DENMARK

OBSERVATIONAL ACTIVITIES

The Danish Meteorological Institute (DMI), in collaboration with the Danish Environmental Protection Agency, conducts permanent measurements of the stratospheric ozone layer. Daily ground-based measurements of the ozone layer thickness as well as weekly balloon based measurements of the vertical ozone profiles are performed in Denmark and Greenland. The measurements are reported to international databases. In addition the measurements are incorporated in validation of satellite measurements, e.g. measurements from ENVISAT and AURA. Balloon-based measurements of the ozone layer are often conducted as part of larger international projects.

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

Daily observations of total ozone are performed by the DMI in Denmark and Greenland:

<table>
<thead>
<tr>
<th>Station</th>
<th>Location</th>
<th>Instrument</th>
<th>Start of observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Copenhagen</td>
<td>56°N, 12°E</td>
<td>Brewer Mark IV</td>
<td>May 1992</td>
</tr>
<tr>
<td>Sondre Stromfjord</td>
<td>67°N, 51°W</td>
<td>Brewer Mark II</td>
<td>September 1990</td>
</tr>
<tr>
<td>(Kangerlussuaq)</td>
<td></td>
<td>SAOZ 1024 diode array</td>
<td>September 1990</td>
</tr>
<tr>
<td>Thule Air Base</td>
<td>77°, 69°W</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Pituffik)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

On non-regular basis, total ozone has also been measured from Qaanaaq (78°N, 69°W) in Greenland, using the DMI Dobson #92 instrument since early 2000.

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

Weekly ozone soundings have been performed using balloon-borne EEC sensors from Scoresbysund (Illoqqortoormiut, 71°N, 22°W) since January 1993. Ozone soundings have also been performed on campaign basis from Thule Air Base each winter since January 1992 and occasionally from Copenhagen.

UV measurements

Broadband measurements

A Yankee Environmental Systems model UVB-1 radiometer has been operated by DMI in Copenhagen since 1996. A custom UV radiometer (erythemally weighted UV and total UV-A) has been in operation in Thule (Pituffik) since 1993. The latter instrument is owned by the Health Protection Agency in the U.K. (former National Radiological Protection Board) and the UV-B part of the instrument is similar to the Solar Light model 500.

Narrowband filter instruments

A narrowband filter instrument – Biospherical Inc., model GUV2511 – has been operated on the east coast of Greenland at Scoresbysund (Illootoorqqortoormiut) by DMI since 2008.

Spectroradiometers

Daily measurements of the surface UV radiation are performed by DMI at Thule (Pituffik), using a high resolution spectroradiometer, since summer 1994. The Brewer MkII instrument at Sondre Stromfjord (Kangerlussuaq) has measured spectral UV-B (290-325nm) since late 1990.

Calibration activities

DMI has contributed with ozone measurements from Greenland to the international projects CINAMON (AO-ID 158), OMI cal/val and GOME-2 validation as proposed in connection with ESA/NASA/EUMETSAT's "announcement of opportunities" concerning the ENVISAT, AURA and METOP satellite missions.
RESULTS FROM OBSERVATIONS AND ANALYSIS

Summer (June, July, August) average column ozone measurements, based on NASA TOMS Nimbus 7 version 8 (years 1979-1991) and DMI Brewer (years 1992-2007) from Kangerlussuaq, Greenland, are shown in left-hand side in the figure below. The whole data series shows a significant trend of -2.1±1.1% per decade (2 σ) while there is no significant trend during the past 15 years.

Likewise summer (June, July, August) average column ozone measurements, based on NASA TOMS Nimbus 7 version 8 (years 1979-1991) and DMI Brewer (years 1992-2007) from Copenhagen, Denmark, are shown in the right-hand side of the figure. The whole data series shows a significant trend of -2.6±1.2% per decade (2 σ) while there is no significant trend during the past 15 years.

THEORY, MODELLING, AND OTHER RESEARCH

DMI has participated in major European Arctic and tropic campaigns since the beginning of the 1990's including EASOE, SESAME, THESEO, THESEO-2000-SOLVE, VINTERSOL, HIBISCUS, and Scout-AMMA, as well as a long series of EU-projects. The research is based on a broad spectrum of accessible observations, including data from the European environmental satellite ENVISAT and analyses of meteorological conditions in the stratosphere. The research includes analysis of transport of ozone depleted air masses from Arctic areas to mid-latitudes and experimental and theoretical studies of polar stratospheric clouds. In addition research is carried out on cirrus clouds from airplane condensation trails, and on cirrus clouds in the tropics, which is important for transport of water vapour to the stratosphere. Studies are performed on the downward influence from the stratosphere on tropospheric climate.

DISSEMINATION OF RESULTS

Data reporting
The measurements are reported to databases under Network for the Detection of Atmospheric Composition Change (NDACC) and World Ozone and UV-radiation Data Center (WOUDC) under the WMO-programme Global Atmosphere Watch (GAW).

Information to the public
UV-index forecasts, based on Danish total ozone measurements, were initiated at DMI in summer 1992. This public service runs every summer season, made public on the Internet and in several media. DMI is responsible for the Near Real Time UV-index processing as part of the EUMETSAT Satellite Application Facility on Ozone and Atmospheric Chemistry Monitoring and provides daily global maps of clear sky UV-indices. As part of the ESA-GMES Service Elements project Promote,
DMI has initiated a UV service for Greenland in collaboration with the Greenland Directorate for Health. DMI’s ozone measurements are made available on the Internet (www.dmi.dk) together with a status report (in Danish language).

Relevant scientific papers


PROJECTS AND COLLABORATION

Thule and Sondre Stromfjord are primary Arctic stations within the Network for the Detection of Atmospheric Composition Change. In addition to the DMI instrumentation, aerosol lidars are operated at these stations by the University of Rome (Italy) and SRI International (USA), respectively, together with an FTIR spectrometer at Thule, operated by National Center for Atmospheric Research (USA). DMI also collaborates with Service d’Aéronomie du CNRS (France) for daily total ozone measurements by a SAOZ instrument at Scoresbysund which is a supplementary NDACC-station. DMI participates in the EU-project Global Earth Observation and Monitoring (Geomon) providing SAOZ total ozone data from Greenland.

Within the current EU-project Stratosphere-Climate links with emphasis on the UTLS (Scout-O3) DMI is involved in modelling aspects of the stratosphere-troposphere coupling, investigating to what extent the downward propagation can increase the performance of operational dynamical seasonal-prediction models, and to what extent a well-resolved stratosphere is important for the modelling of the tropospheric climate. In Scout-O3 DMI is also involved in tropical balloon-borne investigations of transport of water vapour to the stratosphere.

The DMI participates in EUMETSAT’s Satellite Application Facility on Ozone and Atmospheric Chemistry Monitoring, developing operational UV-index products, based on satellite measurements of the ozone layer, and DMI participates in the EU-project Global Earth-System Monitoring Using Satellite and In-Situ Data (GEMS) concerning validation of UV-indices.

FUTURE PLANS

National funding for ozone and UV monitoring in Denmark and Greenland is secured until the end of 2009. After this period the funding situation will be renegotiated.

