UNITED
NATIONS

EP

UNEP/OzL.Conv.9/6

Distr.: General
26 July 2011

Original: English

United Nations
Environment
Programme

**Conference of the Parties to the
Vienna Convention for the Protection
of the Ozone Layer
Ninth meeting**
Bali, Indonesia, 21–25 November 2011
Item 5 (a) of the provisional agenda of the preparatory segment*

**Vienna Convention issues: report of the eighth meeting
of the Ozone Research Managers of the Parties
to the Vienna Convention**

Recommendations of the eighth meeting of the Ozone Research Managers of the Parties to the Vienna Convention

Note by the Secretariat

The eighth meeting of the Ozone Research Managers of the Parties to the Vienna Convention for the Protection of the Ozone Layer was held at the headquarters of the World Meteorological Organization in Geneva from 2 to 4 May 2011. The annex to the present note sets out the recommendations made by the Ozone Research Managers at that meeting, divided into four categories: research needs, systematic observations, data archiving and capacity-building. The full report is also available to the Conference as a background document. The recommendations are reproduced as set out in that report and have not been formally edited.

* UNEP/OzL.Conv.9/1-UNEP/OzL.Pro.23/1.

K1172549 120911

Annex

RECOMMENDATIONS

Research Needs

There are many questions that remain on the expected ozone recovery from the influence of ozone-depleting substances (ODSs). In particular, how do ozone depletion and climate change interact? Recent research reveals that ozone depletion has affected tropospheric climate. In addition, it is becoming clearer that greenhouse gases (GHGs) are altering the stratosphere – the cooling of the upper stratosphere by GHGs is expected to exceed 5K between the years 2000 and 2100, necessitating long-term observations of both ozone and temperature in the stratosphere. The ability to predict future ozone behaviour requires further improvements in the quantification of the roles of chemical and dynamical processes responsible for ozone production, loss, transport, and distribution, and their respective uncertainties. The development of realistic scenarios of the future abundances of anthropogenic and biogenic trace gases in the stratosphere and troposphere is required, particularly with respect to a changing climate. Simulations from the 2010 Scientific Assessment of Ozone Depletion indicate future increases of UV levels in the tropics, but decreases at mid- and high latitudes due to ozone changes. The 2010 report of the Environmental Effects Assessment Panel (EEAP) concluded that research on the impacts of increases in UV radiation resulting from stratospheric ozone depletion has substantially advanced the understanding of the processes by which changes in UV radiation affect a range of organisms and processes. For humans, this poses the risk of more skin cancer in the tropics, but also slightly increases the risk of UV doses that are too low for the production of sufficient Vitamin D at mid-high latitudes. Recent research has highlighted the interactions between the diverse effects of changing UV radiation due to ozone depletion and the effects of climate change. These interactions may lead to feedbacks into climate change (e.g., modification of carbon cycling in terrestrial and aquatic ecosystems), but this remains poorly defined.

A number of general issues are emerging. Coupled chemistry-climate models (CCMs) are more mature, but it is clear that more effort must be devoted to model improvement and validation. Earth System Models that include crude stratospheric ozone parameterizations are being developed, and these models should begin to incorporate improved CCM treatments of the solar forcing, dynamics, radiation, and photochemistry of ozone. In addition, long-term measurements represent an extremely important resource, and the continued and increased exploitation of these data for scientific process studies is strongly recommended. The dramatic contrast between the unusually large 2010 Northern Hemisphere ozone columns and the extreme 2011 Arctic ozone depletion has highlighted the close connection between ozone, meteorology, and climate. Finally, there is still a need for fundamental laboratory studies to estimate photochemical reaction rates, and to refine and update older measurements. In particular, photochemical parameters to improve our understanding of long-lived species and new industrial compounds in the atmosphere are very important.

