCII format via the TOMS web site (http://toms.gsfc.nasa.gov). Ozone data for the TES instrument on Aura can be found on the NASA Langley DAAC at http://eosweb.larc.nasa.gov/. (NASA)

Aura Validation Data Center (AVDC)
Preliminary and near real-time total ozone, ozonesondes, ozone profiles from LIDAR and microwave radiometers are archived from US Government Agencies and investigators worldwide. In addition, the AVDC (http://avdc.gsfc.nasa.gov/) also archives and distributes NASA and NOAA total column, profile and tropospheric satellite data subsets. The collected preliminary ozone data are restricted to participants in Aura validation teams, ESA OMI announcement of opportunity participants, and international validation contributors, while the satellite data is freely available (http://avdc.gsfc.nasa.gov/Data/). (NASA)

Umkehr Dobson Data
Dobson Umkehr data processed using UMK04 algorithm are available from the WOUDC archives. Dobson Umkehr data for six NOAA sites are also available at the web address: ftp://aftp.cmdl.noaa.gov/data/ozwv/Dobson/Umkehr/. Brewer Umkehr data are available for 6 NEUBrew sites at the web address: http://esrl.noaa.gov/gmd/grad/neubrew/. (NOAA, 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 NDACC and the SHADOZ network are available from the programme web sites (http://www.ndacc.org/ and http://croc.gsfc.nasa.gov/shadoz/, respectively), and also are imported to WOUDC. (NOAA, NASA).

NEUBrew Data
UV spectra, total column ozone and Umkehr ozone profile data from the NOAA Environmental network are available at the web site http://esrl.noaa.gov/gmd/grad/neubrew/ (NOAA)

Maps
All daily SBUV/2 total ozone hemispheric analyses generated from NOAA-16, NOAA-17, and NOAA-18 observations are available on the Climate Prediction Center's stratospheric web pages at http://www.cpc.ncep.noaa.gov/products/stratosphere/sbuv2to/. The raw data from the SBUV/2 are available from NESDIS. Additionally, the NCEP/GFS total ozone analysis and forecast fields out to five days are available at http://www.cpc.ncep.noaa.gov/products/stratosphere/strat_a_f/. (NOAA/CPC)
Daily maps from the Version 8 total ozone algorithm processing of GOME-2 data are available from NOAA Operations at http://www.osdpd.noaa.gov/PSB/OZONE/gome.html (NOAA/CPC)

Assessments
NASA and NOAA scientists, along with other scientists from around the world, played key roles as editors, authors, contributors, and reviewers of the 2016 SPARC Report on the Mystery of Carbon Tetrachloride. NASA and NOAA scientists are involved in the planning and will be involved in the writing of the 2018 WMO/UNEP Scientific Assessment of Ozone Depletion, mandated under the provisions of the Montreal Protocol. Other scientists from the U.S. and around the world will contribute to the report, which will be given to the Parties to the Montreal Protocol in late 2018 and on the UNEP and NOAA websites in early 2018. (NOAA, NASA)

Stratospheric Winter Hemisphere Bulletins
Following each hemisphere's winter, an assessment of the stratospheric dynamics and chemistry are presented from a NOAA perspective. The southern hemisphere's winter bulletin focuses upon the ozone hole formation and longevity. Relevant thermal and dynamical attributions are presented. The northern hemisphere's winter bulletin will discuss ozone loss conditions and stratospheric warmings.
http://www.cpc.ncep.noaa.gov/products/stratosphere/winter_bulletins/ (NOAA/CPC)

NASA maintains the Ozone Watch web site at NASA GSFC (https://ozonewatch.gsfc.nasa.gov/) which contains daily updates on the satellite images of column ozone and polar stratospheric meteorological conditions, and near term forecasts. (NASA)