Research efforts will be directed towards improved understanding of the role of stratospheric changes for tropospheric climate including the dynamical coupling between the troposphere and the stratosphere, and to assess how well this coupling is included in current chemistry-climate
models. It is intended to include a stratospheric representation in new developments of an Earth System model complex. In addition research efforts will be directed towards cirrus cloud formation in the tropical tropopause layer and transport of water vapour to the stratosphere, based on improved microphysical modelling and combining experimental balloon-borne experiments with satellite measurements from the International Space Station.

NEEDS AND RECOMMENDATIONS

It is considered important to monitor the recovery of the ozone layer at high latitudes during changing stratospheric climatic conditions (decreasing temperatures, perhaps increased water vapour concentrations and other changes in chemical composition, changes in stratospheric dynamics). Maintaining and running stratospheric monitoring stations in the Arctic and elsewhere is becoming an increasingly heavy burden on national funding sources and possibilities for direct funding of ground-based monitoring activities and data provision should be considered to be included in major international programmes such as the European Global Monitoring for Environment and Security (GMES).

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EGYPT

Ozone Depleting Substances (ODS)
In line with the government’s general policy and reflecting the country's commitment to the Montreal Protocol, the Egyptian Government has shown sustained commitment to reduce the consumption of Ozone Depleting Substances (ODS).

Egypt is neither a manufacturer nor an exporter of ODS. Egyptian Environmental Agency Affairs (EEAA) monitoring Ozone Depleting Substances (ODSs) as CFCs, CC14, Halons, CH3Br, C2H3Cl3, and other.

Data reporting
The annual consumption data of ODSs available from the Fund Secretariat and the Ozone Secretariat in Nairobi Table (1.2) show that Egypt is in compliance for all phase-out targets and according to the control measures of Montreal Protocol Fig. (1.2.):

<table>
<thead>
<tr>
<th></th>
<th>Baseline</th>
<th>1999</th>
<th>2000</th>
<th>2001</th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
</tr>
</thead>
<tbody>
<tr>
<td>CFC</td>
<td>1,668.0</td>
<td>1,373.6</td>
<td>1,267.0</td>
<td>1,334.8</td>
<td>1,294.0</td>
<td>1,102.2</td>
<td>1,047.6</td>
<td>821.2</td>
<td>593.6</td>
</tr>
<tr>
<td>CTC</td>
<td>38.5</td>
<td>33.0</td>
<td>27.5</td>
<td>11.0</td>
<td>11.0</td>
<td>13.0</td>
<td>12.1</td>
<td>5.5</td>
<td>5.5</td>
</tr>
<tr>
<td>Halons</td>
<td>705.0</td>
<td>810.0</td>
<td>860.0</td>
<td>790.0</td>
<td>230.0</td>
<td>180.0</td>
<td>193.0</td>
<td>145.0</td>
<td>4.4.0</td>
</tr>
<tr>
<td>MB</td>
<td>238.1</td>
<td>409.2</td>
<td>420.0</td>
<td>432.0</td>
<td>270.0</td>
<td>238.0</td>
<td>219.0</td>
<td>188.4</td>
<td>180.0</td>
</tr>
<tr>
<td>TCA</td>
<td>26.0</td>
<td>25.0</td>
<td>20.0</td>
<td>15.0</td>
<td>19.0</td>
<td>18.0</td>
<td>17.5</td>
<td>15.0</td>
<td>12.5</td>
</tr>
</tbody>
</table>

Fig. (1.2.a): CFCs Consumption (ODP tons).
Fig. (1.2.B): CTCs Consumption (ODP tons).

Fig. (1.2.C): Halons Consumption (ODP tons).
Fig. (1.2.D): MB Consumption (ODP tons).

Fig. (1.2.E): TCA Consumption (ODP tons).
Information to the public

- The awareness campaigns especially addressed to decision-makers, customs, investors, labour and general awareness addressed to NGOs, universities and the public.
- Celebrating the International Ozone Day on 16 September, and participating in celebrating other environmental days every year.
- Updating the web page for Ozone Unit activities and the Egyptian achievements for protecting the Ozone layer within the web site of EEAA (http://www.eeaa.gov.eg).

Measurements of Stratospheric Ozone

Egyptian Meteorological Authority (EMA) is responsible for measurements of column ozone amount (stratospheric ozone) and operates the main total ozone-monitoring network. Long-term daily observations of total ozone have been performed at the regional ozone centre of EMA at Cairo (30.08°N, 31.28°E) with the Dobson Spectrophotometer (D096) since 1967. Since 1984 second Dobson instrument (D069) has been maintained at Aswan (23.97°N, 32.87°E) to measure the amount of ozone over tropical area. At the late of 1998 Brewer Spectrophotometer mark II (B143) has been maintained at Matrouh (31.33°N, 27.22°E) to measure the total ozone and SO2 over northwest coast area of Egypt. With the end of 1999 third Dobson Spectrophotometer (D059) has been maintained at Hurghada (27.28°N, 33.75°E) to measure the amount of ozone over Red sea area.

The daily and monthly mean values of total ozone amount are stored in the ozone database at EMA and they are also deposited in the WOUDC, Toronto, Canada.

![Graph](image.png)

Fig. (2.1.A): Annual variation of ozone column over Egyptian ozone stations.
**Vertical Distribution of Ozone**

Vertical distribution of ozone in the atmosphere is measured with Dobson and Brewer Spectrophotometers (Umkehr method) at Aswan, Matrouh and Hurghada. The N-values are stored in the ozone database at EMA and they are also deposited in the WOUDC, Toronto, Canada.

**Surface ozone**

EMA measure surface ozone outside urban regions, at Hurghada (27.28°N, 33.75°E) which is an official WMO Global Atmospheric Watch (GAW) station. Also EMA measure surface ozone at Sidi Branni (31.37°N, 25.53°E). South Valley University (SVU) in cooperation EMA has been measured surface ozone at Qena (26.20°N, 32.75°E).

**UV measurements**

*Broadband measurements*

EMA take the measurements of broadband UV solar radiation using Eppley Ultraviolet Radiometer at Cairo and Aswan since 1989. Also EMA in cooperation with SVU have been measured the broadband UV radiation at Qena since 2000.

*Narrowband filter instruments*

EMA measured the biologically effective solar UV-B radiation by UVB-1 Pyranometer at Cairo, Aswan since 1998 and at Rafaah (31.22°N, 34.20°E) since 2000. The measurements of the global UV-B are performed with the Brewer single monochromator for different solar zenith angles at Matrouh. Also EMA in collaboration with SVU have been measured the UV-B radiation at Qena since 2000.

**DISSEMINATION OF RESULTS**

**Data reporting**

The ozone data collected from the network of Egyptian ozone stations by EMA at Cairo regional ozone centre monthly. Data files of ozone are transmitted regularly with SO₂ to World Ozone Data Center (WOUDC) in Toronto, Canada.
Information to the public

- Updating the web page for Ozone research and the Egyptian Meteorological Authority (EMA) achievements for weather and climate change within the web site of EMA (http://www.nwp.gov.eg).
- Matrouh lie on the coast of NW Egypt and summer resort. The scans are used for calculation of actual values of UV Index (UVI) daily presented for the public during the seasons especially the summer season. UVI is a numerical risk scale and a way of describing the daily danger from solar UVB radiation. The EPA used the following classification of the UV exposure level based on the UV index (0-2 minimal, 3-4 low, 5-6 moderate, 7-9 high and >10 very high). UVB insulation displays a daytime variation with maximum at solar noon, figure (2.1) and variation with months take a maximum at summer months (figure 2.1.c). UVB protection is critical during summer and especially so in the hours around solar noon. A person being out in the sun during midday hours more than ten minutes if you are without protection.

