NATIONAL REPORT ON THE EXISTING PLANNED OZONE RESEARCH AND MONITORING ACTIVITIES

SAMOA

1.1 Introduction

Samoa acceded to both the VC and the MP on 21 December 2002. As a developing country it has been classified as an Article 5(1) country, eligible to receive technical and financial assistance under from the MLF. The proposed TPMP for HCFCs describes Samoa’s approach and associated activities to guide its efforts to comply with the agreed phase-out schedule for HCFCs, from the baseline determination from 2009 and 2010 consumptions to full phase out in 2040. It was prepared by the NOU of MNRE under the supervision of the NOC.

1.2 Country background

Samoa is a Pacific small island developing state that became an independent country in 1962 after a period as a United Nations Trust Territory under New Zealand administration (see Figure 1). This part looks at the background features of Samoa to understand the local setting where the current ozone activities take place and the proposed will be applied and implemented. The setting in this context is the local environment comprising the physical, political, social and economic conditions and the circumstances that would shape decision-making on project activities.

Figure 1 – The islands of Samoa
1.2.1 Geographic features

Savaii is comprised of two relatively large islands, Upolu and Savaii, two smaller inhabited islands, Manono and Apolima, and a number of smaller uninhabited offshore islands, islets and rocks (see Figure 1 above). It is the larger and western part of the Samoan archipelago, located between 13° and 14° south latitude and 171° and 173° west longitude. The islands stretch over a distance of about 200 km covering a total land area of about 2,900 km² (40% in Upolu and 60% in Savaii) and an exclusive marine economic zone of approximately 130,000 km². 80% of total land area is held under customary ownership, 16% is government land and 4% freehold. The capital, Apia, is located about midway on the north coast of Upolu. Salelologa is the main centre on Savaii, located on the southeast coast.

The Samoan islands are composed mainly of volcanic, with areas of recent lava flows still exposed on Savaii. Soils are generally clay in texture, free draining, porous and relatively shallow. About 40 per cent of Upolu and 50 per cent of Savaii are characterised by steep slopes descending from volcanic crests, with the interior of both islands covered by montane forests. Cloud forest is found at the higher altitudes on Savaii. The country is rugged and mountainous with the Upolu crestal ridge rising to 1,100 m, and Savaii’s highest mountain reaching up to about 1,850 m. A coral reef surrounds the islands for nearly half of the coastline except where there are coastal cliffs and headlands, and where young lava flows have filled the lagoon.

The climate is generally hot and wet with distinct dry (April to November) and wet (December to March) seasons. Annual rainfall is about 3,000 mm m (varying from 2,500 mm in the rain shadow areas of Savaii’s northwest to over 6,000 mm in the Savaii highlands), with most of the precipitation occurring in the wet season. The average temperature is 27 degrees Celsius with 80% humidity. Samoa experiences southeast trade winds almost all times of the year with tropical cyclones occurring during the wet season.

2.1 Current activities and implementation programmes carried out by the NOU

There are two Implementation programmes and plans currently in place. This is the Terminal Phase out Management Plan for CFCs and the HCFC Phase out Management Plan.

Majority of the activities under the TPMP for CFCs have been completed with only the incentive programme which is scheduled to be completed before mid 2011. On the other hand the HCFC Phase out Management Plan is already in place for Samoa and has been submitted as a Regional Approach to the Executive Committee Meeting in April 2011.

The following will provide the existing and planned research and monitoring activities currently in place for Samoa.

3.1 ODS legislation

In spite of the strong provisions of the current ODS regulations, observance by importers and RAC companies was extremely poor. There was only limited compliance with annual licensing and quarterly
reporting requirements. As a result, it was extremely to obtain accurate information on the use and consumption of ODS. Data provided by the MfR were also found to be incomplete and inconsistent making it quite difficult to determine actual volumes of imported ODS and the number of ODS-based equipments that were brought into Samoa.

However, review of the ODS legislation is currently taking place and the Legal Consultant from the Ministry of Natural Resources and Environment is assessing this review whether it should become an Act or an Amendment. This review will most likely be completed by the end of 2011.

4.1 ODS Consumption

Samoa is not an ODS producing country with demand only for RAC services. Australia, New Zealand and Fiji are the main exporters of ODS to Samoa, although some ODS or ODS-based equipment may have been brought in illegally by local residents or foreign ships.

5.1 Terminal Phase-out Management Plan – Activities

The Terminal Phase-out Management Plan for ODS in Samoa was approved by the Executive Committee in its 53rd Meeting in November 2007. According to the agreement between the Government of Samoa and the Executive Committee of the Multilateral Fund for Phase-Out of Ozone-Depleting Substances, Samoa will provide annual report on the implementation of previous year plan and annual implementation plan for the current year.

The National Ozone Committee (NOC) oversees the implementation of the TPMP. One staff member of Samoa Ministry of Natural Resources, Environment and Meteorology is dedicated to the implementation of TPMP. NOC meetings are conducted to discuss arising issues in the implementation on a monthly basis or by request of National Ozone Unit (NOU) or NOC members depending on arising monitoring issues from time to time.

Samoa TPMP implementation started in mid 2008 after the signing of agreements between the Government of Samoa with UNEP and UNDP. The NOU is dedicated to accelerate the implementation of both UNEP and UNDP TPMP components to ensure achievement of all objectives stated in these Agreements before the end of the Project.

This report therefore will provide a summary of the activities undertaken during the time the TPMP started its implementation programme in Samoa in mid 2008 till 2010.

5.1 Achievement of Targets.

Samoa fully met the 2009 targets which is 0.0 ODP tons for CFC import and 0.0 ODP tons for servicing.

Samoa reported zero consumption in 2008 for CFC and other ODSs (except HCFCs) to the Ozone Secretariat as shown below.
Table 1: ODS Consumption during 2003-2010 (ODP Tons)

<table>
<thead>
<tr>
<th>ODS</th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>CFCs</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Halons</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Other Fully Halogenated CFCs</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Carbon Tetrachloride</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Methyl Chloroform</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>HCFCs</td>
<td>0.2</td>
<td>0.4</td>
<td>0.2</td>
<td>0.2</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td></td>
</tr>
<tr>
<td>HBFCs</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Bromochloromethane</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Methyl Bromide</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Source: Ozone Secretariat

Licensed companies provided the NOU with their annual consumption data before 1 March every year as obligated under the license conditions. These data, as well as data from Customs, are reviewed by the NOU before providing a final report of the ODS consumption.

6.1 IMPLEMENTATION OF 2009 & 2010 ANNUAL IMPLEMENTATION PROGRAMME

6.1 Component 1: Policy, Regulatory and Institutional Support

6.1.1 Review of the Atmospheric Policy:
The Atmospheric Policy has been reviewed and it is now still in its final draft. The Ozone Layer Regulations 2006 has been reviewed and is currently being assessed by the Attorney Generals Office.

A total number of two consultations and two workshops were carried out for the review of the Ozone Layer Regulations 2006, however it is intended that an Amendment of Ozone Regulation will be proceed in the near future.

6.1.2 Training of Enforcement Officers:
Training has been carried out for enforcement officers including Customs, Quarantine and conservation officers that are monitoring of imports and enforcement of the regulations. Technicians were hired to conduct these trainings. The customs officers have improved
awareness and capacity to carry out their duties to control the banned refrigerants and equipments that are under control of the Montreal Protocol.

6.2  Component 2: Training Course for Refrigeration Technicians, Capacity Building and Awareness Activities

6.2.1  Support for Refrigeration Association:
The Samoa Refrigeration Engineering Association (SREA) is functioning well and collaborating with the NOU in conducting trainings and monitoring of the licensing system. A JICA volunteer is now working closely with the NOU and the SREA in reviewing the Samoa Technicians Certification System; this system is regarded very important towards the licensing system in Samoa. It is expected to be in place in July 2011.

6.2.2  Expansion of Technician Training Programme
Refrigeration and Air conditioning technicians’ trainings were conducted and 101 technicians were certified during 2009, with 41 technicians certified in 2010. All in all, there were four Trainings carried out for Good refrigeration practices carried out by authorized technicians from SREA and NUS lectures. As a result of this, a total number of 152 technicians certified. However, some of these technicians attended the trainings twice for refreshment purposes.

6.3  Awareness:
Awareness programs have been carried out for the relevant national stakeholders including workshops to further inform them of the relevant information that they need to be aware of. Also a consultation with the MNRE IT personnel have been conducted for future posting of updated Ozone Issues in the MNRE Website. This is accessed by the public.

Furthermore, a number of Important Ozone Issues pertaining the Phasing out of CFCs have been published in the Samoa Observer Newspaper and the main Television channel for effective awareness of the public towards Ozone issues and results of workshops. Also displays of Ozone boards were carried out at the National University of Samoa’s Open Day and Career Day for two years.

6.4  Component 3: Technical assistance and equipment support for servicing/training establishments
6.4.1 Training / Demonstration Equipment:
The Freeze Dry Systems Ltd, Auckland New Zealand was the selected Company for the supply of equipments and the consultant selected was John Campion from the same company. He has been in the refrigeration and vacuum industry business for thirty years.

A whole week Workshop was carried out at the Australian Pacific Technical College Workshop area for the demonstration and trainings were carried out in July 2010.

Representatives from all the ODS Servicing Companies and Importers attended as well as NOC members and Institutions. A total number of 62 participants attended the training and demonstration of equipments.

6.4.2 Equipment procurement:
Procurement of 3 sets of recovery recycling for Refrigeration Service Shops and 2 sets of MAC Recovery and Recycling and selection of shops and distribution of the equipment is completed.

**Ongoing / Planned Activities for 2011.**

*Component 4: Technical Assistance and Equipment Support*

6.4.1 Incentive Programme:
Under the TPMP, training and demonstration equipment to the refrigeration and air conditioning servicing industry association was provided with assistance made available in the first tranche. Funding for the second tranche would be used for assisting the country in reducing its dependence on CFC based air-conditioning equipment in Mobile Air-Conditioning (MAC) applications through retrofit incentive program for conversion to alternatives.

This component will cover the following activities:

- Incentive programme for retrofit of 1,000 CFC-based MAC systems at $30 per car. The NOU would have the flexibility to decide on the focus of their incentive programme on MAC or other RAC equipment depending on prevailing situation. The incentive should not be more than 50% of actual retrofit cost.

- Awareness campaign for popularizing the programme as well as to familiarize the automobile users with the prospective vehicle inspection and registration mechanism and the ban on CFC-based systems after 2009. The awareness activities would be undertaken as a part of the ongoing ODS phase-out initiatives under IS project.
6.5 Component 5: Coordination and Monitoring

National Ozone Committee meetings are held with representatives from Ministry of Commerce, Industry and Labour, Customs Department, Office of the Attorney General, Samoa Refrigeration Engineering Association, Samoa Institute of Technology, Ministry of Finance regularly to discuss any required issues from time to time.

Regular contact with UNEP DTIE, Asia Pacific Regional Network, SPREP, Samoa Refrigeration Engineering Association, the National Ozone Committee, the Private Sector, other government departments/agencies/corporations; and other sections/divisions of the MNRE regarding matters pertaining to the implementation of the Montreal Protocol in Samoa.

7. HCFC Phase out Management Plan

7.1 ODS importation

Primary data on annual imports of HCFCs from 2007 to 2010 was compiled from information from received from importers and cross-checked against Customs Department import data. When the NOU started the implementation of the ODS import licensing system, 11 companies were granted licenses of which six were active (Table 4). Two of these six, BOC Gases and Trade Supplies, were importers/resellers while the rest imported ODS for their own use.

Table 2: Registered RAC companies, 2010

<table>
<thead>
<tr>
<th>Company</th>
<th>Refrigerants</th>
<th>Equipment</th>
</tr>
</thead>
<tbody>
<tr>
<td>BOC Gases Samoa Ltd</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Origin Energy Samoa Ltd</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Samatic Refrigeration Ltd</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Trade Supplies (Samoa) Ltd</td>
<td>-</td>
<td>Yes</td>
</tr>
<tr>
<td>DJ Grevel Refrigeration</td>
<td>-</td>
<td>Yes</td>
</tr>
<tr>
<td>Kool Line Refrigeration (Samoa) Ltd</td>
<td>-</td>
<td>Yes</td>
</tr>
<tr>
<td>SL Refrigeration Ltd</td>
<td>-</td>
<td>Yes</td>
</tr>
<tr>
<td>West End Co. Ltd</td>
<td>-</td>
<td>Yes</td>
</tr>
<tr>
<td>Supercool Refrigeration &amp; Air Conditioning</td>
<td>-</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Source: NOU survey
7.2 ODS use and consumption

Samoa consumption of HCFCs is shown in Table 5, with a baseline of 3.88 MT or 2.13 ODP (MT) for Samoa. The survey found that the most common refrigerants were HCFC-22 (HFC-134a and R-404A), R-407C, R-410A and R-507A; there was currently no hydrocarbon-based refrigerant being offered. The importation of CFCs was discontinued in 2003 as a direct outcome of the implementation of the CP and RMP and in response to the TPMP for CFC phase-out. Since the ban on CFC imports, recovered and recycled CFCs and drop-in alternatives were used to meet the servicing and maintenance needs of existing equipment.

Table 2: Estimated HCFC consumption for Samoa, 2005-2010

<table>
<thead>
<tr>
<th>HCFC (MT)</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
<th>Baseline</th>
</tr>
</thead>
<tbody>
<tr>
<td>ODP (MT)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2.13</td>
</tr>
</tbody>
</table>

Source: NOU survey

7.3 RAC sector

The RAC sector is the only sector consuming HCFCs in Samoa. Since there is no national manufacturing HCFC or HCFC-based equipment, the entire consumption is in servicing of refrigeration and air conditioning equipment.

7.3.1 Domestic refrigeration

Domestic refrigerators are not manufactured in Samoa and the requirements are set and determined by imports. The importation of new non-ODS refrigerators commenced in late 1990s from Australia, New Zealand and other Asian countries. Second-hand HCFC refrigerators are also being imported from Australia and New Zealand.

It was estimated that there were about 30,000 units of HCFC-based refrigerators operating in 2010. With over 90% of households served by the national electricity grid this will lead to increased use of domestic refrigerators. It is more than likely that most villagers will purchase second hand refrigerators, and these communities will need to be informed about the impending phase-out of HCFCs and the proposed incentives to convert their equipment to non-ODS refrigerants.

7.3.2 Commercial refrigeration

Commercial refrigeration equipment includes chest freezers and visi coolers. Chest freezers are mainly used in supermarkets, grocery shops, food product stores and restaurants.

The population of HCFC-based commercial refrigeration equipment in 2010 is estimated at about 700 units. While a significant percentage of existing commercial refrigeration equipment is reaching the end
of its existing life most units, for economic reasons, will be repaired rather than replaced. Second hand equipment is being imported and retrofitted using HCFCs because the new generation refrigerants are expensive to acquire.

The servicing demand in Samoa is very low for commercial refrigeration equipment due to small numbers of existing equipment. It was assumed that 400 gms per unit was required for recharge consumption of commercial equipment during servicing, with about 50% of equipment needing servicing. It is expected that the majority of new commercial equipment will be serviced with non-ODS alternatives.

7.3.3 Industrial refrigeration

Industrial refrigeration equipment is being used primarily for refrigeration applications in food processing industries such as the ice cream factories (about 20 units). About 7 chillers for centrally air-conditioned applications were installed in public buildings in Apia including the new Justice and Court Administration complex.

7.3.4 Mobile air conditioning (MAC)

The usage of vehicles in Samoa has experienced exceptional growth in recent years. As shown in Table 6, the number of registered vehicles more that doubled during 2002-07. The majority of the vehicles imported into the country were second-hand using ODS-based MACs.