Chemistry Climate

- Provide support for studies that quantify the chemical, radiative, and dynamical factors contributing to ozone-layer evolution in a changing atmosphere (i.e., ozone recovery from the effects of ODSs and ozone response to climate change), including studies of the unintended consequences of climate-change mitigation and adaptation strategies. There have been important advances since the 7th ORM in recognizing the close two-way coupling between ozone and climate (see WMO Synthesis and Assessment Report No. 52), but an evolving research effort in specific attribution studies is required. For example, while we are able to diagnose the large Arctic ozone loss of 2011, precise attribution is more controversial. Because of what we have learned to date, particular studies to advance our understanding

would include:

- Continued studies to improve our evolving understanding of the effects of climate change on ozone production, loss, transport, and distribution, as well as possible feedbacks.
- Continued studies to improve our evolving understanding of the coupling and exchange between the upper troposphere and lower stratosphere, particularly as it applies to water vapour (including its long-term changes), short-lived halogen species, and ozone, and leading to an improved understanding of stratospheric temperatures, the stratospheric overturning circulation, and their connection to climate change.
- Studies of aerosol and polar stratospheric cloud microphysics, and of cirrus in the tropical transition layer.

- Support studies to investigate the role and impact of changes in stratospheric ozone and ODSs on surface climate. Also, support studies of the influence of these stratospheric changes on tropospheric processes that are influenced by stratosphere-troposphere exchange and UV penetration.
- Support studies to improve our understanding of changes in aerosols relative to changes in volcanic activity, air pollution sources (sulphates), and proposed geoengineering approaches.
- Support studies of the effects of solar-cycle influence on climate, with special focus on the importance of middle-atmosphere chemical and dynamical processes, and their coupling to the Earth's surface using both observations and models.

Ozone-Depleting Substances

- The 2011 ozone assessment highlights some remaining uncertainty in ODS budgets (e.g., the inconsistency of CCl_4 emission estimates). Support studies aimed at understanding the emissions (both natural and anthropogenic), banks, and the tropospheric and stratospheric evolution of ozone-depleting substances, their substitutes, and other climate-related trace gases. This includes studies of the effects of climate change on the sources, sinks, and lifetimes of these gases, and the study of very short-lived species, especially in the tropics, where these species could potentially reach the stratosphere. Here, changes in terrestrial and marine biophysical processes could change the concentrations of many of these important species.

Underpinnings for Observations and Models

- Provide continued support for laboratory, photochemical, kinetic, and spectroscopic studies that relate to ozone evolution and its monitoring. These studies provide critical improvements to models (for example, they provide key inputs to determining lifetimes of ODSs), as well as retrievals of atmospheric parameters from satellites and ground-based instruments.
- All observational operations that rely on the optical properties of the atmospheric constituents are only as good as the spectroscopic parameters obtained by laboratory spectroscopic studies. Thus, there is a need for continued studies to improve the standardization and consistency of cross sections for ozone and related species in different wavelength regions (e.g., UV, IR, microwave). The ACSO effort on ozone absorption cross sections is progressing in the right direction, but has been limited so far to UV cross sections. Extension to visible and infrared parts of the spectrum is recommended, as well as similar studies for other species like NO_2 and HNO_3, where uncertainties on spectroscopic parameters remain a limiting factor.
- Support investigations to resolve the differences between tropical total-ozone column trend estimates, and those trends computed from satellite profiles.

Ultraviolet and Environmental Effects

- Support studies that allow quantitative disaggregation of the factors affecting UV radiation at the surface, so that the influence of factors other than ozone (e.g., cloud cover, aerosol abundance, albedo, and temperature) can be better assessed.
- Support studies on the effects of stratospheric ozone change, and the resulting changes in UV radiation and on human health, ecosystems, and materials. These studies should include quantitative analyses that will allow the assessment of the magnitude of specific impacts in relation to UV radiation changes. Research also should take account interactions between the effects of changes in UV radiation and those of climate change, particularly effects that may lead to feedbacks to climate change, for example, through altered carbon cycling or tropospheric chemistry.
- Support studies that look at the environmental effects of ODS substitutes, and their degradation products on other factors that affects human health and the environment.

Systematic Observations

Data Networks

Systematic observations are critical to understanding and monitoring long-term changes in atmospheric composition and the associated response in ground-level UV radiation. The ability to predict expected ozone recovery in a changing atmosphere and to understand the interactions with a changing climate requires observations of key trace gases and parameters highlighting the role of chemical and dynamical processes. Vertically resolved measurements, especially in the upper troposphere/lower stratosphere (UTLS) region and in the upper stratosphere, are of prime importance. Global data networks thus provide the backbone of our understanding of ozone, ozone- and climate-related trace gases, and UV, and involve many nations around the world. Their operations also provide training for atmospheric scientists in both developed and developing countries. The demands on these networks are high, in that they provide the basis for all research activities and decision-making. These networks fall into two categories, ground-based and space-based.