![Diurnal variation of DUV and UVI on a clear summer day over Matrouh.](image)

**Fig. (2.1):** Diurnal variation of DUV and UVI on a clear summer day over Matrouh.

(a) Winter
Fig. (2.2): Diurnal variation of UV index over Matrouh at different seasons.
NEEDS AND RECOMMENDATIONS

- Continuity of the rule of the MLF (technical and financial support to Article 5 countries will automatically lead to enabling Egypt and other developing countries to meet the changing requirements after 2010.
- We are in great need for scientific research program in ozone and climate change model.
- We will appreciate assistance to start measurements of vertical ozone distribution advice to elaborate a by ozonesonde especially at Aswan station (tropical area).
- We need technical and financial assistance for the regular calibration of Brewer with the traveling standard.

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INTRODUCTION AND OVERVIEW
Stratospheric research was a priority of the European Framework Programmes for Research and Technological Development (FPs) from the very beginning and has been coordinated at European level since the late 1980s. The early European stratospheric research programmes (FP1-FP3, 1982-1994), focused on the investigation of potential severe Arctic ozone losses and increased UV radiation across Europe and the populated northern mid-latitudes. Results from a series of national and international programmes including the European Arctic Stratospheric Ozone Experiment (EASOE, 1991-92) and the Second European Stratospheric Arctic and Mid-latitude Experiment (SESAME, 1994-95) concluded that the winter polar stratosphere over northern Europe was primed for severe ozone losses. Large ozone losses over the Northern Hemisphere have indeed been observed in some winters in the early 1990s. This trend has continued in the early 2000s, coincide with a stratospheric cooling trend and new record low temperatures. Low stratospheric temperatures favour the development of Polar Stratospheric Clouds (PSCs) which play a key role in the process of ozone destruction.

In the 4th Framework Programme for Research and Technological Development (FP4, 1994-1998) stratospheric research was focusing on basic processes affecting ozone depletion, in particular over Northern Europe. The Third European Stratospheric Experiment on Ozone (THESEO, 1998-2000) was a major component of this coordinated programme. Moreover, research addressed the mid-latitude lower stratosphere, the interaction with other layers of the atmosphere, the Arctic vortex, and exchanges processes between the Troposphere and the Stratosphere in the tropics and sub-tropics.

The 5th Framework Programme for Research and Technological Development (FP5, 1998-2002), Programme Energy, Environment and Sustainable Development (EESD) was designed to support environmental legislation and international commitments such as the Montreal Protocol, promoting interdisciplinary research. Research focused on understanding, quantification and prediction of stratospheric changes and changing of UV-radiation levels. The programme has been implemented through multitude projects organised in a number of research clusters addressing similar topics: UV radiation (ATUV), impact of aircraft emissions (CORSAIRE), ozone–climate interactions (OCLI), stratospheric ozone loss (SOLO).

The 6th Framework Programme for Research and Technological Development (FP6, 2002-2006) was designed to promote interdisciplinary research in a more integrated way. The newly designed funding instrument, called Integrated Project (IP), was a very effective implementation tool for stratospheric research at European level. Stratospheric topics of the Programme addressed future stratospheric ozone levels and physical and chemical processes affecting ozone depletion. Also ozone-climate interaction and the study of exchange process between the Troposphere and the Stratosphere received high priority. Projects funded under FP6 (still ongoing) are listed in Table 1.

Integrated and interdisciplinary UV and stratospheric research will continue in the 7th Framework Programme for Research and Technological Development (FP7, 2007-2013) under Programme 6. Environment (including climate). In addition, the GMES (Global Monitoring for Environment and Security) initiative, part of Programme 9. Space, addresses some stratospheric research aspects (related to pre-operational services) under topic 'Pilot Services Atmosphere'.

In the past effective links have been maintained with existing international observational programmes such as NDACC and the Global Atmosphere Watch programme of the World Meteorological Organisation (WMO-GAW). This collaboration will continue. The International Ozone Commission and the WCRP programme Stratospheric Processes And their Role in Climate (SPARC) should also be mentioned in this context.

Overall, European research has greatly benefited from the European research programmes which have provided an effective co-ordination mechanism and have helped European scientists to make major advances to the understanding of stratospheric ozone depletion, climate-stratospheric
interactions and changing UV levels. As a result, they have significantly contributed to the international Scientific Assessment of Ozone Depletion: 2006, basically concluding that the Montreal Protocol is on track.

**STRATOSPHERIC RESEARCH IN FP6 (2002-2006)**

The following section gives a more detailed overview of the FP6 stratospheric research priorities and the objectives of the ongoing FP6 research projects supported by the European Commission (EC). Stratospheric research was mainly addressed under topic I.5. *Stratospheric Ozone and Climate Interactions* in the Work programme of the Thematic Sub-Priority 1.1.3 Global Change and Ecosystems, as indicated below:

**I.5. Stratospheric Ozone and Climate Interactions**

Research will focus on future stratospheric ozone levels affected by halogens, aerosols, water and greenhouse gas emissions and how physical, radiative and chemical changes in structure and circulation in the global stratosphere will be affected by climate change. UV radiation fluxes reaching the ground and the factors affecting their transfer in the atmosphere as well as the effects of surface pollution, aviation and natural factors on the upper troposphere and lower stratosphere will be studied in the context of ozone-climate interactions.

Under FP6 European Commission supported 3 IPs focusing on ozone-climate interactions and UV radiation (*SCOUT-O3*, Stratospheric-Climate Links with Emphasis on the Upper Troposphere and Lower Stratosphere), on quantifying the impact of emissions from the transport sector on climate and ozone depletion (*QUANTIFY*, Quantifying the Climate Impact of Global and European Transport Systems) and on atmospheric observations (*GEOMON*, Global Earth Observation and Monitoring of the atmosphere), respectively. In addition, IP *GEMS* (Global and regional Earth-system (Atmosphere) Monitoring using Satellite and in-situ data) has a work package on the assimilation of gas-phase chemical species in the stratosphere and troposphere, and the project *DYNAMITE* (Understanding the Dynamics of the coupled Climate System) has a component which investigates the Troposphere/Stratosphere coupling. Please note that the financial volume of some IPs exceeds that of FP5 research cluster (for details see Table 1).

Furthermore, the European Commission funded a number of Specific Support Actions (SSAs) to underpin stratospheric research and relevant policies. *ATTICA* (European Assessment of Transport Impacts on Climate Change and Ozone Depletion) was designed to assess the impact of the transport sector (aviation, land traffic, shipping) on climate change and ozone depletion, and the *HCFC-Workshop* (5-6 April 2008, Montreal) should help to find ways to reduce and early phase-out HCFCs consumptions and emissions. Furthermore, the EC also contributed to the Quadrennial Ozone Symposium 2004 (Kos, Greece, 1-8 June, 2004).