Table 3: Number of registered vehicles in Samoa, 2001-2007

<table>
<thead>
<tr>
<th>Year</th>
<th>Total number of registered vehicles</th>
<th>Light vehicles¹</th>
<th>Estimated amount of refrigerants (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Number</td>
<td>% of total</td>
</tr>
<tr>
<td>2001</td>
<td>7,731</td>
<td>6,359</td>
<td>82</td>
</tr>
<tr>
<td>2002</td>
<td>9,196</td>
<td>7,910</td>
<td>86</td>
</tr>
<tr>
<td>2003</td>
<td>11,288</td>
<td>9,932</td>
<td>88</td>
</tr>
<tr>
<td>2004</td>
<td>13,485</td>
<td>12,120</td>
<td>90</td>
</tr>
<tr>
<td>2005</td>
<td>14,400</td>
<td>13,000</td>
<td>90</td>
</tr>
<tr>
<td>2006</td>
<td>15,012</td>
<td>13,603</td>
<td>91</td>
</tr>
<tr>
<td>2007</td>
<td>16,215</td>
<td>14,794</td>
<td>91</td>
</tr>
</tbody>
</table>

Source: SBS
The amount of 0.9 kg was prescribed by the RAC servicing companies as the average amount of refrigerant contained in each imported vehicles. It was also assumed that 75% of the light vehicle population have MAC units and 30% are serviced annually.

7.3.5 Domestic and commercial air conditioning

There are 3,000 installations of HCFC-based room air-conditioning units (mainly in office and commercial buildings, hotels, restaurants and hospitals) with a few in private homes.

7.3.6 Servicing establishments

There were 21 licensed refrigeration service and repair workshops mainly on Upolu Island. Of these, about 14 catered to the domestic, commercial and industrial refrigeration sub-sectors and 7 dealt with the MAC sub-sector. There are a total of about 120 technicians operating in the RAC servicing sector with varying skill and competency levels.

8. Recommendations:

In regards to the recommendations mentioned in the Ozone Research Managers Meeting, 2008. Samoa does not have any further recommendations at this stage.

Samoa is looking forward to participate in this Ozone Research Managers Meeting in order to become fully aware and understand activities planned to be implemented for research and monitoring activities.
South African

A report for the 8th WMO/UNEP Ozone Research Managers Meeting, WMO, Geneva, Switzerland, May 2011

Introduction

The depletion of the stratospheric ozone layer, increases in troposphere ozone, higher levels of acidity in rain, rising carbon dioxide and methane concentrations, and changes in the radiative balance of the earth-atmosphere energy system - all reflects the increasing influence of human activity on the global atmosphere, the life-support system of planet Earth. Environmental issues and policy matters have to play a pivotal role in meeting the developing needs and challenges of the people in a new democratic South African Society. Clauses in protecting and respecting the environment in a sustainable context, is embedded in the South African Constitution.

To underline these facts: - An excerpt by the Minister of Water and Environmental Affairs Me. Bee Molewa, on Wednesday 20 April 2011, in the National Assembly, Parliament.

"We rank among the world's top 20 greenhouse gas emitting countries. As a country, we must strive to maintain a balance between development and environmental conservation. Like many other countries of the world, the number one threat to our long term sustainable development, economic growth and quality of life are related to the impacts of climate change.

Climate change is already a reality! Its early impacts can be seen on declining agricultural production, higher food prices and food insecurity; which are most severely felt in developing countries like ours. Working together we must ensure that our response to climate change seizes the new growth opportunities presented by the global effort to address climate change.

President Jacob Zuma announced prior to the Copenhagen United Nations Climate Change Conference in December 2009 that South Africa will implement nationally appropriate mitigation actions which will result in the reduction of our carbon emissions by 34 % by 2020 and by 42 % in 2025, dependant on availability of finance and technology.

As a department working together with the people of South Africa, we are ready to give practical meaning to this commitment. Consequently, our Climate Change Response Policy is nearing completion and we will present the Climate Change White Paper for Cabinet approval, later this year. This evolving policy outlines our vision for an effective climate change response and our transition to a climate resilient and low-carbon economy and society.

From the 28th of November to the 9th of December this year 2011, our country will host the United Nations Climate Change Conferences in Durban (COP17)."

In light of the above stated commitment the activities following describes the ongoing systematic monitoring efforts in South Africa.

1. OZONE OBSERVATIONAL ACTIVITIES

The South African Weather Service (SAWS), an agency of the Government Department of Environmental Affairs and Tourism (DEAT), is the focal point of ozone monitoring and research activities in South Africa. These activities are enhanced by collaboration with a few national research centers and universities.
The ozone monitoring and research activities are conducted within the context of the World Meteorological Organizations (WMO) Global Atmosphere Watch (GAW) program. The Cape Point Global Atmosphere Watch (GAW) station undertakes a regional network of observations.

1.1 Atmospheric Ozone Monitoring

The first South African column ozone measurements were made during 1964 until 1972 with Dobson #089 operating from Pretoria. Reinstating South Africa’s commitment to the Vienna Convention, the Weather Service now operates two Dobson ozone spectrophotometers, #089 at Irene near Pretoria (25.9 S, 28.2 E) since 1989, and #132 at Springbok (29.7 S, 17.9 E) since 1995. Both these instruments have been regularly calibrated with reference to the world standard. Our participation at the recent UNEP/WMO Dobson Data Workshop held in Hradec Kralove, Czech Republic re-affirmed good quality data sets.

During 2009, the 3rd African UNEP/WMO International Comparison of Dobson Spectrophotometers was organized by the World Meteorological Organization and the South African Weather Service in close cooperation with the World Calibrations centre at NOAA and the European calibrations centre hosted by DWD, Germany. This event was conducted during October 2009 at the Irene Weather Service Technical Centre, just south of Pretoria.

After a three year break the Weather Service has been fortunate to reinstate its ECC RSG92-15GE Ozonesonde sounding program, which operated during the period 1990’s until early 2007. Regular ozonesonde soundings are once again scheduled for 2011. This data is shared with the Southern Hemisphere Additional OZonesondes (SHADOZ—http://croc.gsfc.nasa.gov/shadoz/) program from NASA, USA, which also is submitted to WOUDC.

Figure 1: Dobson #132 Total Ozone Column for Springbok

![Figure 1: Dobson #132 Total Ozone Column for Springbok](image1)

Figure 2: Dobson #89 Total Ozone Column for Irene

![Figure 2: Dobson #89 Total Ozone Column for Irene](image2)
Surface ozone measurements are continuously undertaken at Cape Point since 1982. Our program has also extended surface ozone measurements to the South African National Antarctic Expedition Base (SANAE IV) in Antarctica since December 2003. Surface ozone monitoring is to be extended to the two Dobson stations, Irene and Springbok during 2011.

1.2 Other relevant Trace Gases and profile measurements

The pristine location of the Cape Point Global Atmosphere Watch GAW station (34.3S, 18.5E) enables measurements to be made in air that has passed over the vast clean Southern Ocean. Such long-term observations are representative of background conditions, making it possible to detect changes in the atmosphere’s composition. The Cape Point GAW Laboratory is also scientifically twinned with a research partner, namely the Fraunhofer Institute for Atmospheric Environmental Research (IFU) in Garmisch, Germany, now IMK-IFU (Forschungszentrum Karlsruhe).

Measurements include a wide range of parameters namely: - surface O$_3$, gases which lead to stratospheric ozone depletion such as: CFCl$_3$, CCl$_2$F$_2$, CCl$_2$FCCIF$_2$, CH$_3$CCl$_3$, CCl$_4$ and N$_2$O greenhouse gases in the troposphere such as CO$_2$ and CH$_4$ and reactive gases such as CO.

Furthermore, UV-A, UV-B and global radiation (total and diffuse) are also measured as well as the normal surface meteorological parameters. Radon measurements to assist with the classification of air masses arriving at Cape Point have been successfully established over the last five years. Regular scientific audits from EMPA, Switzerland for surface O$_3$, CO and CH$_4$ have been successfully conducted over the past seven years. In 2003 the WCC-N$_2$O (Forschungszentrum Karlsruhe IMK-IFU and Umweltbundesamt) conducted an audit for N$_2$O at Cape Point. During 2006 with German collaborations (GKSS Research Centre Geestacht) the Cape Point gashouse mercury measurement program was also revived.

Since 2005 a project was undertake for the continuous measurements of aerosols. This is now a well established program at the Cape Point GAW station and includes physical, chemistry and optical properties being measured. This milestone was reached with start-up funding support from WMO, scientific partnering with NOAA ESRL scientists (who designed and constructed the aerosol system) and local SAWS station scientist running and maintaining the system. The latest addition was the establishment of Aerosol Optical Depth (AOD) measurement relevant to global climate change in accordance to detailed guidelines set out in GAW Precision Filter Radiometer Network (GAWNET) http://www.pmodwrc.ch/worcc and Global Atmosphere Watch Program of the World Meteorological Organization (GAW) http://gaw.tropos.de

1.3 Ultraviolet-B measurements

Since January 1994 the Weather Service has maintained a routine program for monitoring erythemally weighted UV-B radiation at Cape Town (34.0S, 18.6E), Durban (30.0S, 31.0E) and Pretoria (25.7S, 28.2E), De Aar (30.7S, 24.0E) and Port Elizabeth (33.9S, 25.5E). The equipment used in this network is the Solar Light Model 501 Robertson-Berger UV-Biometer. The program was motivated by and in collaboration with the School of Pharmacy at the Medical University of Southern Africa (MEDUNSA), near Pretoria.

Since December 2001, the UV-Biometers are directly linked on the Services wide area network, and available in real-time on the SAWS WWW-site http://www.weathersa.co.za/. UV-B forecasts are also issued for the Cape Town, Durban and Pretoria-Johannesburg metropolitan areas since 1 December 1997. The main purpose of the UV-Biometer network is to make the public aware of the hazards of excessive exposure to biologically active UV-B radiation, and it contributes to the schools’ awareness programs for education. Regular enquiries from scholars are dealt with to satisfy their need to acquire more ozone and ultraviolet radiation knowledge. Celebrations around 16 September, each year, usually focuses
to create public awareness. Once a year on this day it is also dedicated to the hard working ozone observers and technicians gathering the measurements.

Renewed UV research is being undertaken by the Council for Scientific and Industry Research (CSIR). Their research unit for health is conducting research towards UVB exposure amongst scholars.

2. **Other Observation/Monitoring Networks**

2.1 **Research Aircraft**

The South African Weather Service’s two research aircraft Aerocommanders are used as Airborne monitoring platforms. Site sampling is conducted at a speed of 100 ms$^{-1}$, at low atmospheric levels (500 – 3000m above ground level) and the range of the aircraft is around 3.5 hours, over predetermined pollution hotspot areas over the country.

In addition to standard meteorological parameters, instruments mounted in and on the aircraft measure the following trace gases and aerosols:

- Carbon dioxide, Carbon monoxide, Sulphur dioxide, Hydrogen sulphide, Oxides of nitrogen, Ozone, Volatile organic compounds, and the concentration of aerosols between.

There has been a shift in air quality management in South Africa from source control to pollution prevention by focussing on ambient air quality is intended to ensure improved air quality for future generations. The aircraft monitoring capabilities complements other ground-based research and monitoring processes to ensure that information and data associated with air pollution are of the highest quality and are accessible to all South Africans.

The primary airborne monitoring project objectives are:

- To determine the spatial and temporal characteristics of air quality over South Africa through the use of ground-based, airborne and satellite measurements;
- To validate the various measurements and integrate them into a holistic picture of the South African air quality situation with the context of the region;
- To build capacity in the fields of air quality and atmospheric chemistry through hands-on training.

The Aircraft research and monitoring facilities are jointly managed by the South African Weather Service and the Climatology Research Group of the Witwatersrand University (Wits) in Johannesburg. These aircrafts and logistical staff have taken part in field experiments conducted in Australia and India during the last three years.

2.2 **LIDAR**

During the past three years, the Council for Scientific and Industrial Research - CSIR has developed a new mobile LIDAR. The Light Detection and Ranging (LIDAR) has become an excellent tool for monitoring the atmosphere in a relatively short period of time (within a few seconds to minutes). Currently, LIDAR systems are used for studying the atmospheric structure and dynamics, trace constituents, aerosols, clouds, boundary and mixed layers and other meteorological applications [1]. Although ground based LIDAR systems are deployed for atmosphere studies in many developed countries, it is still a very novel technique for South Africa and African countries. There are currently two different LIDARs available in South Africa, located in Pretoria and Durban respectively. The Durban LIDAR is operated at University of KwaZulu-Natal as part of cooperation between the Reunion University and the Service d’Aéronomie (CNRS, IPSL, and Paris) for climate research studies. It allows for studying the stratosphere-mesosphere (30-80 km) thermal structure and troposphere-stratosphere aerosol
(8-40 km). Future plans include field campaign measurements in and around South Africa, for qualitative industrial pollutant measurements and higher atmosphere characteristic changes in ozone, aerosol and other parameters.

3 CALIBRATION ACTIVITIES AND DATA SUBMISSIONS

All primary GAW data (ozone and trace gas data) are submitted regularly to WMO recognised World Data centers. Dobson column ozone is submitted to WOUDC, Toronto, Canada. Since the inception of the Dobson programs these instruments have been internationally calibrated through inter-comparison campaigns as supported by UNEP and WMO. Various regular international scientific audits remain in place for the Cape Point GAW station.

4. COLLABORATION - NATIONAL AND INTERNATIONAL

Ozone and related research are conducted sporadically within the country, mostly at a few academic institutions such as the CSIR, University of Kwazulu Natal in Durban, the University of Cape Town, and the University of the Witwatersrand in Johannesburg. Typical GAW type of collaborations is ongoing with the University of North West, School of Chemistry in Potchefstroom.

South Africa must also acknowledge its many international collaborators with specific references to international programs and institutions such as:

- The World Meteorological Organization (WMO) and many other NHMS in our region
- SHADOZ/Penn State University
- USA NOAA ESRL, Boulder
- WOUDC and ARQP, Toronto, Canada
- Training assistance from GAWTEC http://www.schneefernerhaus.de/e-gawtec.htm, Germany also DWD (European Dobson Calibration facility)
- EMPA http://www.empa.ch/plugin/template/empa/704/
- GAWSIS http://www.empa.ch/gaw/gawsis/ and IMK-IFU Garmisch, Germany
- GAWNET http://www.pmodwrc.ch/worcc/pmod.php
- LSCE, CNRS and DEBITS, Paris and Toulouse, and La Reunion Island - France. (Flask sampling, the SASRIO project and GDRI offices)
- The CZECH SOO-HK, in Hradec Kralove

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5. FUTURE PLANS AND RECOMMENDATIONS

Priority research work at the South African continues to include a service rendering UVB Forecast, especially during summer months. South Africa has some of the world’s highest UVB levels. There still remains the need to establish long term continued high-resolution spectro-radiometer UV observations at some suitable sites in southern Africa.

To maintain and enhance our data quality and to gain near real-time access of the data from the monitoring processes to various user-communities.

The SAOZ ozone monitoring instrument from SANAE, Antarctica has been brought back to South Africa and needs to be refurbished before resuming its monitoring capabilities.

The South African Weather Service is now well settled in it role of the custodian of the South African Air Quality Information System (SAAQIS) which has been developed and launched during 2010. The SAAQIS is a web-based interactive air quality information system which seeks to provide state of the air quality information to citizens and it is a research portal for strengthening policy development related to air quality issues. This has a profound advantage in that the country we can begin to assess whether air quality is improving and also identify areas where potential air pollution problems exists.