Ozone-Related Gases and Variables

Aura Data

Gas and Aerosol constituent data from Aura instruments (OMI, MLS and HIRDLS) are routinely distributed by the Goddard Earth Sciences (GES) Data and Information Services Center (DISC) at http://disc.sci.gsfc.nasa.gov/acdisc. Both level 2 (measured) data and level 3 (grid averaged) data are distributed in HDF format. OMI level 3 data are distributed in ASCII format via the TOMS web site (http://toms.gsfc.nasa.gov). Data for the TES instrument on Aura can be found on the NASA Langley DAAC at http://eosweb.larc.nasa.gov/ (NASA)

Ozone-Depleting Substance Data

Ongoing measurement data for ozone-depleting substances from the NOAA sampling network are updated at least every six months on the website (http://www.esrl.noaa.gov/gmd/) and are 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 (*e.g.*, the Atmospheric Tomography Experiment Campaign), are posted shortly after mission completion. (NOAA)

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 Carbon Dioxide Information and Analysis Center (CDIAC) <http://cdiac.esd.ornl.gov/>. Data from the UCI flask sampling network are also archived at CDIAC. (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)

NEUBrew Network UV Data

Spectral UV irradiances are available from the NEUBrew website http://esrl.noaa.gov/gmd/grad/neubrew/ (NOAA)

NOAA Antarctic UV Data

Spectral UV irradiances, derivative UV products, and GUV data will be available from NOAA's Antarctic UV website.
http://esrl/noaa.gov/gmd/grad/antuv (NOAA)

USDA UV-B Monitoring and Research Programme (UVMRP)

UV, visible and ancillary data from the UVMRP network is available next-day on the UVMRP website (http://uvb.nrel.colostate.edu/).

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 the OMI instrument on Aura is routinely distributed via the NASA web site (http://toms.gsfc.nasa.gov/). Data are usually available within 48 hours, though faster access can be arranged. The site provides online access to both TOMS (1978-2006) and OMI (2004-present) data. While used mostly by scientists, educators and students also use the site extensively. An Ozone Hole Watch web site, http://ozonewatch.gsfc.nasa.gov/ provides information for anyone interested in the Antarctic ozone hole. Near real time Ozone profile data from MLS now exist, and are available at http://disc.sci.gsfc.nasa.gov/Aura/data-holdings/MLS/ml2o3_nrt.002.shtml. (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 in the U.S. The other is a map displaying the UV Index forecast at each of the 58 cities' locations. These can be found at http://www.cpc.ncep.noaa.gov/products/stratosphere/uv_index/. Additionally, gridded fields of the noontime forecast for the U.S. and Alaska are made available via the NOAA/CPC and NOAA/NCEP ftp sites. UV Index forecast gridded fields covering the entire globe at one hour increments out to five days are available on the NCEP ftp site: ftp.ncep.noaa.gov/pub/data/nccf/com/hourly/prod. (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 Stratospheric Chlorine (EESC) derived from global surface measurements of ODSs in the NOAA network, has been implemented. The observation-derived EESC, along with WMO/UNEP ozone-depleting gas scenarios, are used to estimate the progress being made towards ozone recovery in the mid-latitude and Antarctic stratosphere (ODGI = 100 on January 1, 1994 when EESC reached its maximum value and 0 at 'recovery' (presumed to be 1980 EESC levels)). Values for the 2016 index range are approximately 80 for Antarctica and 58 for mid-latitudes, indicating substantial progress in ODS reductions. The index is updated annually and posted at http://www.esrl.noaa.gov/gmd/odgi. (NOAA)

PROJECTS AND COLLABORATION

NOAA
The Dobson and ozonesonde measurements are included in the WMO Global Atmosphere Watch (GAW) and in the NDACC. 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 including support for satellite validations. The World standard Dobson instrument is maintained and calibrated by NOAA under the WMO GAW program. It provides calibration to regional Dobson standards at 6 centers. The NOAA Environmental Brewer spectrophotometer network (NEUBrew), initially established in collaboration with the EPA, consists of six stations located in the western, central, and eastern United States.