**Core objectives of SCOUT-O3**

The aim of this project is to study and predict the evolution of the coupled chemistry/climate system with emphasis on reliable prediction of the future evolution of the ozone layer and surface UV. Forecasts will be build on refined and improved models by exploiting existing data for model testing and validation and by provision of new data on fundamental processes. In order to meet these goals, 10 project activities have been defined:

- Determination of air residence time (with major field campaign)
- The influence of clouds on the tropical UTLS (with major field campaign)
- Understanding the stratospheric water vapour trend and its consequences
- The stratospheric aerosol layer – role of TTL and possible changes
- Past UV changes, variability and trends
- Ozone variability and past changes at mid-latitudes
Inter-annual variability in polar processes and likely changes in a changing atmosphere
Improved understanding of the Brewer-Dobson and general stratospheric circulation.
Stratosphere/troposphere coupling – past and future.
Predictions of ozone recovery, effect on climate change on recovery and the impact of the ozone changes on surface UV.

Campaigns
- Tropical aircraft campaign has been carried out November-December 2005, Darwin, Australia (Russian stratospheric research aircraft M55 Geophysica was contributing).
- Atmospheric research campaign with M55 Geophysica from July 31 to August 18, 2006 in Ouagadougou, Capital of Burkina Faso, West Africa.
- SCOUT-O3 UV radiation and aerosol campaign, Thessaloniki (Greece) July 2006 in Southern Europe.
- Balloon campaigns are planned for 2008.

Core objectives of QUANTIFY
The main goal of QUANTIFY is to quantify the impact of global and European transport systems on climate and ozone depletion for the present situation and for several scenarios of future development. The climate impact of various transport modes (land transport, shipping, and aviation) will be assessed, including those of long-lived greenhouse gases like CO₂ and N₂O, and in particular the effects of emissions of ozone precursors and particles, as well as of contrails and ship tracks.

Several transport scenarios and potential mitigation options will be assessed on a sound common basis to identify the most effective combination of short and long-term measures as input for policy- and industrial decisions. The project aims to provide such guidance by focused field measurements, exploitation of existing data, a range of numerical models, and new policy-relevant metrics of climate change. The project will focus on the following activities:

- Establishment of transport Scenarios and emission inventories.
- Regional dilution and processing (with emphasis on chemical conversion of ship emissions).
- Large –scale chemistry effects (impact of transport emissions on chemical composition for past and present day conditions).
- Long-term measurements of UTLS compounds.
- Aviation, shipping and clouds (generation and modification of clouds by emissions of different traffic modes, with emphasis on cirrus clouds).
- Radiative forcing and climate change (contribution from different modes of transport)
- Development of improved metrics of climate change.
- Synthesis of the results.

Campaigns
- CIRCLE-1 aircraft campaign ship emissions, Brest, June 2007.

Core objectives of GEOMON
The goal of GEOMON is to sustain and analyze European ground-based observations of atmospheric composition complimentary with satellite measurements. It is a first step to build a future integrated European atmospheric observing system dealing with observations of long-lived greenhouse gases, reactive gases, aerosols, and stratospheric ozone. GEMON is a European contribution to GEOSS (Global Earth Observation System of Systems) helping to optimize the European strategy of environmental monitoring in the field of atmospheric composition observations. Furthermore, the project is also relevant for the European GMES (Global Monitoring for Environment and Security) initiative integrating in-situ and satellite measurements. Main activities:
• Unify and harmonise the main European networks of surface and aircraft-based atmospheric measurements.
• Support data gathering at existing networks.
• Co-ordinate and access to data and data-products at a common data centre.
• Integrate surface measurements with those of satellites with emphasis on data gathered by NDACC stations.
• Develop new methodologies to use these data for satellite validation.
• Enable new ground based measurements complementary to satellites.
• Deduce biases and random errors in satellite observations, to identify long-term trends in tropospheric and stratospheric composition related to climate change.

Core objectives of GEMS
The GEMS project will create the first-ever system for operational global monitoring and medium & short range forecasts of atmospheric chemistry and dynamics. Much improved exploitation of the best available satellite and in-situ data will be achieved through assimilation into numerical models. By 2008, GEMS will produce near-real-time & retrospective analyses of greenhouse gases, reactive gases and aerosols in the troposphere and in the stratosphere on the regional and on the global scale. GEMS covers the atmospheric theme within the GMES initiative of the EC, and GEMS data products will provide valuable new analysis & forecast products for the GMES Service Element. Focus is on:
• Global Greenhouse Gases.
• Global Reactive Gases.
• Aerosols.
• Regional air quality.
• Data assimilation and production.
• Data validation.

Core objectives of DYNAMITE
The aim of the project is deepen the understanding of strongly and weakly coupled processes underlying the natural variability of ENSO and NAO/AO. It will evaluate the representation of the coupled processes underlying ENSO and the NAO in state-of-the-art models used to predict climate change. Furthermore, it will advance understanding of the response of ENSO and NAO/AO to climate change and will assess the role of ocean biology in the variability of the tropical coupled climate system, including ENSO. The coupling between the Troposphere and Stratosphere forms part of the modelling activity as indicated below:

• To quantify strongly and weakly coupled processes underlying the natural variability of ENSO and NAO/AO.
• To evaluate the representation of the coupled processes underlying ENSO and the NAO in state-of-art models used to predict climate change including tropospheric/stratospheric coupling.
• To identify the response of ENSO and NAO/AO to climate change.
• To quantify the role of ocean biology in the variability of the coupled climate system, including ENSO.

Core objectives of ATTICA
The SSP ATTICA will provide a coherent series of assessments of the impact of transport emissions on climate change and ozone depletion. Three assessments will cover the emissions of single transport sectors (aviation, shipping, land traffic). Another assessment will deal with metrics that describe, quantify, and compare in an objective way the effects of the transport emissions in the atmosphere. Finally, the synthesis will summarise the key results of the individual reports in a coherent way, considered as a reference document for stake holders and environmental policy makers.
Core objectives the HCFC workshop
The international HCFC workshop, scheduled for 5-6 April 2008, Montreal, Canada, is focusing on the reduction of HCFC consumption in developing countries between now and 2015. Furthermore, it will identify ways to further reduce consumption and dependence on HCFCs between 2016 and 2040. Specifically, the workshop will provide developing country stakeholders with the technical tools and needed to phase-out HCFCs (e.g., information on viable alternatives, technology transfer, funding opportunities) and to build consensus among stakeholders on next steps for this important issue that faces all of the Parties to the Montreal Protocol.

STRATOSPHERIC AND UV RESEARCH IN THE 7TH FRAMEWORK PROGRAMME (FP7, 2007-2013)

UV and stratospheric research will remain a priority in FP7, mainly implemented under Theme 6: Environment (including Climate). More general speaking, research under the Environment theme 6.1 Climate Change, Pollution and Risks will support the implementation of relevant international environmental commitments, protocols, and initiatives concluded by the European Union and its Member States, such as the UN Framework Convention on Climate Change (UNFCCC) and the Kyoto and Montreal Protocols, respectively. Research is considered as an essential component in the increasing efforts of the European Commission to combat climate change and stratospheric ozone depletion. Furthermore, health risks associated with changing UV radiation levels will be investigated under Activity 6.2 Environment and Health.

Please note that Programme 9. Space under the GMES initiative also supports a topic on 'pilot services atmosphere in new application fields' which includes stratospheric aspects.