Various national air-quality monitor stations is linked in real time gathering vital atmospheric data for decision making for improving ambient air quality in especially our industrial areas. Technical staff off the Weather Service is tasked to calibrate and maintain these monitoring stations as part of the normal weather observational system across the country.


To continue building our scientific capacity – ozone, atmospheric research and monitoring in general, and related Climate Change Activities). The South African “ozone” community is very small and published peer reviewed articles of research findings remain admittedly very scarce.

CONTACT INFORMATION

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1. OBSERVATIONAL ACTIVITIES

1.1 Column measurements of ozone

Total ozone is monitored at two sites in Sweden by SMHI (Swedish Meteorological and Hydrological Institute) on behalf of the Swedish Environmental Protection Agency. Daily measurements started in Norrköping in 1988 using the Brewer #6, which was replaced by Brewer #128 in 1996. In Vindeln manual measurements started in 1991 using the refurbished old Dobson #30 and since 1996 the automatic Brewer #6 is also used.

The instruments are calibrated and served regularly. Efforts have been spent on improving the methods to retrieve good observations at low solar elevations since the 1990-ties, Josefsson (2003) and to improve the algorithms for cloud covered skies Josefsson and Ottosson-Löfvenius (2008). This year one Dobson and one Brewer participated in the CEOS campaign in Sodankylä.

1.2 Profile measurements of ozone and other gases

At the Swedish Institute of Space Physics in Kiruna there are a number of sophisticated instruments in operation. Special radars can track the circulation in the stratosphere. LIDAR gives a profile of the ozone and aerosols in the stratosphere, when there are no interfering clouds. There is also an instrument KIMRA (Kiruna Millimeter wave radiometer) that is used to monitor O₃, ClO, N₂O and HNO₃. The vertical resolution may not be the best, but it is independent of the weather so it can operate continuously.

Forschungszentrum Karlsruhe has located a FTIR (Fourier-Transform Infrared) Spectroradiometer at the same site to record long-term trends, Kohlrepp et al. (2011).

There is also a DOAS-instrument from NIWA and University of Heidelberg recording primarily total ozone and the column amounts of a number of other species.

1.3 Satellite measurements

The satellite Odin (Sweden, France, Canada and Finland) has now been in orbit for more than ten years. On board there are two instruments with connection to stratospheric studies a submillimeter radiometer, SMR, and an optical spectrograph and infrared imaging system, OSIRIS.

1.4 UV measurements

1.4.1 Broadband measurements

Monitoring of broadband UV (CIE-erythema weighted) started relatively early in Sweden. Supported by SSM (the Swedish Radiation Safety Authority) SMHI has been measuring since 1983. Josefsson (2006). There has also been a small network of five stations for a limited period. Presently, SMHI operates one station in Norrköping using a Solar Light Model 501. In the northernmost part of Sweden the Abisko Scientific Research Station is also using a similar instrument.

1.4.2 Narrowband filter instruments

The SSM have operated three stations, Stockholm, Tylösand and Visby, using GUV-instruments.

1.4.3 Spectroradiometers
In the past one UV-spectrum was recorded in between the monitoring of total ozone. Both Brewer instruments operated by SMHI were used. These data have been included in EC-funded projects SUVDAMA, EUDUCE and SCOUT-O3, e.g. Bais et al. (2007), Outer den (2006). In recent years data are still collected despite that funding ceased, but there is no calibration done.

1.5 Calibration activities

The Brewer instruments for total ozone are calibrated and serviced regularly by three year interval by IOS (International Ozone Services Inc.). Thus the output will be traceable to the Brewer Triad, which forms the WMO/GAW calibration centre. The Dobson instrument is recalibrated roughly every fifth year by visits to the WMO regional calibration centre at Hohenpeissenberg, Germany. The last calibrations were in 2007 and in 2010, when the instrument was served, calibrated and the electronics was replaced.

The broadband UV-meter used at Norrköping has participated in a number of international comparisons, see e.g. Gröbner et al (2002), Johnsen et al. (2006) and Josefsson (2006). Also the radiometers used by SSM have participated in comparisons or have been compared to the one of SMHI.

Due to lack of funding the absolute calibration (lamp or intercomparisons) of the spectroradiometers have not been done for recent years.
2. RESULTS FROM OBSERVATIONS AND ANALYSIS

Controlled and processed total ozone and broadband UV-data are available from web-sites of SMHI and/or WOUDC. Below is shown a summary of various observations made at Norrköping, Sweden. Interestingly, the Brewer spectrophotometer data can also be used to compute the aerosol optical depth (AOD), Cheymol et al (2006).

![Figure 2.1](image)

*Figure 2.1. Long-term, 1983-2010, CIE-weighted UV, total ozone, global radiation and sunshine duration from Norrköping, Sweden. A linear trend is tested on the level of 95% significance for each variable.*
Figure 1.1 HCl and ClONO$_2$ from FTIR-measurements over Kiruna, from Kohlrepp et al. (2011).

Figure 1.2 The ozone change in several atmospheric layers over Kiruna has been studied using the FTIR, from Barthlott et al. (2011).
3. THEORY, MODELLING, AND OTHER RESEARCH

3.1 Modelling

In early 2000 the STRÅNG-model system Landelius, Josefsson and Persson (2001) was launched, see http://strang.smhi.se/ as a co-operation between SMHI, the Swedish Environmental Protection Agency and the Swedish Radiation Safety Authority. Now, there is over 10 years of hourly data available for anyone to download, period 1999- up to yesterday. The modelled variables are CIE-weighted UV, global radiation, direct solar radiation, sunshine duration and photosynthetic photon density (PAR). The geographical area covers a large part of northern Europe with a present spatial resolution of 11 km.

Swedish UV-data has also been used for validation of re-constructed past UV-variation based on ERA-40 data, for validation of models based on satellite input and for validation of various UV-models, see e.g. Feister et al. (2008), Kaurola et al (2007), Kaurola et al (2010), Lindfors et al (2007), Lindfors et al (2009) and den Outer et al. (2010).

3.2 Satellite

Results from the Odin satellite instruments have published see e.g section 1.3 and Rösevall et al.(2007, 2007a, 2007b, 2008), Jones et al. (2009).

The observations have been compared with data from CTMs (Chemical Transport Models) see Khosravi et al. (2008) and Khosravi et al. (2009).

![Figure 1.2. Here two CTMs (CLaMS and Kasima) and one CCM (E5M1) are compared to the Odin/SMR data at two potential temperatures levels (500 and 650 K) for one month, namely March. Additionally the ILAS/ILAS-II data has been included in this comparison. The 500 K level is the one to look at how well ozone loss during Arctic spring is represented by the models. In general, models tend to underestimate ozone loss as can be seen from the deviation of the curves, they all show higher values than the observations from Odin/SMR or ILAS/ILAS-II, from Koshrawi et al (2009).](image-url)
4. **DISSEMINATION OF RESULTS**

4.1 **Data reporting**

Daily total ozone data are submitted once a month to the WOUDC. These data are also available at the [www.smhi.se](http://www.smhi.se) where also daily UV can be downloaded.

4.2 **Information to the public**

General information on the stratospheric ozone and UV-radiation can be found at [www.smhi.se](http://www.smhi.se) and at [www.naturvardsverket.se](http://www.naturvardsverket.se/)

The SSM (the Swedish Radiation Safety Authority) has more public information on their web-site [www.ssm.se](http://www.ssm.se). This governmental authority also produce brochures and some of them are possible to download from their web site. They also have had activities with the goal to change the behaviour of people mainly directed towards children. One activity was to publish and distribute “A book about the sun” to all kindergartens (8000) in Sweden, [http://www.ssi.se/UVindex/PDFer/EnBokOmSolen.pdf](http://www.ssi.se/UVindex/PDFer/EnBokOmSolen.pdf) another one was to educate the teachers of preschools and primary schools on the basics of and risks of UV. Collaboration with the Swedish Life Saving Society offers sun protection information to many thousands of children every year.

The distribution of daily UV-index forecasts started in 1993 from SMHI. In 1996 the UV-index forecast was introduced on the web ([http://www.smhi.se](http://www.smhi.se)) as a Table for 15 regions in Sweden and three resorts. Next year, 1997, the graphical layout was improved and since then the daily course of the UV-index is presented for a number of climatological similar regions in Sweden. During the first winters there was no forecasting of UV-index done. The season started in late March and stopped at the end of August. Since the year 2000, it is in operation all the year around. There is also some additional text presenting some specific features of interest regarding UV-radiation in general.

5. **RECOMMENDATIONS**

Concerning future research and activities regarding the ozone layer monitoring is still needed using both ground and space based instruments. Models needs to be improved, especially the CCMs. Predictions about when and to what extent the ozone layer will recover have still uncertainties and the model results deviate from each other by one or two decades.

Another valuable contribution from long-term measurements of ozone and related species from ground or from satellites are their connection to the climate change issue.

**Relevant scientific papers**


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1 OBSERVATIONAL ACTIVITIES

1.1 Column measurements of ozone
• Total ozone is measured regularly at Arosa since 1926. Presently, the measurements are performed with two partly computer-controlled Dobson spectrophotometers (D101 & D062) and three Brewer instruments B040, B072 (Mark II) and B156 (Mark III).

1.2 Profile measurements of ozone
• Balloon ozone soundings are measured from the Payerne Aerological Station three times per week since 1968. Until August 2002, Brewer-Mast (BM) ozonesondes were used while since September 2002 ECC (ENSCI – 0.5%) sensors are the operational instruments.
• The Umkehr ozone profiles are recorded at sunrise and sunset at Arosa since 1956 in clear sky conditions. Originally the measurements were performed manually but since 1989, the data acquisition of the Dobson Umkehr (D051) is computer-controlled. In 1988, the Brewer (B040) Umkehr series have started and presently the three Brewer are simultaneously measuring the Umkehr profiles.
• Since 1995, ozone profiles (20 – 70 km) are retrieved from ground based microwave radiometry from Bern (GROMOS) and in addition since 2001 also from Payerne (SOMORA). Both instruments deliver thirty minutes averaged profiles continuously. Data products are provided to the NDACC database. The microwave radiometers have been recently updated by replacing the aging (AOS) Acousto-Optical Spectrometers to digital FFT spectrometers. The SOMORA data processing software has also been changed adapting the widely used ARTS/Qpack package.

1.3 UV measurements
• The Swiss Atmospheric Radiation Monitoring programme (CHARM) consisting of 4 stations covering the altitude range of 366 to 3587m was build up between 1995 and 2000. The measurements programme consists of :
  - Broadband measurements: the direct, diffuse and global components of the broad-band erythemal UV-ERY radiation (Solar Light UV-Biometers) are measured,
  - Narrowband filter instruments: spectral direct irradiances are measured with Precision Filter Radiometers (PFR) at 16 wavelengths in the range 305 nm to 1024 nm.
• Besides the direct measurements, the UV index, the AOD at various wavelengths as well as the Integrated Water Vapor (IW) are calculated from those data.
• Spectral Brewer UV measurements: at Arosa, since 1994 spectral global UVB measurements are recorded with the Brewer instruments 072 on the range 290 nm – 325 nm. Since 1998, the Brewer Mark III 156 is in operation and it measures the range 286.5 - 363 nm.

1.4 Calibration activities
• At Arosa, regular calibrations and maintenances are organised for the Brewer (every 2 years) and for the Dobson instruments (every 4 years) traceable to the world standards.
• Each ECC ozonesonde is calibrated prior to the flight against a reference UV photometer traceable to the national standard from METAS.

• The CHARM instruments are compared to reference instruments traceable to the world standards.

1.5 Halocarbon measurements at the global GAW station Jungfraujoch (Empa, Dr. S. Reimann, Dr. M.K. Vollmer)

The high Alpine site of Jungfraujoch (3580 m asl) is one of a few stations covering the entire measurement programme of the GAW concerning greenhouse gases and reactive gases. The measurements of ozone depleting substances and halogenated greenhouse gases, such as HFCs, CFCs, HCFCs chlorinated solvents, and bromocarbons are performed continuously at Jungfraujoch since the year 2000 in a joint project of Empa and BAFU (HALCLIM). A thorough description of the project (in German) is available at:


The measurements are part of the world-wide AGAGE network (Advanced Global Atmospheric Gases Experiment). Since February 2008 the identical preconcentration unit (“MEDUSA”) as used within the AGAGE network has been installed at Jungfraujoch for the continuous measurements. Empa has a track record of producing first world-wide measurements of newly produced HFCs (see figure 1).

![Figure 1: Comprehensive time series of the new hydrofluorocarbons HFCs--365mfc, -245fa, -227ea and -236fa, measured at several global stations within the AGAGE network (incl. Jungfraujoch) (Vollmer et al., 2011). For HFC-245fa and HFC-365mfc the first measurements world-wide have been performed at Jungfraujoch. In-situ measurements (in blue and black) are extended by air archive measurements (in green and brown).](image-url)
2 RESULTS FROM OBSERVATIONS AND ANALYSIS

2.1 Ozone at MeteoSwiss / Payerne (P. Jeannet, Dr. R. Stübi)

A detailed analysis of the 35 years long series of BM ozone sounding at Payerne has been published in 2007 (Jeannet et al. 2007) and a trend analysis was presented in this paper. The trend analysis was updated recently to emphasise the change of behaviour of the ozone profiles before and after the mid-nineties. In figure 2, the results of this analysis are illustrated for the period prior to 1995 in the left panel and after 1995 in the right panel. The red broken line is the corresponding trend calculated from the Dobson total ozone series measured at Arosa station.

Figure 2: Trend profiles of the Payerne ozone sounding series. Left panel: trends over the periods 1975-1995 on various pressure levels. On the right panel: similar results for the period 1996-2009. The red dashed vertical line corresponds to the trend of the Dobson total ozone series from Arosa.

These figures show clearly a change of the tendency where the well defined stratospheric ozone decrease for the former period is now mostly on the positive side but with larger uncertainties. The tropospheric ozone shows also a change of tendency but the other way around, from an increase in the former period to decrease tendency for the last decade. This trend analysis was done with the standard model including a bi-linear trend term with a change of slope beginning of 1996.

2.2 University of Bern / IAP (Prof N. Kämpfer, Dr. K. Hocke)

Long-term monitoring of the vertical distribution of stratospheric ozone was continued with a 142-GHz microwave radiometer at Bern. Ozone profiles with a time resolution of 2 hours and a vertical resolution of about 10 km were submitted to the Network for the Detection of Atmospheric Composition Change (NDACC). These ozone data were utilized for satellite validation, atmospheric modeling and ozone trend studies by the scientific community. The impact of sudden stratospheric warming on the ozone distribution was analysed.
Figure 3: Ozone volume mixing ratio as function of time and pressure level above Bern. Observations were obtained by a 142-GHz microwave radiometer (IAP, Bern). Tick marks are on January 1.

2.3 ETH Zurich / IAC (Prof J. Staehelin, Dr. J. Mäder, Dr H. Rieder, Dr. C. Schnad)

Mäder et al. (2010) studied the changes in the ozone layer as response to the effect of the Montreal Protocol by a statistical modeling approach: Long-term ground-based measurements were first fitted by proxies explaining most of the variability of the measurements using backward elimination; subsequently the models of the individual sites were optimized for latitudinal bands. In a further step the long-term changes were described in the models either by fitting the individual time series by a term using EESC (development as expected from the Montreal Protocol, red in Fig. 4) or a linear trend term (as expected without the Montreal Protocol, blue in Fig. 4) and it was determined for which stations a better fit was obtained with the EESC curve (Montreal Protocol) or a linear trend. The results show that the majority of the series follow a time evolution better described by EESC than by a linear (downward) trend (see Fig. 5) (it was also checked that measurements of individual stations contain independent information).