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).

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 the UV Alert system; collaboration with NASA in ozone monitoring, calibration of the SBUV/2 instruments, dynamical processes influencing ozone changes, and ozone assimilation; 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 NDACC Data Host Facility.

NASA
NASA collaborates extensively with several NOAA laboratories in all areas of ozone and UV research, including space-based, airborne, balloon-borne, and ground-based measurements, as well as in various modeling and analysis activities. NASA often supports research activities within these laboratories, including support for NOAA groundbased measurements for satellite validation. The NDACC, which is championed by NASA and NOAA within the U.S., is a major contributor to WMO's Global Ozone Observing System (GO3OS) 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. NASA is assisting NOAA in the implementation of the OMPS nadir and limb instruments on the NPOESS Preparatory Satellite (NPP) by developing the limb operational algorithms and by performing assessments of the nadir operational products.

USDA
USDA is actively collaborating with the NASA TOMS and AERONET groups on aerosol absorption using UV-MFRSR and Cimel instruments.

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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 to process all historical zenith-sky data using this algorithm.

In 2015-2016 NOAA performed a thorough assessment of all its historical Dobson datasets. Some inconsistencies were found in the total and Umkehr data submitted to the WOUDC and NDACC archives. NOAA is preparing to resubmit the revised dataset in 2017.

New algorithms to utilize multi-wavelength Brewer zenith sky measurements for improved ozone profile retrieval require detailed information on optical parameters of individual instruments (i.e., band-pass and stray light filters). The work on improvement of optical characterization of Dobson and Brewer instruments for stray light minimization will continue through in-lab and in-field characterization of the instruments in the WMO network.

NOAA will work to implement Serdyuchenko et al (2014) ozone cross-section datasets for its Dobson and Brewer ozone data processing. The future work will be focused on developing methods to incorporate daily and climatological variability in stratospheric temperature into the ozone data processing. (NOAA, NASA)

Ozone profiles from Dobson/ Brewer Zenith-Sky Measurements
NOAA GMD will continue to retrieve ozone profiles from the NOAA operated stations, and will submit results for Dobson stations to the WOUDC, and will make the amendment to the UMK04 algorithm to replace the look-up tables for the SER (2014) cross-section. Results from the NEUBrew instruments will be posted on the network website http://esrl.noaa.gov/gmd/grad/neubrew/. The set up for automatic submission of raw NEUBrew data (B-files) to the WOUDC Brewer archive depends on the future funding for the NEUBrew network.

A new multi-wavelength ozone profile retrieval algorithm for processing Brewer Umkehr measurements (similar to the SBUV retrieval) will be made available for the WOUDC and scientific communities after the optical characterization of instruments for stray light and polarization parameters becomes part of the recurrent calibration routine in the operations of the Brewer networks. The pass forward is through a NOAA collaboration with the European Joint Research Project Consortium. The future activity is in line with the ATMOZ (Traceability for atmospheric total column ozone) project under the European Metrology Research Program that focuses on assessing the accuracy in total column and profile ozone measurements. Optical characterization of instruments (in the lab and in the field) allows developing schemes to compare and reconcile differences in ozone column data derived from different instruments, including in applications for satellite validation projects.. The proposed multi-spectral Brewer algorithm is expected to significantly reduce operational time for the zenith sky measurements as compared to the established "Umkehr" measurements schedule in Brewer operations. It will also allow to process historical data that were not available for standardized processing due to shortness of the solar zenith range coverage. The data processed by the new algorithm will be archived at the WOUDC (NOAA).