In preparation of FP7 the European Commission had established a Science Panel on Atmospheric Research to discuss and prioritize research needs. As a results a report has been prepared and was published, entitled “Atmospheric Change and Earth Science AIRES III: Research challenges” (EUR 21465). The report indicates a number of topics (given below) which should receive high priority in FP7. Most of them include UV and stratospheric research aspects:

1. Bio-geochemical cycles and climate
2. Atmospheric self-cleansing capacity
3. Lower-middle atmosphere interactions
4. Aerosols, clouds and water cycle
5. Global change and radiation transfer
6. Air quality, megacities and global change

Consequently, in the first call of FP7, Programme 6. Environment (2006/2007), the European Commission has opened a topic on megacities, air quality and climate. As a result of this call two projects will be funded. Furthermore, in response of the first call of Programme 9. Space, one project on atmospheric data services, closely linked to IP GEMS will be supported.

The second FP7 call (Programme Environment) has been launched end of November 2007, deadline 25 February. It included two topics which are directly relevant for UV and stratospheric research. It is expected that for each topic at least one project will be funded. Headlines and research objectives are described below:
Area 6.1.1.2 Emissions and Pressures: Natural and anthropogenic

ENV.2008.1.1.2.1. Climate-chemistry interactions in the stratosphere related to ozone depletion
Anthropogenic emissions of chemical species have altered the atmospheric composition with long lasting impacts and consequences such as changing air quality, the forcing of climate change and stratospheric ozone depletion. Climate change in turn is affecting atmospheric chemistry with many unknown feed-back mechanisms and may further delay ozone recovery. Changes in stratospheric composition need to be detected. Research should help to better understand stratospheric dynamics, trends and processes of stratospheric composition changes, the role of climate-chemistry interactions, including the dynamical response of the stratosphere to the chemical composition changes, and its impact on stratospheric ozone depletion. Feed-back mechanisms between climate change and stratospheric processes need to be better understood in order to predict the future evolution of ozone abundance. Standard climate change scenarios should be applied to assess the impact on the future evolution of stratospheric composition and its impacts on the climate.

Area 6.1.2.1 Health effects of exposures to environmental stressors

ENV.2008.1.2.1.5. Quantification of changing surface UV radiation levels and its impact on human health
The overall aim is to better characterise changing UV exposure in relation to important leisure (skiing, beach) and working activities in Europe and to assess its impact on human health (e.g. immune response) including risk/ benefit estimations. Furthermore, improved measurement techniques and radiative transfer models should be developed to better represent radiation in climate models and for prediction of future UV levels. Spectral radiance distribution at ground level under changing climate and atmospheric composition condition should be quantified, taking into account e.g. the role and interference of clouds and atmospheric pollution at ground level.

Projects finally supported under these topics will ensure continuation of UV and stratospheric research at European level, also maintaining a critical mass essential for future contributions to international ozone and UV assessments.

FUTURE ACTIVITIES

The complexity of the atmospheric processes, the scale of the scientific problems and the potential devastating impact on humans and the ecosystems caused by climate change, stratospheric ozone depletion and changing UV radiation require real interdisciplinary research collaboration. This has already started under the 5th and 6th Framework Programmes and, as indicated above, and will continue in the 7th Framework Programme. The AIRES III report points to the need to consolidate and strengthen these efforts to establish a solid scientific basis for developing policy options to protect the stratospheric ozone layer and the climate system. The European Commission will largely follow the suggestions as indicated in the AIRES report and will implement these topics in the cause of FP7.

Moreover, the European Commission is prepared to take new challenges onboard. In particular, the ongoing discussions regarding new laboratory measurements and (contradicting) results related to chlorine monoxide dimer absorption cross section are of concern. If the new laboratory results proof to be correct, than there is a serve lack of understanding of the polar stratospheric ozone loss rate. In 2007 a number of consultations and meetings have taken place on this pending issue. In any case, depending on the outcome of these discussions, the European Commissions is prepared to address this scientific problem in a coming call.
Table 1: Relevant research projects supported under FP6

**SCOUT-O3 (Stratosphere-Climate Links With Emphasis On The UTLS)**
Co-ordinator: Prof. John Pyle, University of Cambridge, UK
Budget: 15.000.000 €
Starting date: 1 May 2005                Duration: 5 years
Web-link: http://www.ozone-sec.ch.cam.ac.uk/scout_o3/index.html

**QUANTIFY (Quantifying the Climate impact of Global and European Transport Systems)**
Co-ordinator: Prof. Robert Sausen, DLR, DE
Budget: 8.388.172 €
Starting date: 1 March 2006              Duration: 5 years
Web-link: http://www.pa.op.dlr.de/quantify/

**GEMON (Global Earth observation and monitoring of the Atmosphere)**
Co-ordinator: Prof. Philippe Ciais, CEA, FR
Budget: 6.621.740 €
Starting date: 1 February 2007             Duration: 4 years
Web-link: http://geomon.ipsl.jussieu.fr/

**GEMS (Global and regional Earth-system (Atmosphere) Monitoring using Satellite and in-situ data)**
Co-ordinator: Dr. Adrian Simmons, ECMWF, UK
Budget: 12.450.000 €
Starting date: 1 March 2005               Duration: 4 years
http://www.ecmwf.int/research/EU_projects/GEMS/

**DYNAMITE (Understanding the Dynamics of the Coupled Climate System)**
Co-ordinator: Prof. Helge Drange, NERSC, NO
Budget: 2.000.000 €
Starting date: 1 March 2005               Duration: 3 years
Web-link: http://dynamite.nersc.no

**ATTICA (European Assessment of the Transport impacts on Climate and Ozone Depletion)**
Co-ordinator: Prof. Robert Sausen, DLR, DE
Budget: 680.000 €
Starting date: 1 June 2006                  Duration: 3 years 6 months
Web-link: http://www.pa.op.dlr.de/attica/

**HCFC workshop**
Co-ordinator: ICF international
Budget: 300.000 €
Starting date: 1 January 2007           Duration: 1 year 6 months
The HCFC workshop is scheduled for 5-6 April 2008, Montreal, Canada

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FINLAND

OBSERVATIONAL ACTIVITIES

Column measurements of ozone and other gases/variables relevant to ozone loss
The discovery of the Antarctic "ozone hole" in the mid 1980s initiated several ozone monitoring activities also at northern high latitudes. In Finland, ozone column monitoring has been carried out by the Finnish Meteorological Institute at Sodankylä (67.4°N, 26.6°E) since 1988 and at Jokioinen (60.5°N, 23.3°E) since 1994. At both stations an automated system based on Brewer spectrophotometer is continuously operated. At Sodankylä Arctic research centre (FMI-ARC) wintertime ozone columns are also monitored with a SAOZ spectrophotometer which is operated in cooperation with CNRS-Paris already since 1990. The SAOZ measurements also provide NO₂ and OCIO column amounts. This instrument works at large solar zenith angles and is thus capable of measurements during the wintertime at high latitudes. Multiyear ozone measurements from both stations have shown large inter-annual variations, in addition significant ozone loss has been observed in the Arctic stratospheric vortex during several years since early 1990s. In 2006 and 2007 FMI hosted at Sodankylä a NASA lead comparison/validation campaigns aiming to achieve < 1% total ozone measurement accuracy in both ground based and satellite based platforms. Sub-percent accuracy is needed for reliable monitoring of the effects of Montreal protocol.

Profile measurements of ozone and other gases/variables relevant to ozone loss
Ozone soundings has been carried out since 1989 at Sodankylä where balloon ozone sensor measurements are carried out regularly throughout the year, while in Jokioinen these measurements are conducted during winter and spring when chemical ozone depletion is expected.