Figure 4: Time series of EESC (in red, Equivalent Effective Stratospheric Chlorine, describing the integral effect of chemical ozone depletion by ozone depleting substances on stratospheric ozone for midlatitude) compared with a linear trend (blue). Grey: Measurements of column HCl measured at Jungfraujoch (Switzerland).
In northern midlatitude the results are most convincing, whereas in southern midlatitude only few long-term measurements are available probably making the result statistically insignificant. For tropical stations the results are not conclusive probably attributable to the fact that the long-term total ozone trends are much smaller in the tropics than in the extra tropics. The results of Antarctica need to be taken with care since at the South pole ozone chemical ozone depletion is presently saturated by ODS. For more details see Mäder et al., 2010.

Rieder et al. (2010 a,b) applied for the first time extreme value statistics to analyze stratospheric ozone measurements. They fitted daily mean values of the total ozone series of Arosa with the Generalized Pareto Distribution allowing classifying the observation into “extreme high ozone values (EHOs)”, “extreme low ozone values (ELOs) and “normal” values. The time series of the frequency of EHOs and ELOs show characteristic features which can be attributed to different processes such as caused by dynamics (e.g. ElNino, or NAO), volcanic eruptions and chemical ozone depletions including strong Arctic ozone depletion. The same approach was also applied to five other European long total ozone series (Rieder et al., 2011) confirming the results of the Arosa series.

Total ozone reached record low values in the Northern midlatitude in the years following the large volcanic eruption of Mt. Pinatubo in 1991 whereas no similar decrease was found in the Southern midlatitude. Schnadt et al. (2011) found that particular dynamics compensating chemical ozone loss were responsible for the lack of low ozone values in the Southern hemisphere. They found that besides of the phase of QBO and aerosol heating several significant wave events from fall 1991 through 1992 most probably led to significantly enhanced Brewer-Dobson circulation and more ozone transport from the tropics to the Southern hemisphere.

Schnadt et al (2009) studied ozone time evolution at the tropopause region based on regular aircraft measurements performed in the second part of the 1970s (Global Atmospheric Sampling Program (GASP)) and the second part of the 1990s MOZAIC (Measurement of Ozone and Water Vapor by Airbus in Service Aircraft Program) showing large increases in ozone mixing ratios in spring and summer at the upper troposphere over Turkey, India and China, most probably attributable to increases in ozone precursor emissions. Ozone changes over Europe in the upper troposphere were small, contradicting results obtained by Brewer Mast ozone sondes used in this period at Uccle (Belgium), Payerne (Switzerland) and Hohenpeissenberg (Southern Germany).
3 DISSEMINATION OF RESULTS

3.1 Data reporting

• The ozone data from Arosa, respectively Payerne are regularly deposited at the WODC and at the NDACC data centers. They are also deposited at NILU data center for validation projects and measurements campaigns (Satellites, ECMWF, MATCH).
• The GROMOS and SOMORA radiometers data are deposited at NDSC and NILU (SOMORA only) data centres.
• The radiation data from the CHARM Payerne station are deposited at the WRM-BSRN data center.
• The data of the continuous halogenated greenhouse gas measurements at Jungfraujoch performed by Empa/BAFU are regularly reported to the WDCGG (World Data center for Greenhouse Gases) of WMO.

3.2 Information to the public

The UV forecasts are issued daily during the summer months in many newspapers, on different web sites (public media, national institutions) and at the TV weather presentations. The alerts for high ozone concentration at surface level are also announced when necessary in the same information channels.

3.3 Relevant scientific papers


4 PROJECTS AND COLLABORATION

Besides of the activities in the framework of the national and international monitoring and research programmes, Switzerland contributes to the international WMO/GAW programme through the following services and collaborations:

• Support to the ozone sounding station Nairobi of the Kenyan Meteorological Institute,

• World Optical Depth Research Centre (WORCC) at Physikalisch-Meteorologisches Observatorium / World Radiation Centre (PMOD/WRC) in Davos

• World Calibration Centre (WCC) and Quality Assurance / Science Activity Centre (QA/SAC) for Surface Ozone, carbon monoxide and methane at the Swiss Federal Laboratories for Materials Testing and Research (EMPA) in Dübendorf.

• Support to the Jungfraujoch site which recently reached to the status of global GAW station

At the national level, there is an important cooperation between the national Weather and Climate office (MeteoSwiss) and the academic and research institutions. This collaboration organised within a national GAW-CH programme allows to support research projects for the development and improvement of the monitoring programme as well as for the data analysis.

The continuous measurements of ozone-depleting substances (CFCs, HCFCs, halones) is part of the SOGE – network (System for Observation of Halogenated Greenhouse Gases in Europe), which is an associate programme to the world-wide AGAGE program (Advanced Global Atmospheric Gases Experiment). Combine information on remaining emissions of ozone-depleting chloro-and bromocarbons (CFCs, HCFCs, halones) by merging measurements and meteorological information from different European background sites within the SOGE network in conjunction with AGAGE will be further developed.
TOGO - Introduction

Togo has established regulations for each specific problem in environmental issues. Thus, in the process of Ozone Depleting Substances (ODS) eliminating, several actions are carried out with significant results at the location of the various stakeholders. But ozone research needs huge efforts and financial support to achieve objectives of the laboratories in developing countries. This report reviews current research and future research on releases of chemicals.

RESEARCH

In Togo, the research on chemical releases into the environment are conducted by the Laboratory of Atmospheric Chemistry, the laboratory of waste management, the Water Chemistry Laboratory at the University of Lome and the Laboratory of Sanitation Water Science and Environment at the University of Kara. Unfortunately, these laboratories conduct environmental impact studies of ecosystems through physicochemical characterizations of the samples. They lack the necessary scientific equipment to monitor ozone research.

Furthermore, the observation station Kuma Konda National Service of Meteorology provides only the temperature, pressure, rainfall. It is unable to provide data on the evolution of the ozone layer.

The research laboratories are therefore intended to reduce and eliminate or substitute these substances that deplete the ozone layer. The research is mainly based on evaluation of chemical releases into the environment. To this we can include research of Sabi Kokou and Ajavon on the estimation of ODS from 2000 to 2005 in Togo (Sabi, Déchets – revue francophone d’écologie industrielle, 2008, N° 51). In this article the authors evaluated the amounts of CFC11, CFC 12 and HCFC-22 consumed during the period from 2000 to 2005. In the area of waste can also meet the work Koledzi (Koledzi, Déchets – revue francophone d’écologie industrielle, 2011).

Besides research, they conducted training activities for the different actors involved in the issue of ODS. Several actions are also conducted within the framework of the implementation of the Management Plan for Final Disposal of ODS. This work was carried out by the Ministry of Environment with support from UNEP.

This involved strengthening the capacities building of those who involved in the management and use of ODS. At the Ministry for the Environment the magazine called the "environment " had initiated in 2009 an information campaign for users and importers of ODS and ODS equipment repairers. The information is based on the dangers of these substances on the environment. These awareness are commonly organized by the National Ozone Unit (focal point) at the location of refrigeration technicians, main manipulators of CFCs. They are also educated on best practices in the refrigeration sector.
PROJECTS
- monitoring the evolution of the stratospheric ozone layer;
- looking for new hazardous substances;
- rehabilitation of Kouma Konda meteorological station;
- monitoring the process of reduction and ODS elimination;
- alternative research;
- qualitative and quantitative estimation of discharges of pollutants into atmosphere.

NEEDS AND RECOMMENDATIONS

Needs
- slight scientific equipment for the recovery and recycling of ODS involving research laboratories;
- financial support to the location of the laboratories on the basis of projects submitted to conduct research activities;
- rehabilitation of the station Kouma-Konda station to monitor evolution of stratospheric ozone in the sub-region.

Recommendations
- material and financial support of laboratories in developing countries;
- establishment in Africa of a regional center for research on ozone-climate interactions;
- initiation of research projects involving sub-regional researchers from several countries;
- encouragement of research structures in developing countries;
- creation of regional networks and international trade data, information and experiences on ODS;
- industrial involvement in the search for solutions to the ODS;
- more awareness among decision-makers to become more involved in finding solutions to environmental problems.

Conclusion
Despite the availability of researchers to become more involved in research on ozone, the lack of funding slows their activities. For similar reasons, the recommendations of 2008 (7th Meeting) were unsuccessful and no further significant. Unfortunately, when the Ozone Secretariat has launched an appeal to submit projects, we submitted the draft of Togo but no action was taken in our project. So we hope that new opportunities will be offered to submit our research projects.

Kara, 14th March 2011
Prof. Gnon Baba
TURKEY

Turkish State Meteorological Service is responsible for observing and promoting research activities on measurements of ozone and UV radiation.

OBSERVATIONAL ACTIVITIES

Two methods are commonly used for ozone measurements in Ankara. One method is to use the Electrochemical Concentration Cell (ECC) ozonsonde. The second method is using Brewer Spectrophotometer.

UV radiometers are used to measure UV radiation at 10 stations in narrow band and at 1 station in broad band with varied instruments.

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

Brewer Spectrophotometer

<table>
<thead>
<tr>
<th>Station</th>
<th>Instrument</th>
<th>Institution</th>
<th>Latitude</th>
<th>Longitude</th>
<th>Start date of observation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ankara</td>
<td>Brewer MKIII-188</td>
<td>TSMS</td>
<td>39° 57’ (N)</td>
<td>32° 53’ (E)</td>
<td>Sep., 2006 to present</td>
</tr>
</tbody>
</table>

Brewer spectrophotometer is deployed on a solar azimuth tracker which allows daily automatic measurements of total ozone, zenith sky and direct sun in Ankara station which is the component of WMO-Global Atmosphere Watch Programme.

All data measured by Brewer MK III Spectrophotometer #188 are stored in the database of Research and Data Processing Section of TSMS and are also sent to be recorded at the World Ozone and UV radiation Data Center (WOUDC) in Toronto, Canada.

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

Ozonesonde

<table>
<thead>
<tr>
<th>Station</th>
<th>Instrument</th>
<th>Institution</th>
<th>Latitude</th>
<th>Longitude</th>
<th>Start date of observation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ankara</td>
<td>Ozonesonde(ECC)</td>
<td>TSMS</td>
<td>39° 57’ (N)</td>
<td>32° 53’ (E)</td>
<td>Sep., 2006 to present</td>
</tr>
</tbody>
</table>

Research and Data Processing Section of TSMS has been making ozone vertical profile measurements through the atmosphere using balloon borne ozonesondes since 1994 in Ankara station.

Data obtained from ozonsonde are received from Vaisala ground receiving station located in Ankara.

UV measurements

Broad band measurements

<table>
<thead>
<tr>
<th>Station</th>
<th>Instrument</th>
<th>Institution</th>
<th>Latitude</th>
<th>Longitude</th>
<th>Start date of observation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ankara</td>
<td>Solar Light 501</td>
<td>TSMS</td>
<td>39° 57’ (N)</td>
<td>32° 53’ (E)</td>
<td>1997 to present</td>
</tr>
<tr>
<td>Antalya</td>
<td>Solar Light 501</td>
<td>TSMS</td>
<td>36° 42’ (N)</td>
<td>30° 44’ (E)</td>
<td>1997–2003</td>
</tr>
</tbody>
</table>

UV-Biometer Model 501 is used for broad band UV radiation measurements.
Narrow band filter instrument

<table>
<thead>
<tr>
<th>Station</th>
<th>Instrument</th>
<th>Institution</th>
<th>Latitude</th>
<th>Longitude</th>
<th>Start date of observation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Akçaabat</td>
<td>Middleton Solar UVR1-B Radiometer</td>
<td>TSMS</td>
<td>41° 01' (N)</td>
<td>39° 35' (E)</td>
<td>2009 to present</td>
</tr>
<tr>
<td>Aksaray</td>
<td>Middleton Solar UVR1-B Radiometer</td>
<td>TSMS</td>
<td>38° 23' (N)</td>
<td>34° 03' (E)</td>
<td>2009 to present</td>
</tr>
<tr>
<td>Elazığ</td>
<td>Middleton Solar UVR1-B Radiometer</td>
<td>TSMS</td>
<td>38° 60' (N)</td>
<td>39° 28' (E)</td>
<td>2009 to present</td>
</tr>
<tr>
<td>Göksun</td>
<td>Middleton Solar UVR1-B Radiometer</td>
<td>TSMS</td>
<td>38° 01' (N)</td>
<td>36° 30' (E)</td>
<td>2009 to present</td>
</tr>
<tr>
<td>Mardin</td>
<td>Middleton Solar UVR1-B Radiometer</td>
<td>TSMS</td>
<td>37° 30' (N)</td>
<td>40° 73' (E)</td>
<td>2009 to present</td>
</tr>
<tr>
<td>Oltu</td>
<td>Middleton Solar UVR1-B Radiometer</td>
<td>TSMS</td>
<td>40° 33' (N)</td>
<td>41° 59' (E)</td>
<td>2009 to present</td>
</tr>
<tr>
<td>Sivas</td>
<td>Middleton Solar UVR1-B Radiometer</td>
<td>TSMS</td>
<td>39° 75' (N)</td>
<td>37° 02' (E)</td>
<td>2009 to present</td>
</tr>
<tr>
<td>Tarsus</td>
<td>Middleton Solar UVR1-B Radiometer</td>
<td>TSMS</td>
<td>36° 55' (N)</td>
<td>34° 54' (E)</td>
<td>2009 to present</td>
</tr>
<tr>
<td>Tokat</td>
<td>Middleton Solar UVR1-B Radiometer</td>
<td>TSMS</td>
<td>40° 30' (N)</td>
<td>36° 57' (E)</td>
<td>2009 to present</td>
</tr>
<tr>
<td>Van</td>
<td>Middleton Solar UVR1-B Radiometer</td>
<td>TSMS</td>
<td>38° 45' (N)</td>
<td>43° 32' (E)</td>
<td>2009 to present</td>
</tr>
</tbody>
</table>

UVR1-B Global Spectral Radiometers are used for narrow band UV radiation measurements.

**Spectroradiometers**

Spectral UVB measurements (290-325 nm) by Brewer spectrophotometer #188 MK III have started from 09 Sep., 2006 in Ankara station.

<table>
<thead>
<tr>
<th>Station</th>
<th>Instrument</th>
<th>Institution</th>
<th>Latitude</th>
<th>Longitude</th>
<th>Start date of observation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ankara</td>
<td>Brewer MKIII-188</td>
<td>TSMS</td>
<td>39° 57' (N)</td>
<td>32° 53'(E)</td>
<td>Sep.2006 to present</td>
</tr>
</tbody>
</table>

**Calibration activities**

Calibration of Brewer spectrophotometer #188 MK III has been performed biennially. First Brewer S. calibration was carried out by International Ozone Services Inc. (IOS) which provides worldwide ozone and UV calibration services to customers with Brewer Ozone Spectrophotometer instruments. IOS used Brewer Ozone Spectrophotometer #017 as a reference instrument on 07–12 October 2008 in Ankara station.
Figure 1. First calibration of Brewer MKIII #188 with the reference Brewer MKIV #017 in Ankara station.

Figure 2. Second calibration of Brewer MKIII #188 with the reference Brewer MKIII #158 in Ankara station.

Second Brewer S. calibration was carried out by Kipp& Zonen on 22–29 September 2010. Kipp& Zonen used Brewer Ozone Spectrophotometer #158 as a reference instrument in Ankara station.

RESULTS FROM OBSERVATIONS AND ANALYSIS

Figure 3. Comparison of OMI_TOMS from satellite with the total ozone measurements of Brewer S.#188 between 11 June 2006 and 31 December 2010.