The Brewer Umkehr data set series from NOAA and other international ground-based stations will be compared to other available co-incident ozone profile data from ozone-sondes, microwave, lidar and Dobson Umkehr profile data. Results will be reported at the LOTUS SPARC activity aimed at understanding of past changes in the vertical distribution of ozone, and will be made available for the next UNEP/WMO Scientific Assessment of Ozone Depletion. (NOAA)

Archiving of the "raw" data at the WOUDC
According to the SAG-Ozone recommendations NOAA will participate in the international effort at the finalization of formats for the storage and reporting of ECC ozonesonde measurements at WOUDC, archiving of R-values of Dobson measurements and related calibration information as well as B-files and relevant information for Brewer measurements. It will provide the updated and modified algorithms used to process these data. NOAA will assist WOUDC with changes of ozone absorption cross sections or other changes that may demand the reprocessing of data records. (NOAA)

Ozone in Climate Forecast Models
NCEP has modified and extended its synoptic forecast model (GFS) to time scales of three weeks to nine months. Ozone forecasts as well as stratospheric temperatures and heights have significant errors in these forecasts. Experiments modifying the model's physics and structure will need to be conducted in order to improve these forecasts. (NOAA/CPC)

Ozone in the NCEP/Climate Forecast System Reanalysis
NCEP is replacing the NCEP/DOE Reanalysis 2 (R2) with the Climate Forecast System Reanalysis (CFSR). The CFSR improves upon the R2 in many ways. One is by using ozone profile information from the SBUV/2. The CFSR is being rerun from 1979 to present and will continue as the model for NCEP's Climate Data Assimilation System (CDAS). The CFSR should be the reanalysis of choice to study ozone-dynamics interactions. (NOAA/CPC)

NOAA Antartic UV Network
Future plans are to deploy two NEUBrew Mark IV spectrophotometers to the McMurdo and Palmer stations to provide daily total column ozone and overlapping spectral UV measurements. The two Brewers will be temperature stabilizied and modified for Antarctic operation. Before deployment both Brewers will be converted to "red" Brewers to facilitate ozone retrievals in the Chappuis band. After conversion and before deploying they will be operated at the CUCF's Table Mtn Test Facility (Lat 40 N) over the boreal winter to determine the quality of ozone retrievals from this solar spectral region when compared to direct-sun retrievals from the Hartley-Huggins band.

NASA Ozone satellites
NASA will continue to operate the Aura satellite, assuming it continues to receive high science value through the NASA senior review process. NASA will also operate the SAGE-III satellite on the ISS through the three-year design lifetime of the instrument and will continue beyond that if the science value is determined to be high and no other instrument is scheduled to assume the location on the ISS that SAGE-III is occupying. (NASA)

Ozone-Relevant Gases/Variables:

OMPS and CrIS on NPP and JPSS
The Ozone Mapping and Profiler Suite is the operational US ozone monitoring instrument in the JPSS period. The suite consists of two nadir detectors; one with coverage in the 310 to 380 nm range to provide daily global total column ozone maps, and the other with coverage from 250 to 310 nm to provide nadir ozone profiles to continue the SBUV(/2) record. The first OMPS has been on the NASA Suomi-NPP since 2010. The Cross-track Infrared Sounder is a hyperspectral IR instrument with spectral coverage including the ozone lines around 9.7 microns. NOAA has implemented ozone retrieval algorithms with the AIRS instrument on EOS, and plans to use similar algorithms with the IASI on MetOp-A and the CrIS on NPP and JPSS. (NOAA, NASA)

Ground based networks
NASA and NOAA plan on continuing investment into the ground based networks supported by the NOAA Global Monitoring Division as well as the Network for Detection for Atmospheric Composition Change, SHADOZ ozone sondes, and AGAGE. (NOAA and NASA)

NASA Earth Venture (EV) Investigations and missions
NASA selected 5 investigations (EVI-2)that will last for 5 years to use suborbital platforms for sustained investigations of Earth System processes. 1 of these selected studies have direct

relevance to Ozone related science, the Atmospheric Tomography Mission These activities started in 2014 and will continue until 2018. One new competed space mission Announcements of Opportunities (AOs) was be released in 2016 for a cost constrained instrument for a mission of opportunity (EVI-4). (NASA)