Another long-term initiative at FMI-ARC related to stratospheric ozone is the measurements of polar stratospheric cloud (PSC) properties. PSCs play an essential role in chlorine activation and subsequent ozone depletion. PSCs are generally divided in two types based on their optical parameters, type II are large particles of primarily water ice, type I are typically smaller particles of nitric acid trihydrate or supercooled ternary solution droplets. At Sodankylä these stratospheric cloud particles have been observed during stratospheric campaigns since 1991/1992 by lidar and since 1994 by aerosol backscatter sondes.

At Sodankylä, since December 2002, stratospheric humidity is monitored in winter months using Cryogenically cooled Frost point Hygrometer (CFH) from university of Colorado and/or alpha-lyman hygrometers developed at Central Aerological Observatory of RosHydromet. Already earlier, in January 1996 an Arctic dehydration event was recorded and investigated at Sodankylä using NOAA/CMDL hygrosonde, a predecessor of CFH. FMI has also hosted an international intercomparison campaign of lightweight hygrosondes in January-February 2004.

The national meteorological institutes in Finland (FMI) and Argentina (SMN) started a joint ozone research program in 1987, including total ozone measurements at Marambio (64.1°S, 56.4°W), Antarctica. In 1988 routine ozone soundings were started at Marambio. Recently FMI and SMN have started Aerosol optical depth and radionuclide measurements at Marambio.

UV measurements

Broadband measurements
FMI operates SL501 broadband instruments at six sites in Finland. These instruments provide on-line information on the erythemal irradiance that is published through the internet along with the UV-Index forecast.

Narrowband filter instruments
FMI cooperates with Argentina and Spain on Antarctic ozone and UV. In 1999 the collaboration was extended to include UV radiation research. The established UV monitoring network consists of NILU-UV instruments in Marambio, Belgrano and Ushuaia, and a travelling reference. In
Sodankylä a NILU-UV radiometer has been used to measure UV radiation of a reference field within a large field experiment of FUVIRC (Finnish Ultraviolet International Research Center). One NILU-UV, in Helsinki, has been acquired for campaign use.

Spectroradiometers
FMI has measured spectral UV irradiance with Brewer instruments in Jokioinen (Mark III since 1995) and Sodankylä (Mark II since 1990). Additionally, a Bentham DM150 has been acquired for campaign use, as well as, more recently, a new diode array spectroradiometer SP-J1009.

Calibration activities
FMI has dark room UV calibration facilities both in Jokioinen and Sodankylä. FMI has participated in several UV measurement comparison campaigns, where it has been established that the quality of Finnish Brewer measurements is excellent and steady. The Brewer instrument of Jokioinen served as one of the core instruments of the QUASUME project (Quality Assurance of Spectral Ultraviolet Measurements in Europe). FMI is also responsible for calibration of the Antarctic NILU-UV instruments and data quality assurance. Brewer ozone measurements in Jokioinen and Sodankylä are calibrated by annual visits of a travelling Brewer standard instrument, which in turn is calibrated against the Brewer Triad at Toronto.

Satellite observations and instrument development
FMI has a strong participation in three satellite instruments that are targeted for monitoring ozone in the atmosphere (GOMOS/Envisat, OSIRIS/Odin, OMI/EOS-Aura). The GOMOS instrument onboard the ESA’s Envisat satellite has been operating since spring 2002. Ozone profiles that cover the altitude range from upper troposphere to lower thermosphere during years 2002-2007 are already available.

The OSIRIS instrument onboard the Swedish small satellite Odin has measured ozone profiles since 2001. The ozone profiles are processed also at FMI and during the last years the validation and optimization of the algorithms have taken place.

The Dutch-Finnish OMI instrument onboard the NASA’s EOS-Aura satellite has measured total ozone columns since 2004. FMI is hosting the OMI UV irradiance processing and archiving facility and the validation of the ozone and UV products are ongoing. In addition, local maps of total ozone columns and UV irradiance covering Central and Northern Europe are processed at FMI. These Very Fast Delivery products exploit the Direct Broadcast antenna at Sodankylä, Northern Finland. The total ozone and UV irradiance maps are available in the Internet (omivfd.fmi.fi) within 15 min after the overpass of the satellite.

To continue the high resolution ozone profile measurements of OSIRIS and GOMOS instruments FMI proposed the OLIVIA (Occultation and limb viewing of the atmosphere) instrument to the ESA Earth Explorer program in 2005.

RESULTS FROM OBSERVATIONS AND ANALYSIS

Only Brewer UV measurements are considered to have a sufficient quality for assessment of long-term changes. The smaller the change is the longer time series is required for detection of it. A study on the Sodankylä UV time series 1990-2001 revealed no consistent trend during this 12 year period. An increase in UV radiation was observed in early 1990s and then a decrease towards the end of the period with the largest values occurring in 1993 and after the cold winters of mid 1990s. These observations are consistent with the ozone layer development in the same period.

Ozonesonde observations have been conducted in Sodankylä since 1989. This data along with the data from other Arctic stations have been analyzed. It was found that during the recent decades the largest ozone changes in the stratosphere and troposphere have occurred in the late winter/spring period. The observed negative trend in the stratosphere prior to 1996-1997 can be attributed to the combined effect of chemical and dynamical changes, while the observed increase since then is primarily due to the dynamical changes. In the troposphere, trends have been positive
regardless of the chosen time period. This may be related to the long-term changes in Arctic oscillation as it regulates the transport of ozone and its precursors from industrialized regions towards the pole and it may also modulate stratosphere-troposphere exchange.

Water vapour changes in the UTLS have a large impact on the climate system. Yet the accurate measurements of the UTLS water vapour remain a technological challenge. FMI hosted a major field campaign of comparison of light-weight instruments capable of water vapour measurements in the upper troposphere and lower stratosphere. This campaign led to better understanding of the accuracy of the in situ instruments and contributed to significant improvement of the technology. In addition, the data provided a unique opportunity to study meteorological processes in the lower stratosphere and upper troposphere.

**THEORY, MODELLING, AND OTHER RESEARCH**

The modelling activities related to middle atmospheric ozone includes the use of a global 3D chemistry transport model of the stratosphere and mesosphere (FinROSE-ctm), a global chemistry coupled climate model covering the altitude range from the surface to ca. 250 km (HAMMONIA) and a model of the ionosphere (Sodankylä Ion Chemistry model). The modelling work includes both studies of long term trends of stratospheric ozone utilizing reanalyzed meteorological data (ERA-40) as well as process studies (PSC, chlorine activation, ozone loss rates). Also trajectory modelling is utilized for studying the ozone and water vapour distribution in the UTLS region and for determining ozone loss rates from sounding campaign measurements (e.g. the International Polar Year Antarctic Match campaigns). The scientific use of satellite measurements is increasingly important and an assimilation system combining OSIRIS and GOMOS profile data with a CTM model has been developed. In addition, the impact of solar proton events on the stratosphere and mesosphere is studied. In this study the unique night time ozone profile measurements of the GOMOS instrument are used. GOMOS data is also used for studying turbulence and gravity waves in the stratosphere.