In figure 3, Relationship between total ozone measurements of Brewer #188 and OMI_TOMS observed total ozone data from satellite indicates high correlation. Correlation coefficient is R=0.97 and R²=0.9396.
DISSEMINATION OF RESULTS

Data reporting

Products of ozone and UVB radiation measurements are stored at the Research and Data Processing Section of TSMS and can be accessible through intranet to users.

All data measured by Brewer MK III Spectrophotometer #188 and ozononde are sent regularly to the World Ozone and UV radiation Data Center (WOUDC). They are archived and published with the station number 348 in Toronto, Canada.

Information to the public

A TUBITAK project, under contract no.105G032 titled “Observing the Variability in the Troposferic and Stratosferic Ozone and UVB measurements and Analyzing the Results”, was conducted at TSMS under the collaboration with some scientist from Istanbul Technical University and completed in 2008. As a result, a statistical model was developed to forecast daily total ozone and UV index.

The model runs for 125 stations in Turkey and 5 stations in the Turkish Republic of Northern Cyprus and the model results are published through internet web site. http://www.dmi.gov.tr/kurumici/tahmin-ozon-dmi.aspx

Figure 4. The TSMS Model outputs for daily forecasted total ozone and UV index in Turkey.
A joint efforts between the TSMS and Deutscher Wetterdienst (DWD) lead to publishing information on daily forecasted total ozone and maximum UV index to the public at the TSMS web page: [http://www.dmi.gov.tr/kurumici/tahmin-ozon-dwd.aspx](http://www.dmi.gov.tr/kurumici/tahmin-ozon-dwd.aspx)

![Figure 5](image.png)

**Figure 5.** DWD model products showing information on daily forecasted total ozone and maximum UV index to the public at the TSMS web page for Turkey.

### Relevant scientific papers


### PROJECTS AND COLLABORATIONS

The ground-based Brewer data #188 and model predicted output data on total ozone and UV index have been compared systematically with satellite observations.
FUTURE PLANS

- to establish a Brewer Spectrophotometer Network to cover and to represent whole Turkey for measuring total ozone and UV index by purchasing more Brewer Spectrophotometer.
- to examine tropospheric ozone profile.
- to examine stratospheric ozone profile.
- to study on interactions between stratospheric ozone and climate change.
- to examine variation in ozone and UV index in time.
- to evaluate interaction between ozone change and climate change.
- to contribute to ozone assessments by sharing information.
- to seek for research at the European level implemented through the Framework Programmes for research and technological development (FPs) of European Commission.
- to participate seminars, conferences and meetings related with global ozone research and international monitoring programme.

NEEDS AND RECOMMENDATIONS

Providing a continued maintenance and calibration of instruments such as Brewer S. and UV sensor with the support of WMO is important.
TURKMENISTAN - Atmospheric Ozone Monitoring

In Turkmenistan the atmospheric ozone monitoring is carried out by the National Hydrometeorology Committee at the Cabinet of Ministers of Turkmenistan ("Turkmenhydomet"). At present the regular daily monitoring for the total atmospheric ozone content is carried out at 4 stations:

<table>
<thead>
<tr>
<th>#</th>
<th>Stations</th>
<th>Coordinates</th>
<th>Area Height.</th>
<th>Devices Used</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>North Lat.</td>
<td>East Long.</td>
<td>Type</td>
</tr>
<tr>
<td>1</td>
<td>Mary</td>
<td>37.36°</td>
<td>53.00°</td>
<td>M-124</td>
</tr>
<tr>
<td>2</td>
<td>Bekrevé</td>
<td>37.57°</td>
<td>58.21°</td>
<td>M-124</td>
</tr>
<tr>
<td>3</td>
<td>Repetek</td>
<td>38.34°</td>
<td>63.11°</td>
<td>M-124</td>
</tr>
<tr>
<td>4</td>
<td>Turkmenbashi</td>
<td>40.03°</td>
<td>53.00°</td>
<td>M-124</td>
</tr>
</tbody>
</table>

The first monitoring for atmospheric ozone commenced in 1953 on the basis of the Chardzhou aerologic station (Turkmenabat now). In 1975 the ozone station was transferred to a meteorological site of the Repetek station and the ozone monitoring has been carried out at this station so far.

In 1961 the ozone measurements commenced on a meteorological site of the Keshi station. In 1998 this meteorological station was transferred to Berzengi village and later in Bekrevé village in 2001. The ozone measurements have been carried out at this station so far.

In 1994 in Turkmenbashi (Krasnovodsk) the measurements of the total atmospheric ozone content commenced. Within 2000-2002 due to delivery of M-124 ozonometer for calibration the monitoring was not carried out. After calibration of this device the monitoring has commenced since October 2002 and it continues at present.

In 2001 the monitoring of the total atmospheric ozone content was arranged in the Murgab meteorological post. This ozone station was transferred to a meteorological site of the Mary station in 2005 where the ozone monitoring has been carried out so far.

Measurements of the atmospheric ozone content are carried out by means of M-124 ozonometers produced in Russia. The ozonometers used have become physically outdated. Lack of spare and reserve ozonometers for replacement of operating devices during their calibrations (a case in Turkmenbashi) results in a monitoring failure for a long term.
Over the last years due to the absence of possibilities for calibrations and routine maintenance of the devices used a technical state of ozonometers has considerably worsened. Overheat of device’s bodies, essential deviation of the measured values from former data and others are observed. After 2002 the ozonometers have not been calibrated. The situation developed in aggregate impacts negatively on quality of the data obtained. In support it is possible to demonstrate the Monitoring Result Review for OCO over the CIS countries for 2008 carried out by the Central Aerologic Observatory under the guidance of the Main Geophysical Observatory where poor quality of ozone monitoring data at some stations is highlighted including Repetek, Turkmenbashi and Bekreve.

Daily data on the total atmospheric ozone content (Chardzhou), Turkmenbashi (Krasnovodsk) and Bekreve (Ashkhabad) are preliminary processed and sent by telegramme at the address: AVIA Moscow 736 OZONE. Monthly Tables O-3 are sent to the Main Geophysical Observatory named after Voyeykov not later than on the 3rd day of the following month. Then, all information is delivered to the data exchange coordinated international network of the World Meteorological Organization (WMO).

All primary data are stored in “Turkmengidromet” archive in a paper form.

**Director of “Klimat” STC**
**G. Muhyyev**
UNITED KINGDOM

1. OBSERVATIONAL ACTIVITIES

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

The UK Government Department for Environment, Food and Rural Affairs (Defra) funds an on-going monitoring programme that records total values of stratospheric ozone at two UK locations. Measurements with a Dobson instrument are taken at the Lerwick Observatory in the Shetland Islands (N of Scotland) and a Brewer spectrophotometer is used at the Reading site in Berkshire (S England). The latter site replaced the Camborne Observatory site in Cornwall at the end of 2003, where a Dobson instrument had been used for ozone measurements. The spectrophotometers sample the ozone column at frequent intervals throughout the day to produce daily mean values, except for when weather conditions prevent values from being recorded and during the winter at Lerwick when the sun is too low in the sky.

Column ozone measurements are also made at the University of Manchester (N England) using a Brewer instrument. These are also made available to the above monitoring programme (but are separately funded) and similarly submitted to the WOUDC. Measurements using a SAOZ instrument are made in Aberystwyth, and are submitted to the NDACC network.

The British Antarctic Survey continues total column ozone measurements at Halley with a Dobson spectrophotometer, and supports those made at Vernadsky (Ukraine). BAS also continues total ozone and NO$_2$ column measurements at Rothera with a SAOZ spectrometer. A radiosonde programme continues at both Halley and Rothera, supported by the UK Met Office.

The UK Met Office has lent Dobson #35 to the South African Weather Service. It is not yet in active use, but has been intercompared.

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

High frequency, real time in situ measurements of the principal halocarbons and radiatively active trace gases have been made at Mace Head on the West coast of Ireland since 1987, as part of the Global Atmospheric Gases Experiment (GAGE) there. For about 70% of the time the measurement station, which is situated on the Atlantic coast, monitors clean westerly air that has travelled across the North Atlantic Ocean. For about 30% of the time, Mace Head receives substantial regional scale pollution in air that has travelled from the industrial regions of Europe. The site is therefore ideally situated to record trace gas concentrations associated with both the Northern Hemisphere background levels and with the more polluted air arising from Europe.

Using the Mace Head data with a Lagrangian dispersion model that determines the origin of the air arriving at Mace Head at the time of each observation, estimates of the Northern
hemisphere baseline concentrations are made for each trace gas. By removing the underlying baseline trends from the observations and by modelling where the air originated from on a regional scale, an iterative best-fit technique then searches a set of random emission maps to determine the one that most accurately mimics the Mace Head observations.

The UK Department for Energy and Climate Change is intending to expand the Atmospheric Observation Network to include three additional sites in the UK, to be located at Edinburgh, Tacolneston, and Ridge Hill. These sites will result in significant increases in spatial and temporal resolution for the interpretation work, enabling UK Devolved Administration emission estimates from atmospheric observations as well as decreasing the uncertainties associated with all the analytical outputs of this project.

Analysis of the atmospheric observation data also identifies sources of and trends in ozone formation from different areas, including comparison of observed data with expected trends, to identify any new substances with ozone depleting or radiative forcing properties. The possible use and analysis of any data coming from other sites that could be of policy relevance is currently under consideration.

1.3. UV measurements

1.3.1. Broadband measurements

The solar UV index is measured at six sites at approximately 2 degrees of latitude increments (from 50 to 60° N) across the UK by the Centre for Radiation, Chemical and Environmental Hazards of the Health Protection Agency (HPA). A seventh site on Mount Snowdon in Wales has been temporarily removed while the site is developed. In addition, spectral UV measurements are carried out at the HPA site at Chilton. A portable spectral measurement system is currently under development for temporary deployment during extreme weather or atmospheric events or at locations where large numbers of people gather outside. The Department of Health provides support for this UV monitoring work, which provides information for the Global Solar UV Index in association with WHO, WMO, UNEP and the International Commission on Non-Ionizing Radiation Protection.

1.3.2. Narrowband filter instruments

No instruments of this type are currently being used in the UK.

1.3.3. Spectroradiometers

A spectroradiometer is co-located with the Brewer spectrophotometer in Reading, funded as part of the Defra monitoring programme. The Bentham DM150 UV spectroradiometer has been in place since 1993, and is regularly calibrated in situ. The instrument takes spectra from 290nm to 500nm at 0.5nm resolution at half-hour periods during daylight hours, every day of the year.

A spectroradiometer is also co-located with the Brewer spectrophotometer at the University of Manchester, which provides five minute averages in each of the five narrow wavebands (305, 313, 320, 340, 380nm). Apart from calibration periods, the Manchester instrument has
been in continuous operation since 1997, and provides a southern site in the Nordic network of GUV radiometers. Data are submitted to WOUDC alongside the ozone data series.

The British Antarctic Survey makes spectral measurements of UV using a Bentham spectroradiometer at Rothera.

1.4. Calibration activities

Regular calibrations have been carried out on both Met Office Dobson instruments and the Reading Brewer spectrophotometer. The current recommendation is to re-calibrate every two years.

Dobson #32 and the Brewer #075 were taken to Spain in September 2007 for international inter-comparison at El Arenosillo. The Brewer results were good, but the Dobson calibration identified a problem with the CD measurements, which required re-evaluation of historical data. This was carried out and it was demonstrated that the new calibration provided a much more accurate dataset.

Dobson #41 was taken to Hohenpeissenberg for international inter-comparison in June 2009 and was found to be performing well. A further calibration is scheduled for September 2011.

Brewer instrument #075 was taken to El Arenosillo during September 2009. The change in instrument response for measuring ozone over the two year period was found to be 0.3%, well within the acceptable limits. Following technical problems and subsequent repairs, Brewer #075 was calibrated at the RBCC-E home site at Izana, Tenerife, where a new calibration was determined and verified against the European triad of Brewer instruments. During the intervening period, the instrument was temporarily replaced with Brewer #126 courtesy of the UK Met Office in order to maintain the time series.

2. RESULTS FROM OBSERVATIONS AND ANALYSIS

The long-term annual mean trend in ozone for the Lerwick site, and a combined southern England trend from the Camborne (up to 2003) and Reading (2003 onwards) are given below.

A recent trends analysis paper in the International Journal of Climatology (Smedley et al., 2011), analysed the trend data from these sites. This paper demonstrated that the year at which total ozone stopped decreasing over the UK was 1993, by which time statistically significant reductions of 4.8% per decade for Southern England and 5.8% per decade for Lerwick were observed. These rates of decrease are at the upper end of the range in comparison with other European ozone trends before the mid-1990s.

From 1993 to the present the data did not show any significant trend, although small average increases were noted. That there is no trend over this time period is in contrast with Europe as a whole, where a significant increase has been noted.
Long-term Annual Mean Trends in Ozone for Lerwick, Camborne & Reading

The data from the monitoring programme have also been analysed seasonally. Table 1 shows that a significant decline at Lerwick since 1978 is seen in the annual mean, Spring and Autumn for both single and multiple regression analysis. There are no significant changes at Reading since 2003. Multiple regression has a large impact on seasonal trends at Reading because of the shorter record.

<table>
<thead>
<tr>
<th>Location</th>
<th>Annual</th>
<th>Winter (DJF)</th>
<th>Spring (MAM)</th>
<th>Summer (JJA)</th>
<th>Autumn (SON)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lerwick - SR</td>
<td>-0.62 +/- 0.20</td>
<td>-0.12 +/- 0.58</td>
<td>-0.85 +/- 0.30</td>
<td>-0.24 +/- 0.17</td>
<td>-0.61 +/- 0.21</td>
</tr>
<tr>
<td>Lerwick - MR</td>
<td>-0.50 +/- 0.21</td>
<td>-0.08 +/- 0.60</td>
<td>-0.69 +/- 0.26</td>
<td>-0.22 +/- 0.14</td>
<td>-0.40 +/- 0.18</td>
</tr>
<tr>
<td>Reading - SR</td>
<td>+2.97 +/- 1.19</td>
<td>+2.86 +/- 2.69</td>
<td>+2.18 +/- 1.70</td>
<td>+1.76 +/- 0.74</td>
<td>+2.19 +/- 1.70</td>
</tr>
<tr>
<td>Reading - MR</td>
<td>+2.02 +/- 1.65</td>
<td>+0.07 +/- 1.79</td>
<td>+2.10 +/- 1.87</td>
<td>+1.66 +/- 0.89</td>
<td>+0.49 +/- 1.15</td>
</tr>
</tbody>
</table>

Table 1 Column ozone trend in DU per year with standard errors. Numbers in bold are significant at the 95% confidence level (P<0.05) SR: single regression; MR: multiple regression. Lerwick since 1978 and Reading since 2003 both to December 2010.
Low ozone events observed by the Defra monitoring programme are reported in near real-time. Two events were reported in 2008, two in 2009 and none in 2010. The frequency of these events has been found to exhibit little historical pattern, but there are two features to note. Firstly, an anomalous decade at Lerwick (1977-1987) when there were very few low ozone events reported. Secondly, high ozone events of the southern UK may be increasing – perhaps in line with a northwards displacement of the Atlantic storm track suggested by climate change predictions.

The UV monitoring results from the Defra programme were also assessed in the Smedley et al. paper, which found no significant trend between 1993 and 2008 in the daily totals of UV, but an increase of 6% per decade was seen in the mid-day values of the UV index. This, combined with a lack of correlation between ozone and UV anomalies suggests that changes in cloud cover were the cause.