Ground-Based Networks

These networks cover a broad range of observations using a variety of *in situ* techniques (balloonborne sondes and ground-level concentration sensors), and remote-sensing techniques such UV instruments (e.g., Brewer, Dobson, M124), DOAS UV/visible and FTIR spectrometers, lidars, microwave radiometers, and spectral-UV-monitoring instruments. The two key issues involve the maintenance of existing facilities and expansion as required by scientific needs. These networks must be maintained above a critical level of data quality and geographical coverage. Current challenges to understanding atmospheric responses require network growth in various regions of the globe to better elucidate trace-gas sources and sinks, atmospheric transport, and the various processes affecting atmospheric composition. Geographical areas having less than critical measurement coverage include developing countries, particularly in the tropics, central Asia, and the mid-latitudes of the Southern Hemisphere. Maintenance of the high-latitude networks also is critical, as they provide direct observations of polar ozone processes. Newly developed low-cost instruments for column ozone and other chemical species could play an important role in the expansion and improvement of ground-based networks. Recommendations related to the maintenance and growth of these networks are numerous.

- The recommendation from the 7th ORM regarding the redistribution of instruments from instrument-rich sites to those areas that are poorly populated with instruments has begun with a few redistributions to Asian and African countries where significant data gaps were

noted. Continued implementation of this recommendation is needed along with infrastructure support, as appropriate.

- Following the 7th ORM, several stations within the former USSR network of M124 filter radiometers were phased out. However, the recommendation to operate the M124 in parallel with collocated Brewer and/or relocated Dobson instruments has been followed at only a few stations, and the geographical coverage of ozone measurements has been reduced considerably over Central Asia, with no suitable replacement. There is a need to restore minimal monitoring activities in the parts of the world where M124 instruments had previously operated.
- Brewers are the preferred instruments for all expansion efforts around the globe wherever a new ozone- and UV-monitoring programme is to be established. Unused Dobson instruments are a more economical way to expand these networks, and to introduce observations at new sites. Earlier recommendations in this area have been successfully followed in several cases, and it is recommended to further continue such efforts. The collocation of column- and profile-measuring instruments is especially important for cross-validation, and for separation of tropospheric and stratospheric signals.
- There is a need to continue and further expand Umkehr ozone-profile capabilities, thereby maintaining that time series in the upper stratosphere. This is the primary ground technique for observing the upper stratosphere, since sondes cannot reach these altitudes.
- After careful reevaluation of microwave ozone data to insure adequate quality in the upper stratosphere, new stations should be added, particularly in Polar Regions where Umkehr data are not available. In the upper stratosphere, there may be significant local time variation in ozone during daytime that needs to be accounted for in the data analysis.
- Balloonsonde networks provide critical high-resolution vertical profiles of ozone, water vapour, and temperature, and need to be maintained and expanded, since such data are critical to understanding the interactions between atmospheric composition and a changing climate. The recent decrease in ozonesonde stations reporting data to central data archives, especially over Asia, the Arctic, and North America, is a matter of significant concern.
- Specific suggestions for sondes include:
  - Technical solutions should be implemented to allow ozonesondes to reach 30 km in order to cover the important UTLS region.
  - Archived data reports of ozonesondes should include simultaneously obtained water-vapour profiles.
  - Water-vapour profiles measured by meteorological radiosondes should be more openly available for ozone research and monitoring.
- Key networks that obtain altitude profile information of ozone and ozone-related species are obtained from instruments like DOAS UV-visible and FTIR spectrometers, lidars, and microwave radiometers. These networks should be maintained, as they form the primary non-space-based observations for many of these key species. In addition, these established high-quality observation networks should increase their collaboration to ensure economy of scales, share facilities, increased coverage, etc. Examples of such networks and coordinating bodies include GAW, NDACC, IGACO, GCOS, CEOS, AGAGE, NOAA ESRL, etc.
- With the phasing out of CFCs and other alternate substances, there is a need to expand monitoring capabilities to include newly emerging chemicals. Specific attention should be given to the following classes of compounds:

- Long-lived HFCs, as these are strong greenhouse gases, are current substitutes for CFCs and HCFCs, and are under consideration for phasedown under the Montreal Protocol.
- Short-lived anthropogenic halocarbons (e.g., unsaturated HFCs, known as HFOs or hydrofluorolefines) and their degradation products (e.g. trifluoroacetic acid), which already are used or have a potential to be used as substitutes for long-lived HFCs. The degradation products of such chemicals might impact, for example, the chemical composition of surface water through precipitation and deposition.
- Short-lived natural halocarbons such as the brominated chemicals CH_2Br_2 and $CHBr_3$, as their emissions are potentially sensitive to future climate change and mitigation strategies.