UV

UV Index Forecast
Aerosols and clouds are the greatest cause of UV Index forecast errors. NCEP and NESDIS are working together to improve the skill of forecasting aerosols. When model generated forecasts of Aerosol Optical Depth and Single Scattering Albedo become available they will be included in the UV Index forecast system. (NOAA/CPC)

NEEDS AND RECOMMENDATIONS

Ozone

Column Ozone
Column ozone observations from ground stations and satellites provide the foundation for trend studies. Future levels of total ozone will be modulated by climate change effects. The current predictions of total ozone from state-of-the-art models suggest polar ozone recovery in the 2060-2070 period, and midlatitude recovery in the 2040-2050 period. It is a primary requirement to continue this data record and to enable retrieval improvements of the observations.

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. The work on improvement of optical characterization of Dobson and Brewer instruments for stray light minimization, and therefore improved accuracy at low sun and large total ozone conditions, are under development. In addition, the new ozone cross-section implementation in the Dobson and Umkehr data processing is underway. The improvement in Dobson daily ozone retrievals also depends on the stratospheric temperature variability. The methods to incorporate temperature corrections to the Dobson total ozone retrievals is of importance for reducing Dobson total ozone seasonal biases. The methods for the temperature correction applications (i.e. climatological vs. daily corrections) have yet to be validated. (NASA, NOAA)

Profile Ozone
Ozone profile information has critical importance for both ozone recovery and climate change. The vertical structure of ozone (~ 1 km resolution) near the tropopause is crucial to calculating the radiative forcing of ozone on climate. Furthermore, polar ozone recovery should first manifest itself in the 20-24 km region of the polar stratosphere. Models of ozone suggest that the cooling of the stratosphere will accelerate ozone recovery in the upper stratosphere leading to a "super-recovery". Hence, observations of the vertical structure of ozone have a bearing on two key scientific issues: ozone recovery and climate change. Some of these profile observations have been provided by MLS and OMI instruments aboard the AURA satellite since 2004 and, since 2013, by the OMPS Limb instrument on NPP. The OMPS ozone limb observations will be continued on the JPSS-2 platforms. OMPS-Limb is now joined by the SAGE-III on the International Space Station, which may provide useful data to about the end of the lifetime of ISS (~2023)

The SPARC activity "Observing Composition Trends and Variability in the UTLS" (OCTAV-UTLS) aims to develop unified, consistent, geophysically-based sampling metrics that can be applied to analyze data from different observation UTLS techniques. For the first time, the comprehensive data sets from different platforms will be consistently compared in the UTLS

using the same metrics (e.g. tropopause and jet relative coordinates referencing) derived from reanalysis data. This approach will help to assess the effect of platform dependent sampling on atmospheric composition (i.e. ozone and water vapor) and improve their trend estimates in the UTLS (NOAA, NASA)

A clear understanding of ozone trends and their significance as a function of altitude and latitude is still needed, nearly 20 years after the peak of ozone depleting substances in the stratosphere. A previous activity sponsored by SPARC, IO3C, IGACO-O3/UV and NDACC (SI2N) evaluated trends derived from long-term ozone profile records (ground-based and satellites, including merged satellite data records). The SPARC LOTUS (Long-term Ozone Trends and Uncertainties in the Stratosphere) activity goals are (a) to update and extend stratospheric ozone observations to recent years, (b) to improve our understanding of crucial yet poorly known sources of uncertainties in trend retrieval, (c) to investigate how uncertainties interact and propagate through the different stages of the analysis chain, and (d) to re-evaluate current best practice(s) and possibly establish more suitable alternatives. (NOAA, NASA).