It should be noted that despite the long-term data produced by the UK total ozone and spectral UV records, in order to clearly observe significant trends since the mid-1990s several more years of high quality data are necessary.

3. THEORY, MODELLING AND OTHER RESEARCH

No activities to report.

4. DISSEMINATION OF RESULTS

4.1. Data reporting

The ozone monitoring data from Lerwick and Reading are processed daily by local operators prior to being quality checked and disseminated. A number of checks are performed to ensure the integrity of these data, including comparison of daily results with OMI satellite measurements and the nearest ground-based measurements.

Results are disseminated by uploading to a dedicated website (http://ozone-uv.defra.gov.uk/) and issuing results to the WOUDC Real-time Mapping Centre. Monthly data are submitted to the WOUDC for inclusion on their archive.

Both total ozone and spectral UV data from the Manchester site are submitted regularly to the WOUDC.

Level 0 and Level 1 ozone data from Halley and Rothera were submitted to the WOUDC by the British Antarctic Survey. Near real-time ozone observations are submitted by BAS to the WMO on a weekly basis. Near real-time reporting using CREX code on the GTS will commence in the near future.

4.2. Information to the public

Ozone monitoring results from the Lerwick, Reading and Camborne sites are publically available on the website (http://ozone-uv.defra.gov.uk/), along with relevant reports.

Broadband UV Index graphs produced by the UK Health Protection Agency are also available on their website at:

http://www.hpa.org.uk/Topics/Radiation/UnderstandingRadiation/UnderstandingRadiationTopics/UltravioletRadiation/uv_Index/
5. PROJECTS AND COLLABORATION

The UK Met Office

The UK Met Office has applied its ozone data assimilation scheme to infer chemical polar ozone loss and to examine phenomena such as low ozone events in the southern summer stratosphere. Studies on the impact of the representation of stratospheric ozone on extended range tropospheric forecasts are also being carried out. The above work is being carried out in collaboration with Imperial College London and European partners. In addition, a Met Office representative co-leads the WCRP SPARC Data Assimilation Working Group.

The UK Met Office Hadley Centre (MOHC) is working on the modelling of stratospheric and tropospheric ozone and their relationship to climate change, as part of its joint DECC/Defra funded MOHC Programme. The MOHC is represented on the coordinating/planning committees of two of the WCRP’s SPARC modelling initiatives: CCMVal-2 (Chemistry-Climate Model Validation-2) and DynVar (Modelling the Dynamics and Variability of the Stratosphere-Troposphere System).

The MOHC has further developed its whole atmosphere chemistry model UKCA (United Kingdom Chemistry and Aerosols), in collaboration with Cambridge, Leeds and Oxford universities. These developments are making the UKCA model more self-consistent so that, for example, changes to aerosol concentrations change the chemistry through the photolysis rates. The improvements will also ensure that responses to climate change are well modelled.

Further developments of a full Earth-System Model, in which the UKCA is combined with the MOHC’s climate and ecosystem models, have been made. This is enabling the prediction of feedbacks involving tropospheric and stratospheric ozone between climate, chemistry and ecosystems. This links in strongly with the NERC QUEST programme, its earth-system modelling (QUESM), the atmospheric chemistry component (QUAAC) and the land surface component (JULES).

The Natural Environment research Council

The UK Natural Environment Research Council (NERC) funds a number of research programmes relating to stratospheric ozone. The CLEARFOGG (Checking Layers of the Earth’s Atmosphere For halogenated Ozone-depleting and Greenhouse Gases) project, due to complete in 2011, is performing a systematic screening of various layers in the Earth’s atmosphere for unknown halocarbons, and will determine the influence of these halocarbons on stratospheric ozone depletion.

The Southern hemisphere climate change in an era of ozone recovery project, due to complete in 2011, will use state of the art climate modelling to derive a range of predictions of future climate change which take account of our uncertainty in future ozone change, particularly focussing on the southern hemisphere and the Antarctic ozone hole.

The SOLCLI consortium are running a 4-year coordinated study which began in 2007, on the influences of solar variability on atmospheric composition and climate. The consortium is led by Imperial College, with partners at the Universities of Cambridge, Leeds and Reading and the British Antarctic Survey and with collaborators in Germany, Japan, the USA and the UK.
Met Office. Study topics include: variability over the past 150 years in solar spectral irradiance; detection of solar signals throughout the lower and middle atmosphere; response of stratospheric composition, specifically ozone, to varying UV; mechanisms for stratosphere-troposphere dynamical coupling; and better representation of solar effects in climate models.

Further NERC-funded research projects relating to stratospheric ozone include: the impact of the representation of ozone on tropospheric weather forecasts; multi-scale modelling of mesospheric metals, and the impact of the mesosphere on stratospheric ozone and climate; interactions of the lower stratosphere with the tropospheric chemistry/climate system (including recovery scenarios for stratospheric ozone); producing a century-long record of trace gases in the northern hemisphere from the NEEM ice core drilling project in Greenland.

*The University of Manchester*

The University of Manchester is represented on the WMO Brewer sub-committee, and has been active in discussions on the effective changeover of ozone absorption coefficients and the need for a reliable historical dataset on ozone profiles, required for trend analysis in the presence of climate and circulation changes.

*The British Antarctic Survey*

An opinion piece by Jonathan Shanklin was published in Nature, and a celebratory meeting held in Cambridge in 2010, to mark the 25th anniversary of the discovery of the ozone hole. Work is in progress on re-evaluating BAS ozone data collected since 1972.

**6. FUTURE PLANS**

Defra does not have any plans at present to provide direct government funding for any additional ozone, UV or ODS monitoring sites in the UK. The current basic levels of monitoring will, however, be continued.

Defra is keeping future research needs for policy development on stratospheric ozone under review.

NERC is continuing to provide some funding support for new research projects on ozone.

**7. NEEDS AND RECOMMENDATIONS**

International agreement needs to be reached on the form of zenith polynomial for use in Dobson zenith sky measurements.

Maintenance of long time-series remains essential, especially for trend analysis and ground-truthing of satellite data.

Further work to model emissions of trace gases and ODS will be beneficial for assessing emissions inventories.
UNITED STATES OF AMERICA

OBSERVATIONAL ACTIVITIES

Column Measurements

Ozone
US Satellites
Long-term dataset of total column ozone continues to be produced from the SBUV\(\frac{2}{2}\) instruments on the NOAA polar orbiting environmental satellites (NOAA-16, 17, 18 & 19). The SBUV record extends back to April, 1970 with a data gap between 1974 and 1978. The TOMS total ozone series started in October 1978 and ended in December 2006. All TOMS data have been reprocessed by applying an empirical correction based on the SBUV\(\frac{2}{2}\) record. Hence the SBUV total ozone record is considered the primary record for trend analysis. (NASA, NOAA)

Total ozone data from the Ozone Monitoring Instrument (OMI) on the EOS Aura satellite is available beginning October, 2004. Two independent algorithms are used to produce OMI total ozone data, one developed by NASA the other by KNMI, NL. NASA now has reprocessed SBUV, TOMS and OMI data using a common (version 9) algorithm. (NASA)

Ozone Estimates from Infrared Sensors
NOAA produces estimates of total ozone by using information in the 9.7 micron channel of HIRS. The retrieval products are combined with SBUV\(\frac{2}{2}\) information to generate global maps of column ozone. See [http://www.osdpm.noaa.gov/PSB/OZONE/TOAST/](http://www.osdpm.noaa.gov/PSB/OZONE/TOAST/). (NOAA)

Total ozone products from thermal emission spectrometers also exist from both the TES instrument on the EOS Aura satellite and the AIRS instrument on the EOS Aqua satellite. These data are available on the NASA GSFC DAAC at [http://disc.gsfc.nasa.gov/](http://disc.gsfc.nasa.gov/). (NASA)

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

UVB Monitoring and Research Programme (UVMRP)
Direct-sun column ozone is retrieved by UV Multi-Filter Rotating Shadowband
Radiometers (UV-MFRSRs) at 34 U.S. sites, 2 Canadian sites, and 1 New Zealand site within the U. S. Department of Agriculture (USDA) UV-B Monitoring and Research Programme (UVMRP).

**NOAA-EPA Ultraviolet Brewer (NEUBrew) Network**

NOAA and the EPA have established a network of Brewer Mark IV UV spectrometers that were deployed at six U.S. locations. The six stations have been operating continuously since the fall of 2006 with funding from the EPA and NOAA. The network Brewers [http://esrl.noaa.gov/gmd/grad/neubrew/](http://esrl.noaa.gov/gmd/grad/neubrew/) take a daily average of 25 total column ozone measurements. (NOAA, EPA)

The total ozone column and Umkehr profile daily data from the NOAA-EPA Brewer and NOAA Dobson network, as well as ozone-sounding profiles will be used in the validation activities of the total column ozone data collected by the soon-to-be-launched satellite under the NOAA’s National Polar-orbiting Operational Environmental Satellite System (NPOESS) Preparatory Project (NPP) and the following Joint Polar Satellite System JPSS program. The NPP launch is scheduled for October 25, 2011. The Ozone Mapping and Profiler Suite (OMPS) on board NPP will monitor the global distribution of ozone on the daily basis. Much of the work in preparation for the validation activities include algorithm development, data quality control, instrument automation, calibration, trending analysis and maintenance, data archiving, and web page and satellite validation updates. (NOAA)

**Ozone-Relevant Gases and Variables**

**Ozone Monitoring Instrument (OMI) on the Aura Satellite**

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

**GOME-2 Instrument on MetOp-A**

NOAA is working to implement additional operational products from the GOME-2 Level 1 data. These include aerosols, nitrogen dioxide, and sulphur dioxide. (EuMetSat/NOAA)

**Network for the Detection of Atmospheric Composition Change (NDACC)**

This international ground-based remote-sensing network was formed to provide a consistent, standardized set of long-term measurements of atmospheric trace gases, particles, and physical parameters via a suite of globally distributed sites. While the NDACC maintains its original commitment to monitoring changes in the stratosphere, with an emphasis on the long-term evolution of the ozone layer its priorities have broadened considerably to encompass the detection of trends in overall atmospheric composition and understanding their impacts on the stratosphere and troposphere, establishing links between climate change and atmospheric composition, calibrating and validating space-based measurements of the atmosphere, supporting process-focused scientific field campaigns, and testing and improving theoretical models of the atmosphere. NDACC instruments that are particularly suited for column measurements include UV/Visible spectrometers for ozone, NO2, BrO, and OCIO; FTIR spectrometers for a wide variety of source and reservoir compounds; and Dobson and Brewer...
spectrometers for ozone. Additional information on the NDACC is available at http://www.ndacc.org. (NASA, NOAA)

Profile Measurements

Ozone

BUV Instrument Series (10 Instruments)
The SBUV/2 instruments on NOAA satellites continue to measure ozone vertical profiles in the upper stratosphere (1-30 hPa) with vertical resolution varying from 6 to 8 km. (This technique also provides accurate estimates of the partial column ozone between 30-700 hPa.) This data record extends back to April 1970, with a data gap between 1974 and 1978. Profile datasets are also being produced from the OMI instrument. OMI provides full daily coverage compared to SBUV which provides daily coverage in approximately two weeks. OMI profiles have similar information content as SBUV in the upper stratosphere (1-30hPa) but have higher vertical resolution (~10 km) at lower altitudes. The long-term ozone profile record from the SBUV/2 instrument series has been significantly affected by drifting orbits. Analysis of these effects is currently in progress. NASA has reprocessed data from the entire BUV instrument series, including OMI, using a consistent algorithm (version 9). Current and archived Version 8 ozone profile data are being used in the NOAA/NCEP Climate Forecast System Reanalysis and Reforecast, a successor of the NCEP/DOE Reanalysis 2. (NOAA, NASA)

Stratospheric Aerosol Measurement (SAM) and Stratospheric Aerosol and Gas Experiment (SAGE) Instrument Series (4 Instruments)
The SAM/SAGE series of instruments has provided the longest data set on the vertical profile of ozone in the stratosphere. Near-global coverage has been provided on a near-monthly basis for the periods 1979 to 1981 and 1984 to 2005. This series will be resumed in 3-4 years from the existing SAGE-III instrument when it is deployed on the International Space Station. (NASA)

Aura Satellite Instruments
Ozone profiles from 0.5- 200 hPa with about 3 km vertical resolution have been produced by the Microwave Limb Sounder (MLS). The high resolution dynamic limb sounder (HIRDLS), which suffers from a partial obscuration of the field of view that occurred during launch, has recently reprocessed the ozone profile data. These data have 1 km or higher vertical resolution in the stratosphere. This data series ended in 2008. Two other instruments on Aura Tropospheric Emission Spectrometer (TES) and OMI produce lower vertical resolution ozone profiles but they measure lower into the troposphere than either HIRDLS or MLS. A new activity to combine the radiances from TES and OMI to obtain better profile information in the troposphere is ongoing. (NASA)

Balloonborne Measurements
NOAA routinely conducts ozonesonde measurements at nine locations (5 domestic, 4 international). NASA, in collaboration with NOAA and numerous international partners, supports the operations of the Southern Hemisphere Additional Ozonesonde (SHADOZ) network of ozonesonde launches from several locations in the tropics and southern
subtropics. NASA also flies ozonesondes and an ozone photometer as components of moderate-scale balloon campaigns that also utilize a submillimeter/millimeter-wave radiometer, an infrared spectrometer, and a far-infrared spectrometer. (NOAA, NASA)

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

**Brewer Umkehr**
Brewer Mark IV UV spectrometers were deployed at six U.S. locations in the last half of 2006 with funding from the EPA and NOAA. Total column ozone and ozone profiles using the Umkehr technique are regularly derived from these measurements. All raw and processed data are posted on the open access NOAA/NEUBrew web-site: [http://esrl.noaa.gov/gmd/grad/neubrew/](http://esrl.noaa.gov/gmd/grad/neubrew/). Dobson Umkehr ozone profile retrieval algorithm has been modified to process Brewer Umkehr data on a selective basis. It is implemented at all NOAA operated sites. It is also made available for the Brewer Umkehr data processing world-wide and has been implemented at several stations (Check republic). However, due to lack of availability of the Brewer raw radiance data at the WOUDC archive, it has not been possible to reprocess all currently operational Brewer Umkehr data using a consistent algorithm. The WMO SAG-O3 and the WOUDC has made an effort to reach out to operators of the Brewer instruments and offered to archive raw data (NOAA)

**Network for the Detection of Atmospheric Composition Change (NDACC)**
NDACC lidars (whose retrievals are limited primarily to the stratosphere) and microwave radiometers (whose retrievals are limited primarily to the stratosphere) are providing long-term ozone profile measurements. Ozonesondes routinely launched at many NDACC stations also provide ozone-profile data. In addition, several of the high-resolution FTIR spectrometers are beginning to yield ozone-profile information. (NASA, NOAA)

**Brewer Umkehr**
**NOAA-EPA Brewer Spectrophotometer UV and Ozone Network**
The NOAA/EPA Brewer Spectrophotometer Network (NEUBrew) consists of six stations located in the western, central and eastern United States. Brewer MKIV instruments provide twice daily ozone vertical profiles based on Umkehr scans. Data is available online with a latency of one day. [http://esrl.noaa.gov/gmd/grad/neubrew/](http://esrl.noaa.gov/gmd/grad/neubrew/) (EPA, NOAA)

**Ozone-Related Gases and Variables**
**Stratospheric Aerosol Measurement (SAM) and Stratospheric Aerosol and Gas Experiment (SAGE) Instrument Series (4 Instruments)**
The SAM/SAGE series of instruments has provided the longest data set on the vertical profile of aerosols in the stratosphere. Near-global coverage has been provided on a near-monthly basis for the periods 1979 to 1981 and 1984 to 2005. Water vapor profiles are also available. This series will be resumed in 3-4 years from the existing SAGE-III instrument when it is deployed on the International Space Station. (NASA)