- Since the 7th ORM, efforts have been made to increase the use of more sophisticated instrumentation (e.g., UV-visible, FTIR, microwave, Raman lidars, airborne, and balloonborne), and they should continue. New techniques for water-vapour measurements are an example. Specifically:
  - Balloon-based measurements of ozone-depleting substances should be maintained in order to check the behaviour of these substances in relation to climate change.
  - Measurements of SF_6 and CO_2 are needed in support of age-of-air studies to assess changes in global atmospheric circulation.
  - Standard Operating Procedures (SOPs) need to be established and implemented, and metadata guidelines also should be available for all operational instruments.
- There are multiple calibration sites around the world within the Global UV Monitoring System that are not tied together sufficiently. Hence, an international calibration infrastructure should be created. It should promote a quality-assured protocol such as that used by the NDACC network. These observation data sets should not be restricted, and should be widely deposited into WOUDC. These activities should be coordinated and supported by the Scientific Advisory Group for UV monitoring. In addition, plans for a future World Calibration Centre for UV should be implemented, together with the further implementation of public information services.

Satellite Networks

These critical networks are associated with the satellite programmes of a number of nations. They include the critical solar backscatter UV observations that have established the trends in midlatitude and polar total ozone since the 1970s. These observations must be continued via the current polar-orbiting systems MetOp, NPP, and FY-3 to ensure continuity until 2018. Further continuation beyond 2018 (e.g., post–EPS) must be planned now. The other critical satellite network is that of limb-sounding observations (including occultation, emission, and scattering) that provide high-vertical-resolution data of ozone and key ozone related parameters that are critical for understanding the science behind changes in ozone in the context of changing climate. In particular, these limb observations enable the characterization of ozone changes in the critical altitude regions of the upper troposphere/lower stratosphere, as well as the upper stratosphere. Based on current space agency plans, and despite obvious efforts to take into account the 7th ORM recommendations and implement gap-filler missions, there will be a serious gap in these types of satellite measurements. Many of these satellite observations also provide key meteorological data that are needed to understand fully stratospheric transport, which controls the distribution of ozone and the evolution of the ozone hole. Specific recommendations for satellite networks include:

- The continuation of the solar backscatter UV observations must be insured, as they constitute a key baseline set of measurements. All of the currently planned missions with solar backscatter instruments are needed to maintain this continuity of observations and maintain

the measurement overlaps required for accurate trends determinations. Improvements of retrieval algorithms also are needed to expand capabilities at high altitudes and high solar-zenith angles.

- Satellite observations of high-vertical-resolution profiles using limb viewing for ozone and key molecules such as HCl, CFCs, ozone-relevant radicals and reservoirs, tracers of atmospheric motion, and water vapour are required in order to understand more accurately the changes in ozone as CFCs decline and climate change occurs.
- Special attention should be given to N_2O, as this gas is becoming one of the most important substances that can lead to ozone destruction. Likewise, attention should be paid to systematic water-vapour-profile measurements, as it is a strong driver for decadal climate variability.
- Availability of high-quality temperature-profile data remains an issue for satellite data retrievals and data comparisons.
- Gap-filling missions providing high vertical resolution of ozone and ozone-related parameters using techniques such as solar occultation FTS and limb-emission instruments should be considered as a low-cost gap filler between the current limb satellite observations and the missions currently planned by the various space agencies. A few such missions have been proposed, and further development of these projects is encouraged.
- Measurements of stratospheric aerosols should be continued.
- Satellite data records have improved significantly in recent years, but problems persist in the UTLS region, particularly at high and low latitudes. Further improvements of calibration and of retrieval algorithms are needed to reach adequate data quality. Hence, it is recommended that an assessment of current temperature-profile data records and measurement capabilities be organized, and, where appropriate, recommendations for new temperature measurements systems be given.
- Satellite measurements of solar irradiance outside of the atmosphere and associated indexes (e.g., the Mg-II index) are needed to understand processes that control ozone photochemistry and the dynamics.