FMI has developed models for reconstruction of the past UV time series as well as for assessment of the future UV levels. These data are essential for assessment of the long-term changes in surface UV. FMI contributed to the Arctic Climate Impact Assessment (ACIA) with a shared lead authorship of the chapter on ozone and UV. FMI has participated in multidisciplinary research projects that aim at better understanding of the effects of increased UV exposures on human health, terrestrial and aquatic ecosystems, or materials.

FMI coordinates the research project UVEMA exploring the Effects of UV radiation on Materials. The study focuses on rubber compounds, natural fibre composites and carbon fibres provided by the industrial partners of the project. A program of long-term outdoor material testing has been set up at seven European sites, including Jokioinen Observatory and Arctic Research Centre at Sodankylä. Prevailing UV radiation and weather conditions are being monitored alongside with the program at each station. Exposed material samples will be investigated in respect of various properties: colour, quality/coarseness of the surface and compression/flexural/tensile strength. As an outcome, more reliable estimates for the useful life-time of the materials are to be gained.

FMI Arctic Research Centre at Sodankylä hosts the experimental fields of FUVIRC-experiment (Finland UV International Research Centre) to study biological impacts of UV-B radiation to boreal plants at enhanced UV-radiation condition. There are two experimental sites representing typical landscape types of northern Fennoscandia, a boreal pine forest test field and peat land test field. Enhancement of the ambient UV-exposure can be regulated to desired values through extensive monitoring and control system. The field serves atmospheric chemistry, human health, and biological research initiatives by providing extensive UV monitoring data, guidance (i.e. calibration of instruments, maintenance of field test sites), and research facilities (i.e. laboratories, instruments, equipment and accommodation for visiting researchers).
DISSEMINATION OF RESULTS

Data reporting
FMI has participated in the Global Atmospheric Watch (GAW) programme since 1994. Within the program, FMI maintains the Pallas-Sodankylä GAW station and conducts an extensive research programme related to atmospheric aerosols. Within this twin GAW station surface and boundary layer measurements are done in FMI clean air site of Pallas while upper air measurements, UV and Ozone monitoring takes place at Sodankylä (fmiarc.fmi.fi). In upper air research Sodankylä functions as an auxiliary station in the global Network of Detection of Atmospheric Composition Change (NDACC).

FMI maintains the European UV Database (EUVDB). EUVDB is a regional WMO database containing some two million UV spectra (uvdb.fmi.fi/uvdb/). The UV spectra of the two Finnish Brewer instruments are submitted to EUVDB.

Regular ozone soundings have been performed at Marambio since 1988, the ozone data is sent to two international databases at the World Ozone and Ultraviolet Data Centre (WOUDC, Toronto, www.woudc.org) and the Norsk institutt for luftforskning (NILU, Oslo, www.nilu.no/nadir/). Furthermore, the UV measurements are available at polarvortex.org. Both the ozone and UV measurements are used in scientific publications, and form a significant contribution to the WMO ozone bulletins (www.wmo.ch).

Information to the public
FMI provides a 2-day forecast of the UV Index in Europe (www.fmi.fi/uvi). The forecast, which is published in the internet, includes a contour map of the local solar noon maximum clear sky maximum UV Index. Additionally, local clear sky UVI forecast is provided for several sites in Finland and Europe. The Finnish broadband UVI measurements are also incorporated in the web page. FMI has actively participated in increasing the awareness of general public on the health effects of UV radiation. In addition, FMI contributed to the Arctic Climate Impact Assessment (ACIA) document with a shared lead authorship of the chapter on ozone and UV.

Ozone depletion has a large public interest due to related health (UV) and environmental issues, e.g. the unprecedented stratospheric conditions and severe ozone loss in the winter and spring 2004/2005 triggered a wide interest in the Finnish media. The major scientific results are published in international refereed journals and are also presented at relevant international conferences. Popularized information is distributed through press releases and interviews. Information about research activities as well as measurements and analysis results are also available through FMI web pages; Arctic and Antarctic research at FMI, www.fmi.fi/research_polar/polar.html, FMI-ARC observations and analyses, fmiarc.fmi.fi, Remote sensing projects and general Ozone and UV related information, www.fmi.fi/research_atmosphere/atmosphere.html.

Recent relevant scientific papers


Yushkov, V., A. Lukyanov, S. Khaykin, L. Korshunov, R. Neuber, M. Mueller, E. Kyrö, R. Kivi, H. Vomel,, I. Sasano, H. Nakane, Vertical distribution of water vapor in Arctic stratosphere based on LAUTLOS field


PROJECTS AND COLLABORATION

The major national funding organisations are the Academy of Finland and the National Technology Agency of Finland. The Antarctic research related to ozone and UV and the as well as the research of the impact of solar proton events on stratosphere and mesosphere is partly funded by the Academy of Finland. FMI collaborates with Finnish Universities on atmospheric modelling and developing data retrieval methods and assimilation techniques for the GOMOS and OSIRIS instruments.

- FARPOCC (Finnish Antarctic Research Programme on Polar Climate Change, [www.fmi.fi/research_polar/polar.html](http://www.fmi.fi/research_polar/polar.html))
- MAIST (Middle atmospheric interactions with sun and troposphere)
• FUVIRC (Finnish Ultraviolet International Research Center, fuvirc.oulu.fi/index.htm)
• MUTUAL (Multiproxy Approach to Estimate Changes in UV Exposure in Arctic Lakes, www.helsinki.fi/bioscience/ecru/projects/mutual.htm)
• UVEMA (Effects of UV radiation on Materials, uvema.fmi.fi/)

FMI has participated in several EU funded Arctic and Antarctic research projects including tasks such as stratospheric modelling and measurement campaigns. The modelling activities include cooperation with the Max Planck Institute, Hamburg and National Center for Atmospheric Research, USA. Sodankylä has participated in all major European stratospheric ozone campaigns. In 1999, 2003 and 2007 the Marambio activities formed an important part of the international stratospheric ozone research campaigns. In addition, FMI takes part in several activities organized during the International Polar Year 2007/2008.

• QUASUME (Quality Assurance of Spectral Ultraviolet Measurements in Europe)
• RETRO (REanalysis of the TROpospheric chemical composition over the past 40 years, retro.enes.org/)
• CANDIDOZ (Chemical and Dynamical Influences on Decadal Ozone Change)
• SCOUT-O3 (Stratospheric-Climatic Links with Emphasis on the Upper Troposphere and Lower Stratosphere, www.ozone-sec.ch.cam.ac.uk/)
• PROMOTE (PROtocol MOnItoring for the GMES Service Element, www.gse-promote.org/)
• ACIA (Arctic Climate Impact Assessment, www.acia.uaf.edu/pages/scientific.html)
• COSMOS (Community Earth System Models, cosmos.enes.org)
• SAUNA (Sodankylä total column ozone intercomparison)

FMI is coordinating the EUMETSAT Satellite Application Facility on Ozone Monitoring (O3M SAF, o3saf.fmi.fi). O3M SAF is one of the SAFs in EUMETSAT SAF network. SAFs are specialised development and processing centres within the EUMETSAT Application Ground Segment (www.eumetsat.int). O3M SAF is developed in co-operation with Koninklijk Nederlands Meteorologisch Instituut (KNMI), Deutsche Zentrum für Luft- und Raumfahrt (DLR), Deutscher Wetterdienst (DWD), Aristotle University of Thessaloniki (LAP), Hellenic National Meteorological Service (HNMS), Danish Meteorological Institute (DMI), Meteo-France (M-F) and Koninklijk Meteorologisch Instituut (KMI).