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. The new Brewer Umkehr algorithm to derive ozone profiles under low sun condition is also in works (NASA, NOAA)

NASA has two Earth Science Decadal Survey satellite missions recommended in the future. One (GEO-CAPE) is a geosynchronous orbit and designed to study North American air quality, but should also provide column ozone. The second (GACM) is described as a follow up to Aura with analogous instrumentation using more advanced technology. This will provide profiles for ozone and numerous trace gases in the stratosphere and troposphere. Though a portion of the GEO-CAPE mission science is being achieved by the competitively selected TEMPO mission of opportunity mission, neither full project has entered the formulation stage, and won't before the next Decadal Survey is released in late 2017. At that time, NASA is expected to reassess the priorities of missions that are programmatically directed. (NASA)

In order for ozone forecasts to improve in the NCEP/GFS, higher quality and greater numbers of ozone profiles need to be available for assimilation than what is available from the current nadir viewing SBUV/2. Ozone profiles from the Aura/MLS and OMI are promising as they provide ozone profiles of greater resolution (MLS) and of greater horizontal coverage (OMI). These products are now available in near-real-time, and are being assimilated into the NCEP/GFS. (NOAA/CPC)

Ozone-Relevant Gases and Variables

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. An intercomparison study, IHALACE, for halocarbon standards between measurement groups that has examined differences in the individual gases was completed and a paper summarizing the results has been submitted for publication. The work found that most independent calibration groups agreed well for most compounds (<5%), but groups using the same calibration standards did not transfer the calibration. (NASA, NOAA)

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)

NEUBrew Network
Future plans for the NEUBrew network are for algorithm development for aerosol optical thickness retrievals and direct-sun data processing to provide aerosol optical thickness estimates at the five direct-sun measured UV ozone and five visible NO_2 wavelengths.

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Field Campaigns
Aircraft, balloon, and ground-based measurement campaigns for satellite validation and science are expected to continue, but at a much lower level than in the past since Aura is in its Extended Mission phase now. These campaigns 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

USDA UV-B Monitoring and Research Programme (UVMRP)
A new site was installed at the University of Texas at El Paso (UTEP) in November 2008. (UDSA)

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 NDACC. 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
It is now well established that the ratio of UVB and UVA can be predicted accurately under clear conditions and to within a few percent in cloudy conditions wherever quality column ozone data exist. Absolute measurements of ozone amounts from satellites are accurate to 2% resulting in a 2% error in UV irradiance at 310 nm and an 8% error at 305 nm with larger errors at higher latitudes. UVA variability is known to correlate with variations in clouds, NO2, and aerosols, some of which are also measured by satellites. Ground based intercomparisons studies are using long time averages to simulate the spatial footprint of satellites. Further studies are required to determine the effectiveness of this approach. (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
AIRS Atmospheric Infrared Sounder
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
COADS Comprehensive Ocean-Atmosphere Data Set
CPC Climate Prediction Center (NOAA, U.S.)
CrIS Cross-track Infrared Sounder
CSD Chemical Sciences Division (formerly the Aeronomy Lab, NOAA, U.S.)
CSD Chemical Sciences Division (NOAA,US)
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
E EuMetSat European Organization for the Exploitation of Meteorological Satellites
P Earth Probe
EPA Environmental Protection Agency (United States)
ESRL Earth System Research Laboratory (NOAA, US)
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.)
GMD Global Monitoring Division (formerly CMDL – NOAA, U.S.)
GOES Geostationary Operational Environmental Satellite
GO3OS 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
HIRS High-resolution Infrared Radiation Sounder
IHALACE International Halocarbons in Air Comparison Experiment
IASI Infrared Advanced Sounding Interferometer
JPL Jet Propulsion Laboratory (United States)
JPSS Joint Polar Satellite System (United States)
KNMI Koninklijk Nederlands Meteorologisch Institut (The Netherlands)

MetOp Meteorological Operational Satellite
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.)
NDACC Network for the Detection of Atmospheric Composition Change
NDIR non-dispersive infrared
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
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
SPARC Stratospheric Processes and Their Role in Climate