Aura Satellite Instruments
The four Aura instruments provide profile measurements of numerous atmospheric constituents and parameters in the stratosphere and troposphere. MLS is delivering profiles of temperature, H2O, ClO, BrO, HCl, OH, HO2, HNO3, HCN, N2O, and CO. HIRDLS retrieved profiles of temperature, O3, HNO3, aerosols, CFC11, and CFC12 at 1.2 km vertical resolution and will soon deliver profiles of H2O, CH4, N2O, and NO2. TES is providing limited profile information for O3, CO, H2O, and HDO from its nadir viewing owing to it’s high spectral resolution. (NASA)

Combined NASA Satellite Data
Past global space-based measurements of atmospheric composition (e.g., from SAGE, SBUV, UARS, and TOMS) are being extended via observations available from the Aura satellite and other A-Train satellites. These new measurements are providing an unprecedented global characterization of atmospheric composition and climate parameters. Efforts are underway to produce merged data sets connecting these recent measurements to past satellite observations of the atmosphere. (NASA)

Balloonborne Water Vapor Measurements
NOAA monitors upper tropospheric and stratospheric water vapor using cryogenic, chilled-mirror hygrometers that are flown with ozonesondes on a biweekly schedule in Boulder, CO, and at Lauder, New Zealand, in collaboration with NIWA, and monthly at Hilo, Hawaii starting in 2010. Water-vapor profiles also are obtained on a campaign basis in Indonesia and, the Galapagos. NASA supports the flights of several balloon instruments (primarily on a campaign basis) capable of providing profile information for numerous atmospheric constituents. (NOAA, NASA)

Airborne Measurements
NASA-sponsored airborne campaigns, using both medium- and high-altitude aircraft, have been conducted with NOAA, NSF, and university partnerships, with a focus on satellite validation and scientific study of ozone and climate change. While designed more for process study than for trend determinations, the airborne measurements have provided a unique view of changes in atmospheric composition at various altitudes in response to source forcings. The most recent campaigns are the GLOPAC mission using the new NASA Global Hawk and the MACPEX campaign using the NASA WB57 have concentrated on the processes that control the concentrations source gases in the upper troposphere and stratosphere with a goal of understanding the effects on stratospheric ozone. The international POLARCAT campaign with components from NASA, NOAA, DOE, and NSF was executed looking at atmospheric processes in the Arctic troposphere. (NASA, NOAA, NSF)
Researchers have completed three deployments of the HIAPER Pole-to-Pole Observations of Greenhouse Gases (HIPPO) mission, with two further deployments scheduled for 2011. HIAPER – the High-performance Instrumented Airborne Platform – is the National Science Foundation’s Gulfstream V research aircraft. The HIPPO program is providing unprecedented seasonal pole-to-pole snapshots of greenhouse gases and ozone-depleting gases in the troposphere, data that will permit climate modelers to verify models and improve models projections of future climate change and the future ozone layer. The program will provide the first comprehensive, global survey of atmospheric trace gases, covering the full troposphere in all seasons and multiple years. (NSF; NOAA)

Among the objectives of the Mid-latitude Airborne Cirrus Properties Experiment (MACPEX) airborne field campaign is an extensive intercomparison of instruments for measuring atmospheric water vapor, as well as understanding the properties of cirrus clouds at mid latitudes. The MACPEX campaign took place in March and April 2011 and is focused on central North America. (NASA and NOAA)

New Aircraft Technologies: Unmanned Aircraft Systems (UAS)
NASA Dryden has obtained new resources in Unmanned Aircraft Systems including General Atomics Aeronautical Systems (GAAS) Altair (leased), Predator-B (IKHANA), and three Northrop Grumman Global Hawks. The first civilian scientific use of the Global Hawk UAS was the Global Hawk Pacific Experiment (GloPac) and was completed in May 2010. There were instruments on board that measured ozone and ozone depleting. GloPac completed a series of UAS flights over the Pacific bearing a variety of instruments to measure ozone, aerosols, and other substances. Three successful science flights showed the impressive range (9700nm), hazardous duty over the Arctic, altitude (65,200 ft) and duration (28.6 hours) capability of the UAS, including one flight from Dryden to the North Pole and back. (NASA, NOAA)

Network for the Detection of Atmospheric Composition Change (NDACC)
Several of the NDACC remote sensing instruments provide profile data for a variety of ozone- and climate-relevant gases and variables. These observations continue the long term trends for ozone, water vapor, CFCs, HCl, HF, CH₄, and N₂O. (NASA, NOAA, DoD/NRL)

Special campaigns to validate satellites
NASA recently (March/April 2011) sponsored a ground-based campaign with a number of DOAS instruments from Fairbanks Alaska. The goal was to compare direct and all sky angle DOAS observations with the OMI instrument to understand the high values of BrO retrieved by OMI, in conjunction with Ozone observations. (NASA)

Ground-Based In Situ Measurement Networks
Both NASA and NOAA support in situ sampling of ozone- and climate-related trace gases via networks of flask sampling and real time in situ measurements. These data provide the basis for determining global tropospheric trends and for computation of effective equivalent chlorine (EECl) in the atmosphere. The NASA Advanced Global
Atmospheric Gases Experiment (AGAGE) network has the longest continuous observational record for such species, extending back almost three decades for some CFCs. New NASA and NOAA instrumentation permits the monitoring of many of the CFC replacements, thereby enabling a tracking of such chemicals from their first appearance in the atmosphere. Measurement and standards intercomparisons between the AGAGE and NOAA networks and with other international collaborators are leading to an improved long-term database for many ozone- and climate-related gases. (NOAA, NASA)

UV Irradiance Measurements

Broadband Measurements

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

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

NEUBrew network
Each NEUBrew station has a Yankee UVB-1 broadband radiometer collocated with the Brewer spectroradiometer. The UVB-1 provides measurements of Erythemal daily dose. The NEUBrew Mountain Research Station also includes a broadband Yankee UV-A instrument. (EPA, NOAA)

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

Narrowband Filter Measurements

Central Ultraviolet Calibration Facility
Currently instruments that have been operating at the Table Mountain test facility in Colorado are a Biospherical Instruments GUV-511 UV radiometer, a Smithsonian 18-channel UV narrow-band radiometer, and two YES UV-MFRSRs. The Smithsonian instrument was removed from operation in 2010 and the two YES UV-MFRSRs were removed from operation at Table Mountain in 2009. A YES UV-MFRSR is deployed at
the Central Ultraviolet Calibration Facility’s High-Altitude Mountain Research Station at Niwot Ridge, Colorado. (NOAA)

**USDA UVB Monitoring and Research Programme (UVMRP)**

UV-MFRSRs deployed within this 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](http://uvb.nrel.colostate.edu/UVB/uvb_dataaccess.jsf) (USDA)

**NEUBrew Network**

Each NEUBrew station has a Yankee UV-MFRSR and visible MFRSR collocated with the Brewer spectrophotometer. (EPA, 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. (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 are deployed at; San Diego, California; (sub-tropical location) and Barrow, Alaska; A BSI SUV-150B spectroradiometer is deployed at the 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.
**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/EPA 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, EPA)

**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 2006, intercomparisons have been held in Melbourne, Australia; Tsukuba, Japan; Buenos Aires, Argentina (twice) and Irene, South Africa. Investigations into the correct characterization of the Dobson instruments are continuing.(NOAA)

Ozone Soundings
NOAA calibrates balloons according to the developed procedures. It participates in international intercomparisons of ozone sonde measurements (chamber tests) and develops methods to resolve instrument related differences. It is done to homogenize 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 Ozone Sondes, Research Centre Juelich Institute for Chemistry and Dynamics of the Geosphere: Troposphere. These chamber calibration tests 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/ (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. 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° 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/EPA 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. 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. (EPA, NOAA)

**RESULTS FROM OBSERVATIONS AND ANALYSIS**

**Ozone**

*Merger 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. (NASA, NOAA)

**Ozone Depletion & Recovery**
Statistical analysis of the Umkehr ground based data, FTIR and merged SBUV profile ozone data set 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 that is expected based on the decline in the ODS abundances. The middle and upper stratospheric ozone has been increasing at some locations at the Northern middle latitudes since 1997, but it is not observed globally. Ground-based and satellite ozone measurements taken at the upper stratosphere since 1997 also indicate positive trends that are consistent with leveling off of the ODS concentrations. However, the derived trends are not always statistically significant, since the natural ozone variability, stratospheric cooling and measurement uncertainties make analyses less certain.

Total ozone levels have remained relatively constant over the last decade (1998-2007). Northern midlatitude ozone reached a minimum of 5.5% below 1979-1980 mean values in 1993 because of forcings from the Mt. Pinatubo eruption and the solar cycle minimum. From 1992-1998 total ozone levels recovered from the effects of the Mt. Pinatubo eruption to about 3% below the 1979-1980 values. In the years since, the northern midlatitude total ozone has been highly variable, but has increased on average, to about 3.5% below the 1964-1980 values. Southern midlatitude ozone decreased steadily until the late 1990s, and has been nearly constant since at 6% below 1964-1980 average values. There are no significant ozone trends over the tropics. (NASA, NOAA)

**Antarctic Ozone Hole**

Since approximately 1997, the underlying trend of Antarctic ozone (i.e., the trend after removal of the effect of natural variability in vortex temperatures) has been zero. This cessation of the downward trend in ozone is consistently seen at 60ºS to 70ºS in TOMS total ozone columns, SAGE/HALOE stratospheric columns, ozonesonde ozone columns at Syowa (69ºS), and Dobson total column measurements at 65ºS and 69ºS. The cessation of the downward trend is primarily a result of the saturation of the losses, and not due to decreasing levels of stratospheric chlorine. Antarctic ozone depletion is primarily controlled by inorganic chlorine and bromine levels (effective equivalent stratospheric chlorine, EESC), and secondarily controlled by Antarctic stratospheric temperatures. Fits of various ozone hole diagnostics to temperature and chlorine and bromine levels suggest that the ozone hole is very slowly improving. 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. (NOAA/CPC)

Ozone-Related Gases and Variables

**Stratospheric Ozone - Climate Connection**

A recent analysis of observations has been combined with radiative transfer considerations to show that changes in stratospheric water vapor have made significant contributions to recent decadal rates of warming of the Earth’s surface climate. Stratospheric water vapor concentrations decreased by about 10% after the year 2000. The study shows that this acted to slow the rate of increase in global surface temperature over 2000-2009 by about 25% compared to that which would have occurred due only to carbon dioxide and other greenhouse gases. The findings show that stratospheric water vapor represents an important driver of decadal global surface climate change. (NOAA)

UV

**Instrumentation**

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 and is on-going.

**UV Trends**

**SURFRAD Network**

A paper co-authored with Colorado State University (CSU) UVB researchers analyzing trends in solar UV irradiance at eight stations in the CSU-USDA network stations over the period 1995 to 2006 has been published in JGR Atmospheres (2008). Both positive and negative tendencies were detected ranging from –5% to +2% per decade. However, inter-annual variability was between 2 and 5%. (NOAA)

**USDA UVB Monitoring and Research Programme (UVMRP)**

The multidecadal change of ozone from 1979 to 2005 was investigated using four UVMRP ground stations, WA01, CO01, MD01, and AZ01. The UV index has increased at the four stations while total ozone has decreased in continental USA. Spatial distribution of ozone shows substantial variation from coastal zones to the Midwest, yet the tendency toward recovery of the ozone layer in the continental USA cannot be fully confirmed. (Gao et al., 2010)

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 indispensable 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:
Ozone-Layer Recovery Estimates
Equivalent effective stratospheric chlorine (EESC) is a convenient parameter to quantify the effects of halogens (chlorine and bromine) on ozone depletion in the stratosphere. EESC has been extensively used to evaluate future scenarios of ozone-depleting substances (ODSs) on the stratosphere. Research has led to a new formulation of EESC that provides revised estimates of ozone layer recovery. The work shows that ozone levels will recover to 1980 levels in the year 2041 in the midlatitudes, and 2067 over Antarctica, assuming adherence to international agreements that regulate the use of ODSs. The researchers assessed the uncertainties in the estimated recovery times. The midlatitude recovery of 2041 has a 95% confidence uncertainty from 2028 to 2049, while the 2067 Antarctic recovery has a 95% confidence uncertainty from 2056 to 2078. (NOAA and NASA) In recent research, hypothetical reductions in future emissions of ODSs and nitrous oxide (N2O) have been evaluated in terms of effects on EESC, globally-averaged total column ozone, and radiative forcing through 2100. The findings show that due to the established success of the Montreal Protocol, these actions can have...
only a fraction of the impact on ozone depletion that regulations already in force have had. If all anthropogenic ODS and N₂O emissions were halted beginning in 2011, ozone is calculated to be higher by about 1 to 2% during the period 2030–2100 compared to a case of no additional restrictions. (NOAA)

**Antarctic and Arctic Ozone Loss**

Contrasts between ozone depletion at the poles have been investigated in a recent study that used available long balloon-borne records and ground-based records that cover multiple decades. Antarctic ozone observations reveal widespread and massive local depletion in the heart of the ozone “hole” region near 18 km, frequently exceeding 90%. The depth of the ozone losses in the Arctic are considerably smaller, and their occurrence is far less frequent. However, the 2011 Arctic Polar vortex was uncharacteristically stable and cold allowing record stratospheric ozone depletion to occur in the late winter and early spring as reported by the Alfred Wegener Institute for Polar and Marine Research (AWI). This was based on their analysis from an ongoing international network of about 30 cooperative ozone sounding stations in the Arctic and Subarctic. Similar studies are being done with satellite data from the MLS instrument. (NOAA, NASA)

**SPARC Initiative on Halogen Chemistry and Polar Ozone Loss**

NASA and NOAA scientists are working with international colleagues to examine the effects of new laboratory data on the photolysis rate of the ClO dimer (ClOOCl) on the quantification of polar ozone depletion. These efforts were coordinated under a new SPARC initiative on “The Role of Halogen Chemistry in Polar Ozone Loss”. The work resulted in publication of a report that gives a comprehensive review of existing and ongoing laboratory studies, atmospheric observations, and modeling activities. (NASA, NOAA)

**Decadal Analyses and Simulations**

Simulated fields of atmospheric constituents derived using NASA’s Global Modeling Initiative (GMI) Chemical Transport Model (CTM) are being used in comparison with Aura data to evaluate the transport and photochemical processes in the upper troposphere and lower stratosphere. These simulations are being used along with trajectory calculations to interpret aircraft measurements of chlorofluorocarbons and to develop better estimates of their atmospheric lifetimes. In addition, 25-year time-slice simulations have been done in which specific years (in terms of halogen amounts) are repeated in order to get better mean distributions and estimates of variability for ozone and relevant chemical compounds. These simulations have been included in the Chemistry Climate Model Validation (CCMVal) exercise and were part of the 2010 WMO/UNEP Ozone Assessment. (NASA)

**Ozone-Related Gases and Variables**

**Environmental Properties of Atmospheric Gases**

**Chemistry Related to Ozone Depletion**

Laboratory work determined the chlorine monoxide radical (ClO) yields in the reaction of O(1D) with Cl₂, HCl, chloromethanes, and chlorofluoromethanes. The formation of the
reactive ClO is particularly important in the stratosphere due to its influence on ozone abundance (e.g., the Antarctic ozone hole) through its participation in the ClOx catalytic ozone destruction cycle as well as the ClO dimer (Cl2O2) cycle, which plays an important role in polar stratospheric ozone chemistry. (NOAA)

Laboratory work has been completed on the kinetics of the ClO + ClO reaction over a range of temperatures and pressures. Rate constants obtained are larger than current recommended values, and modeling work will be done to determine the impact of the new results on ozone-related chemistry in the stratosphere. The reaction is a key step in catalytic cycles that destroy stratospheric ozone in both polar and non-polar regions. (NOAA, NASA).