Consistency and Complementary of Data Sets and Re-Evaluation of Data Records

Needs common to both ground-based and satellite networks include insuring the consistency and complementarities of data sets, and the re-evaluation of data records. For example, there needs to be a systematic understanding of the differences and synergies between different data-observation techniques so that the data can be combined in an appropriate way. Intercomparison campaigns are desired, because they assist in defining and reducing the systematic differences in both identical and different measurement techniques. Examples include the SAUNA campaigns in 2006/2007 that were designed to understand calibration and stray-light issues in ground-based measurements, and to improve techniques for the comparison of remotely sensed data. Specific recommendations include:

- The need for better integration of ground-level, ground-based remote sensing, and satellite data. There are calibration/scale/storage issues between campaigns and continuous networks (e.g., for short-lived natural halocarbons) that would benefit from additional harmonization efforts. Efforts are thus recommended to strengthen the consistency (calibration and data quality) between short-term campaigns and long-term monitoring, e.g., via common transfer standards.
- The further development of methods and tools for a better-integrated use of complementary data with different scale, resolution etc. An example of this is the GEOMON project, in which data-merging techniques are being used to combine data records from different

measurement systems, and multi-dimensional observation operators are being developed to better interpret remotely sensed data.

Data Archiving

Achievements in response to the recommendations made by the 7th ORM include:

- A Dobson Data Quality Workshop was held in Hradec Králové, Czech Republic, 14-18 February 2011.
- The NDACC has adopted the Heirarchical Data Format (HDF) as the standard for data archiving.
- A template for the submission of level-0 Dobson data and metadata has been drafted, and is to be approved by SAG-Ozone at the forthcoming meeting in October 2011.

Many of the recommendations made by the 7th ORM remain relevant, and are repeated and expanded on as necessary below.

Continuing Recommendations

Near-Real-Time and Historical Data

- Different uses of ozone and UV measurements need to be recognized. These uses impose different requirements on the data and on its archiving. For example, the use of ozone measurements in real-time or near-real-time data assimilation requires quick data submission (e.g., onto the GTS), whereas the use of ozone measurements for long-term trend detection requires very precise measurements, maintenance of the homogeneity of the time series, careful management of instrument changes, care in calibration, and derivation of uncertainties on the measurements before they are submitted to international archives (e.g., the World Ozone and Ultraviolet Data Centre, WOUDC). These very different timescales for data submission (i.e., hours vs. months) are not mutually exclusive, and must be recognized. Preliminary data and final archived data are likely to differ.

Archiving Support

- The archiving of raw data and metadata is a resource-intensive activity, and it is essential that funding agencies not only recognize the need for support for raw data and metadata archiving, but also make it clear that archiving of these ancillary data is expected as an important part of the measurement programme. Personnel tasked with making the measurements must be given the support for archiving raw data and metadata, both in national and international databases. However, such archiving of raw data in no way replaces the need for archiving the final data products.

Archiving Management

- Agencies funding measurement programmes are recommended to require that the measurements will be submitted to easily accessible archives in a timely manner. Proprietary data formats should be avoided for data archiving. Where possible, internationally accepted formats that can accommodate a wide range of data types, and that easily facilitate the bundling of raw data and metadata, should be used (e.g., HDF or NetCDF)

Databases

- The number of individual databases through which measurements may be obtained continues to proliferate. Efforts by international organizations to link various data centres (e.g., ozone, UV-radiation, GHG, meteorological) as a means of ensuring access to all available data should be encouraged (e.g., the WMO GAW Station Information System,

GAWSIS). Measurements made during field campaigns or through regional process studies also should be archived to allow free access by researchers.

Level-1 Data Management

- Changes in instruments, observers, retrieval algorithms, calibration protocols, ozone-absorption cross sections, and operating procedures cannot be avoided. Without such changes, improvements never would be possible. Therefore, such changes need to be managed. This includes the recognition that periodic reprocessing of historical raw data will be required to produce new improved versions of long-term homogeneous measurement time series. Archiving of final data products therefore needs to accommodate different versions of measurement records, as well as the ability to inform users of the archived data about the availability of new versions of the data.