The abundance and atmospheric lifetimes of nitrous oxide (N2O) and carbon tetrachloride (CCl4) are 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 of these gases, and to determine the temperature dependence of these values, for which there are few previous studies. The information will help reduce the uncertainties in calculations of the atmospheric lifetimes of these species, which are inputs to atmospheric models. The reduced uncertainties in the N2O and CCl4 absorption cross section data, and in photolysis lifetimes, will enable improved model calculations of ozone recovery. (NOAA)

**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 unsaturated partially fluorinated compounds, as well as methoxy perfluorinated heptenes. A modeling study of the degradation products of a potential substitute for HFC-134a is in progress. A particular focus on the yield of trifluoroacetic acid (TFA), a compound that has possible ecological implications. (NOAA)

The Montreal Protocol with its subsequent amendments and adjustments have led, and will likely continue to lead, to the replacement of chlorofluorocarbons (CFCs), Halons (brominated chemicals) and hydrochlorofluorocarbons (HCFCs) with chemicals that are shorter lived or do not contain either chlorine or bromine. Over the past two decades, potential substitutes with lifetimes as short as a few days have been considered. Researchers have developed a new approach for calculating the fraction of very-short lived substances (VSLS) emitted at the surface (and their degradation products) that reach the stratosphere, and have used those fractions to estimate Ozone Depletion Potentials.
(ODPs) of several short-lived compounds. Calculated values show large regional and seasonal variability. (NOAA)

A recent study has provided the first calculation of the Ozone Depletion Potential (ODP) of nitrous oxide (N2O), a gas long recognized as the primary source gas for nitrogen oxides in the stratosphere. The concept of the ODP, which is used extensively in characterizing the relative roles of halogen-containing ODSs, had not previously been applied to N2O. The study’s analysis uses the ODP to show that nitrous oxide has now become the largest ozone-depleting substance emitted through human activities, and is expected to remain the largest throughout the 21st century. (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 3 Aura instruments (OMI, MLS, and HIRDLS), past TOMS instruments, 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. Brewer Umkehr data are available for 6 NEUBrew sites at the 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-EPA network are available at the web site http://esrl.noaa.gov/gmd/grad/neubrew/ (NOAA, EPA)

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)


Assessments
NASA and NOAA scientists played key roles as reviewers and authors for various chapters in the 2010 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 contributed to the report, which was given to the Parties to the Montreal Protocol in late 2010 and is available in print form and on the UNEP and NOAA websites. (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)

**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*

Long-term data from the NOAA network are updated every six months on the website (http://www.esrl.noaa.gov/gmd/) and submitted annually to the World Data Centre and to the World Data Center for Atmospheric Trace Gases at the Carbon Dioxide Information Analysis Data Center (CDIAC). Data from field missions (firn-air studies, ocean flux studies), are posted shortly after mission completion. Data on very short-lived gases from ocean research cruises are posted for use on the NOAA/GMD website. (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 Chlorine (EECl) measured globally in the NOAA network, has been implemented. EECl and WMO/UNEP ozone-depleting gas scenarios are used to estimate the progress towards ozone recovery (ODGI = 100 on January 1, 1994 when EECl reached its maximum value and 0 at recovery). The method was published, where the results are updated annually and posted at http://www.esrl.noaa.gov/gmd/odgi. (NOAA)

**Relevant Scientific Papers (2008-present)**


Biago, C.D., et al. "Evolution of temperature, O₃, CO, and N₂O profiles during the exceptional 2009 Arctic major stratospheric warming as observed by lidar and millimeter-wave spectroscopy at Thule (76.5N,


Gilman et al., Ozone variability and halogen oxidation within the Arctic and sub-Arctic springtime boundary layer (2010), *Atmos. Chem. Phys.*, 10, 10223-10236.


Hofmann, D. J. and S. A. Montzka (2009), Recovery of the Ozone Layer: The Ozone Depleting Gas Index, EOS Transactions American Geophysical Union, 90(1), 1-12, 10.1029/2009EO010001.


Kiedron, P., M. Beauharnois, J. Berndt, P. Disterhoff, L. Harrison, J. Michalsky, G. Scott, J. Schlemmer and J. Slusser (2008), Calibration, data processing, and maintenance of the
United States Department of Agriculture high-resolution ultraviolet spectroradiometers, *Applied Optics*, 47, 6142-6150, 10.1364/AO.47.006142.


http://eopi.esa.int/esa/esa?topSelectedNavigationNodeId=AOS&sideNavigationType=A O&aooid=300&ts=1295529243613&cmd=aodetail&


Krotkov, N., G. Labow; J. Herman; J. Slusser; R. Tree; G. Janson; B. Durham; T. Eck; B. Holben (2009), Aerosol column absorption measurements using co-located UV-MFRSR and AERONET CIMEL instruments, Proceedings of SPIE Volume: 7462.


Michalsky, J. J. and P. Kiedron (2008), Comparison of UV-RSS spectral measurements and TUV model runs for clear skies for the May 2003 ARM aerosol intensive observation period, Atmospheric Chemistry and Physics, 8, 1813-1821.


Miller, B. R. et al., HFC-23 (CHF₃) emission trend response to HCFC-22 (CHClF₂) production and recent HFC-23 emission abatement measures (2010), Atmos. Chem. Phys., 10, 7875.


**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 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, balloonborne, and groundbased 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.

EPA:
The NOAA/EPA Brewer spectrophotometer network (NEUBrew) consists of six stations located in the western, central, and eastern United States. The NEUBrew network has deployed two Brewer Mark IV spectrophotometers to Brisbane, Australia. The data gathered from this location will be used for atmospheric research and human health effects studies.

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. New algorithms to utilize multi-wavelength Brewer zenith sky measurements for improved ozone profile retrieval are underway. The work on improvement of optical characterization of Dobson and Brewer instruments for stray light minimization and new ozone cross-section implementation is underway. (NOAA, NASA)

According to the ACSO (WMO GAW Ad Hoc Expert team on Absorption Cross-sections of Ozone - ACSO) analysis of the impact of a possible change of ozone absorption cross-sections from Bass and Paur to Brion/ Daumont /Malicet (BDM) on Dobson and Brewer total ozone measurements, SAG-Ozone (Activity A9 within the ICAGO-O3/UV implementation plan) recommended to develop procedure to apply ozone cross section changes to processed total ozone data from Dobson and Brewer observations. A NOAA group will proceed to convert retrieved total ozone measurements and submit results to the WOUDC. (NOAA)

*Ozone profiles from Dobson/ Brewer Zenith-Sky Measurements*

NOAA GMD will convert retrieved 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 BDM cross-section. Results from the NEUBrew instruments will be posted on the network website.
http://esrl.noaa.gov/gmd/grad/neubrew/, with the follow up submission to the WOUDC Brewer archive. Also, all B-files will be submitted to the WOUDC Brewer archive in accordance with the SAG-Ozone Activity (NOAAESRL/GMD). 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. The algorithm will 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 next Vertical ozone workshop 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 stabilized 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.

Ozone-Relevant Gases/Variables:

**OMPS and CrIS on NPP and NPOESS**
The Ozone Mapping and Profiler Suite will become the operational US ozone monitoring instrument in the NPOESS 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 will fly on the NASA NPOESS Preparatory Project Mission in 2010. The OMPS was design to include a third detector, the limb profiler, to provide high-vertical resolution ozone profiles. This instrument was de-manifested due to cost issues. It has been restored on NPP and options for future flights are under consideration. 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 NPOESS. (NOAA, NASA)

**NASA Earth Venture (EV) Investigations and missions**
NASA selected 5 investigations (EV-1) that will last for 5 years to use suborbital platforms for sustained investigations of Earth System processes. 2 of these selected studies have direct relevance to Ozone related science, the Airborne Tropical Tropopause Experiment (ATTREX) and the Deriving Information on Surface Conditions from Column and Vertically Resolved Observations Relevant to Air Quality (DISCOVER-AQ) investigation. These activities started in 2010 and will continue until 2014. Two new competed space mission Announcements of Opportunities (AOs) will be released in 2011. One is for a cost constrained stand alone space mission (EV-2), and one for a cost constrained space based Instrument of Opportunity (EV-Instrument). (NASA)

**NEUBrew Network**
Future plans for the NEUBrew network are to process historical direct-sun measurement data for total column abundance of NO₂ and SO₂ data products. (NOAA, EPA)

**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 70°. 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. (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 will be obtained by the OMPS Limb instrument on NPP during the next 3-5 years. But these observations will not be continued on the following JPSS platforms. OMPS-Limb will be followed by the SAGE-III on the International Space Station, which may provide useful data to about the end of the lifetime of ISS (~2020). (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)

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

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. Neither project is planned to be launch until some time after 2020, leaving a large gap between Aura and the next mission. (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 NO2 wavelengths.
Ozone- and Climate-Related Trace-Gas Measurements
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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 it’s 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. (USDA)

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, U.S.)
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)
KNMI Koninklijk Nederlands Meteorologisch Instituut (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
NPOESS National Polar-Orbiting Operational Environmental Satellite System
NPP NPOESS Preparatory Satellite
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
VIETNAM

Introduction
The National Hydro-meteorological Service of Socialist Republic of Vietnam (NHMS) has three ozone and UV-B observing stations, with Hanoi station (21°01’N, 105°51’E) established in 1992, later joined by Sapa station (22°21’N, 103°49’E) and Tan Son Hoa station (10°47’N, 106°42’E) in 1994. In April 2008, Tan Son Hoa station ceased to observe because of instrumental problems. Observation management in NHMS has been operated by the Aero-Meteorological Observatory (AMO).

Observational activities
The total amount of atmospheric ozone (TO3) and UV-B are measured by Russia’s M124 filter instruments. TO3 is measured seven times a day with sun heights between 20° and 70°, while UV-B is observed eleven times per day from 07:00 to 17:00 from May 1st to October 31st, and nine times per day from 08:00 to 16:00 from November 1st to April 30th. In 2006, AMO sent all the instruments to GGO (Petersburg, Russia) for calibration. However, since the M124 type were no longer in production, most of the instruments after calibration have not produced high quality observational data. Nonetheless, all three stations still make observations according to the National Guide for Observation.

Observation results and analysis
According to the satellite-derived Global Distribution of Total Ozone, Vietnam is located in the region with the total ozone amount between 200DU and 300DU (1), with the minimum in winter and the maximum in summer.

As shown on Table 1 and Figure 1 below, the total ozone amount measured at Tan Son Hoa station varied between 120DU and 240DU from January 2006 and December 2007, which is lower than the satellite measurements. Ozone trends were different in 2006 and 2007, with 2007 seeing an irregular trend with a rapid increase from the minimum of 120DU in February to the maximum of 240DU in June. In general, TO3 in 2006 and 2007 was lower than the normal value.

No data update has been made for TO3 observed at Tan Son Hoa station since 2008 due to instrumental problems.
Table 1: Total amount of ozone, Tan Son Hoa station (Unit: DU)

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Figure 1: Total amount of ozone, Tan Son Hoa station (Unit: DU)

In the same period (2006-2007), TO3 measured at Hanoi station was slightly higher (see Table 2 and Figure 2) than at Tan Son Hoa station. Notably, in 2007 and 2010, total ozone amount abnormally peaked in February instead of summer.

From 2008, TO3 sees a more stable and slightly increasing trend in comparison to 2007, with 2010 having the highest TO3 and 2008 the lowest.
Table 2: Total amount of ozone, Hanoi station (Unit: DU)

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</table>

Figure 2: Total amount of ozone, Hanoi station (Unit: DU)

TO3 measured at Sapa station ranged from 200DU to 300 DU during 2006-2007 (see Table 3 and Figure 3 below). However, the 2007 trend was not consistent with the Global Distribution of Total Ozone. The total amount of ozone in 2010 was the highest since 2004, emphasizing the overall upward trend since 2008. In general, annual TO3 at Sapa station decreased from January to December, except for February.
Table 3: Total amount of ozone, Sapa station (Unit: DU)

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Figure 3: Total amount of ozone, Sapa station (Unit: DU)

In addition, column ozone measurements are currently initiated at Hanoi station in collaboration with Japan, with a planned schedule of 1-2 times per month.
Due to the instrumental obsolescence and limited budget for equipment calibration, the ozone data have not been verified, leading to unverified UV-B. Thus UV-B dataset is not presented in this report.

**Future Plan**
Currently, NHMS is in the process of replacing old M124 instruments with Brewer spectrophotometers. The replacement process was planned to complete at the end of 2010. Due to some difficulties, however, it has to be extended into the first half of 2011.

**Recommendations**
In order to improve the observation and measurement of TO3 and UV-B to meet the data quality requirement, there is a strong need for new, modern equipments along with capacity strengthening for NHMS. It is essential that NHMS receive financial and technical support for its instrumental upgrade and staff capacity-building programmes. In particular, NHMS calls for support for the ozonesounding activity in Hanoi, which is planned to take place at least once a week, in parallel to the twice-a-day radiosounding by Finland-manufactured DigiCORA-RS sonde.

**References**
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National Report About the Status of Ozone Monitoring

Introduction
Zimbabwe ratified The Vienna Convention for the protection of Ozone layer and the
Programme has been implemented since 1995 under the Ministry of Environment and
Natural Resources Management.

Zimbabwe, like most developing countries has struggled to raise the necessary financial
and technical resources to establish National Action Plan for the measurement of Ozone
and other stratospheric and tropospheric substances including UV.

Monitoring and Observational Activities of Ozone (current status)
Zimbabwe is yet to undertake observational activities on ozone methodologies including
column measurement, profile measurement of ozone and other gases necessary for
monitoring the loss of ozone. Although we are very much committed to be among those
countries which are on the forefront of monitoring ozone with the zeal to minimize its
depletion, our biggest challenge remain the lack of equipment and funding. We do not
have anything even the Narrowband filter instruments or Spectro-radiometers and other
instruments for the measurement of UV through broadband.

Although we do have our Meteorological Department within the Ministry of Transport
and Communication with over 30 stations scattered all over the country their activities
have not been anything concerned with ozone. The reason why they have not been doing
this comes back to the issue of economic hard times which then cascade to lack of proper
equipment and good instruments. The only data available is that of the trend in annual
minimum and maximum temperatures up to 2004. Data beyond this date including, 2010
is not available in the national Meteorological Offices suggesting the extend of the
desirable need to start equipping the Ozone Project Office with financial resources and
equipment for the project to be able to kickoff.

Projects and Collaboration

We have never had and any collaborative activities or projects related to
research/monitoring on the status of ozone over Zimbabwe as well as to determine the
level of ground UV/Ozone.

Future Plan

Since we have an office for the ozone project in the Ministry of Environment and
Natural Resources, we plan to start research activities related to the monitoring of
UV/Ozone once the committees are set. We will then have to launch a memorandum of
understanding (MOU) between the University of Zimbabwe, Department of Chemistry,
Various Ministries Concerned and the department of meteorological services. The Ozone
office within the ministry of environment will then do coordination of activities.
Financial Needs
We need the instruments like the Dobson Spectrophotometer, ozonesondes observatory to be set in Harare and other minor instruments including UV sensors or digital UV instruments to help in the measurement of UV.

Conclusion
We intend to contribute immensely in the data provision of the status of ground UV and OZONE.


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