New Recommendations

Level-0 and Metadata Archiving (High Priority)

- The extent to which any reprocessing can be achieved will depend on the archiving of the 'rawest' form of original data, as well as the archiving of a rich set of metadata describing all facets of the data processing. For example, the primary recommendation is for all Dobson stations to submit level-0 observations and calibration data to the WOUDC, in addition to the level-1 analysis.

- The Brewer network already is submitting level-0 data to the WOUDC. To expand the current submission of the Brewer primary data and calibration metadata from the stations, the existing Brewer Data Management System (BDMS) implemented by Environment Canada is recommended for general use.

Availability of Historical Data

- Understanding the potential role of historical (i.e., pre-1980) ozone changes in forcing changes in surface UV radiation and climate is now acknowledged. Therefore, it is recommended that efforts to identify and recover these records be increased. Specific sites that are known to have historically available data that have not yet been submitted to international databases are documented in the Proceedings of the Symposium for the 20th Anniversary of the Montreal Protocol. Governments and agencies are encouraged to provide resources to undertake data salvage as a priority activity.

Emission Inventories and Reporting

- Comprehensive reporting of national ODS production and consumption will improve emissions inventories. Care should be taken when considering practical applications for inventories due to the high current levels of uncertainty.

Education and Training

- Holding workshops that provide training on metadata collection and processes for archiving data may support the effort to improve these activities within the ozone and research community. It is recommended that scheduling be encouraged at times when such workshops can be held easily (e.g., before or following meetings such as the Quadrennial Ozone Symposium, or in conjunction with instrument intercomparisons).

- Some countries not participating in the Dobson Data Quality Workshop mentioned above should be encouraged to do so (see workshop report). It is recommended that a letter be sent from WMO to the WMO Permanent Representatives/Ozone Research Managers of those countries that were, for various reasons, previously unable to participate in these activities.

Capacity Building

While there has been progress in capacity building since the 7th ORM, much remains to be accomplished. A number of key activities have been undertaken over the last three years that have had significant impact. In particular:

- The 2010 relocation of the unused Dobson instrument from Oslo, Norway to Kampala, Uganda, and the unused Dobson instrument from Uccle, Belgium to Kyev, Ukraine through the umbrella effort of the Regional Dobson Calibration Centre (RDCC)-Europe, including the support of Belgium, Norway, Czech Republic, Germany, USA, and WMO. These relocation efforts required the refurbishment and calibration of the unused instruments, and the training of observers.
- The transfer of knowledge and technology from the World Dobson Calibration Centre (WDCC), Boulder, USA to the Africa and South America RDCCs in 2009 and 2010.
- Brewer calibrations supported by the WMO Brewer Trust Fund (supported by Canada)
    - Calibration and maintenance of Brewer #160, Isfahan, Iran, October 2008
    - Calibration and maintenance of Brewer #051, Casablanca, Morocco, September 2009
    - Calibration and maintenance of Brewer #165, Casablance, Morocco, Sepetember 2009
    - Calibration and maintenance of Brewer #180, Punta Arenas, Chile, November 2009
    - Calibration and maintenance of Brewer #056, La Paz, Bolivia, November 2009
    - Calibration and maintenance of Brewer #110, Cachoeira Paulista, Brazil, November 2009
    - Calibration and maintenance of Brewer #167, Santa Maria, Brazil, November 2009
    - Calibration and maintenance of Brewer #081, Cuiaba, Brazil, November 2009
    - Calibration and maintenance of Brewer #073, Natal, Brazil, November/December 2009
    - Calibration and maintenance of Brewer #116, Bandung, Indonesia, November 2010
    - Calibration and maintenance of Brewer #092, Watukosek, Indonesia, November 2010
- Educational workshops such as:
    - The 2011 UNEP / WMO-GAW Dobson Data Quality Workshop held in Hradec Králové, Czech Republic
    - The WMO-GAW Biennial Brewer Users Workshops led by Canada in Northwich, UK (June 2007); Seoul, South Korea (October/November 2007); the half-day workshop in Tromsø, Norway (2008); and the Biennial Brewer Users Workshop held in Aosta, Italy (2009). The 13th Biennial Brewer Users Group Meeting, is tentatively scheduled for 12-16 September 2011 in Beijing, China.

Recognizing the success of these various workshops, it is recommended that their frequency be increased.

There have also been a number of countries that have contributed either directly or in-kind to the Vienna Convention Trust Fund (VCTF). Those countries include: Czech Republic, Estonia, Estonia, Finland, France, Kazakhstan, South Africa, Spain, Switzerland, and the United Kingdom. In addition, a number of countries have developed twinning relationships that have built both capacity

and scientific relationships over this time period. The following are key examples of quality twinning relationships that can be used as models for further endeavours of this kind:

- Finland – Argentina
- Spain – Algeria
- Spain – Argentina
- Switzerland – Kenya
- UK – South Africa
- USA – SHADOZ network

The 8th ORM also recognizes that a number of other organizations (e.g., WMO GAW) support capacity-building activities such as the German GAWTEC (GAW Training and Education Centre). Nevertheless, capacity building is a long-term activity, and many of the recommendations of the 7th ORM are as fully applicable today as they were when first proposed (see section on Capacity Building (pages 32 and 33) under Recommendations, Report of the Seventh Meeting of the Ozone Research Managers, <http://ozone.unep.org/Meeting_Documents/research-mgrs/7orm/7orm-report.pdf>). The 8th ORM, under the guidance of the Bureau of the Vienna Convention, believes a small number of specific, actionable activities be undertaken before the 9th ORM. The following specific recommendations are in-line with the more general 7th ORM recommendations, and provide concrete means of increasing capacity in developing countries over the next three years.

- Recognizing that surplus equipment exists in many developed countries and could be made available for redeployment:
  - A mechanism be developed under the WMO GAW umbrella so that countries would be able to donate good quality, operational equipment to the WMO for deployment to developing countries as a means to enhance the global operational network of ozone- and UV-observing stations.
  - That GAW SAG-Ozone and SAG-UV be tasked with the responsibility of assessing the overall global needs for the distribution of this equipment.
  - That the VCTF, if able, pay for training and aid in the establishment of these stations. It is recognized that agency collaborations (twinning) is preferable, but cannot always be established.
- That capacity building continues through workshop attendance by the professional and technical staff of developing countries. Specifically, the ORM recommends supporting attendance at:
  - The WMO-GAW Biennial Brewer Users Workshop, Beijing, September 2011
  - A second Dobson Workshop, following the success of the 2011 Czech workshop, to be held in 2013
  - That an ozone- and UV-observing workshop be held in association with the 2012 Quadrennial Ozone Symposium (QOS) in Toronto, Canada. This workshop would be developed specifically for scientists from developing countries, and would be held immediately preceding the QOS in order that the meeting could be attended as part of this capacity-building activity. In addition to serving as an educational forum on the various symposium topics, the workshop could help identify scientists who are capable of contributing to forthcoming scientific assessments. The International Ozone Commission should be invited to aid in the development of this workshop, and to waive registration fees for the workshop attendees. It is suggested that this course follow the symposium session topics, and that Session Chairs be encouraged to

present two-to-three-hour courses and question-and-answer sessions within the workshop.

- NASA has developed a specialized education programme to encourage the use of NASA Earth-observation data (GLOBE, <http://globe.gov/events/nasa-s-earth-climate-course-event>) within the NASA Explorer Schools project). The major space agencies are encouraged to develop courses of this type to be specifically directed towards scientists from developing countries. It is strongly recommended that at least two such courses be held before the 9th ORM, one by NASA for Region III, and one by ESA for Region I.

- In order to assess the effectiveness of these and future planned capacity-building activities, a set of metrics be developed by the SAP over the next 12 months. For example, these metrics could consist of one or more of the following:
  - The number of refereed publications in peer-reviewed journal from scientists in developing economies
  - The quantity and quality of data submitted to the WOUDC or other appropriate archives
  - Increased involvement in the Ozone Assessment through publications used, authors, reviewers, etc.
- That, where possible and appropriate, National Ozone Unit Officers in developing countries, being successful in the tasks of phasing out of ODSs in their countries:
  - Be given the responsibility of being the focal point for the distribution of information on, and the coordination of, monitoring and scientific activities, particularly in the area of capacity building.
  - Are the recipients of all information associated with upcoming capacity-building events for its redistribution to the country's monitoring and scientific communities.
- That with the increasing access of high-speed Internet access, web-based training courses should be developed. These new courses could cover the various topics as reported on in the Scientific Ozone Assessment. It is recommended that the OzonAction Programme of the UNEP Paris Office coordinate the establishment and organization of such courses, and that the SAP encourage coordinating lead authors to develop and give such web-based courses over the next three years.