The purpose of the O3M SAF is to produce a set of near real-time and offline products and validation services. Near real-time products are GOME-2 total ozone and ozone profiles, HIRS total ozone and UV clear-sky fields. Offline products derived from GOME-2 data are total column amounts of ozone, NO₂, BrO, ozone profiles, aerosol index and optical depth and UV fields including cloudiness and albedo. The ozone and UV data will be validated against ground-based observations of total ozone and UV as well as balloon borne, microwave and lidar observations of the vertical distribution of ozone. An important part of the O3M SAF activities has been related to scientific work to develop radiative transfer calculation methods and other algorithms used for satellite ozone and related data retrieval.

The Satellite Data Centre of FMI-ARC started in 2002. The activities include a processing facility for the GOMOS/Envisat ozone instrument. The FMI-ARC data centre also process part of the OSIRIS/Odin ozone data. Data reception from the EOS-Aura satellite is also going on for Very Fast Delivery products of the total ozone and UV irradiance maps, available within 15 min after the overpass of the satellite. The Centre is also responsible of reception of OMI data used in near real time O₃ and UV-products.

FMI also hosts the WMO IGACO (Integrated Global Atmospheric Chemistry Observations) Ozone secretariat (www.igaco-o3.fi). IGACO is the atmospheric chemistry component in the Integrated Global Observing Strategy (IGOS). One of the objectives of IGACO strategy, implemented through the GAW programme of WMO, is to ensure long-term continuity and spatial comprehensiveness of atmospheric composition observations, both in the troposphere and the stratosphere.
FUTURE PLANS

Although the basic processes related to stratospheric ozone are now fairly well understood, there remain important research topics related to ozone and UV, such as the interaction between ozone depletion and climate change and the effects of increased UV-irradiance on nature and materials. According to the present understanding the recovery of the ozone layer will take several decades, therefore it is desirable that the research activities will be continued and developed.

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FRANCE

Ozone and UV radiation research in France is managed by the CNRS – Institut National des Sciences de l'Univers (INSU) under a dedicated Programme called Chimie Atmosphérique (CHAT). Long term monitoring activities relevant to the Network of Atmospheric Composition Changes (NDACC) are coordinated by the Institut Pierre Simon Laplace (IPSL). Space and balloon components are managed by the Centre National d’Etudes Spatiales (CNES). Additional contributions are provided by the Institut Paul Emile Victor (IPEV), Météo-France, the Ministère de l’Ecologie et du Développement Durable, the Ministère de la Recherche, the Institut National de Recherche Agronomique (INRA) and a number of Universities. Many of the above programmes are also supported by the European Commission under the 6th and 7th Environmental Work Programmes.

The research include the long term monitoring of the stratosphere and surface UV-B radiation in the frame of NDACC at a variety of sites, the study of ozone depletion in polar areas, at mid-altitude and in the tropics using balloon, aircraft and space borne instruments, most of them being operated in cooperation with other European and international institutes.

OBSERVATIONAL ACTIVITIES

Ground-based

France is running two primary stations of the NDACC at the Observatoire de Haute Provence (OHP) and the Antarctic stations of Dumont d’Urville (DDU) and Dome Concordia, a complementary site at Reunion Island in the Indian Ocean and a number of instruments at other locations in cooperation with local institutes: a lidar at Alomar in Norway and the SAOZ UV-Vis spectrometers at Scoresbysund (Greenland), Sodankyla (Finland), Salekhard and Zhigansk (Federation of Russia), Bauru (Brazil), Tarawa (Republic of Kiribati) and Kerguelen Island.

The list of instruments at OHP includes a series of lidar for stratospheric temperature, aerosol, stratospheric and tropospheric ozone and water vapour, a SAOZ UV-Vis spectrometer, a BrO UV spectrometer of IASB-BIRA in Belgium, an automated Dobson from NOAA, weekly ozonesondes and a spectral UV-B spectro-photometer.

In Antarctica, the instruments operating since 1988 are a PSC / aerosol lidar in cooperation with the Italian CNR, a SAOZ, a UV-B monitor and ozonesondes at Dumont d’Urville. The ozone lidar closed in 2001, has been replaced in 2008. An additional SAOZ is in operation since 1995 at the sub-Antarctic Island of Kerguelen. In addition a SAOZ and ozone soundings have been implemented at the inland French-Italian station of Concordia in 2007.

At the tropical site of Reunion Island, the instruments operating are a temperature / aerosol lidar, stratospheric and tropospheric ozone lidars, a SAOZ and weekly ozone sondes. A high altitude station is under construction at Mâldo at 2500 m asl for hosting all previous instruments after 2010 together with a microwave radiometer for water vapour profile measurements and a FTIR operated by the Belgian IASB-BIRA.

France is also responsible for the temperature lidar measurements at the Norwegian-German lidar station of ALOMAR in Norway.

Part of the data (SAOZ ozone / NO₂ and ozonesondes) are made available in near real time to WMO and to the European data base at the Norwegian Institute for Air Research (NILU) for research programmes and satellite validation. They are made publicly available after reprocessing through the NDACC archive centre. The SAOZ data together with the lidar measurements at OHP and Dumont d’Urville are also part of the GEOmon European project, started in 2007 and which has for objective to harmonize ground-based European observations related to greenhouse gases, air quality, aerosols and stratospheric ozone.
Summary of Ground-based observations

**Column measurements of ozone and other gases /variables relevant to ozone loss**
SAOZ Ozone and NO2 at Scoresbysund (Greenland), Sodankyla (Finland), Sialkhkard (W. Siberia- , Zhigansk (E. Siberia), OHP (France), Bauru (Brazil), Reunion Island (France), Kerguelen (France) and Dumont d'Urville (Antarctica)
Dobson at OHP

**Profile measurements of ozone and other gases /variables relevant to ozone loss**
Stratospheric Ozone lidar at OHP, Dumont d'Urville (Antarctica) and La Reunion Island
Ozonesondes at OHP, Reunion Island, Dumont d'Urville and Concordia
Stratospheric temperature lidar at at OHP, Reunion Island and Alomar (Norway)
Aerosol lidar at OHP, Reunion Island and Dumont d'Urville
Tropospheric ozone lidar at OHP and Reunion Island

**UV measurements**
Broadband measurements at Dumont d'Urville (Antarctica)
Spectroradiometers at Villeneuve d'Asq and OHP (France)

**Calibration activities**
NDACC intercomparison campaign of UV-Vis instruments in Norway, and ozone lidar intercomparison at OHP.

**Satellites**
Relevant to stratospheric ozone research, a variety of space activities have been carried out in France under the auspices of CNES:

- The analysis of the measurements of the SMR instrument (ozone, water vapour and ClO) on board the Swedish-Finnish-Canada-French ODIN satellite placed in orbit in 2001 and still operating.
- The exploitation of the data of the French initiated GOMOS instrument on board the ESA ENVISAT satellite in orbit since March 2002, and more generally a participation to that of both other stratospheric chemistry instruments MIPAS and SCIAMACHY.
- A strong involvement in the validation of the measurements of GOME-ERS-2, ODIN, ENVISAT, OMI and Aura-MLS from ground based and dedicated balloon flights measurements in the Arctic, at Mid-latitude and in the tropics.
- The derivation of ozone total and partial columns from the IASI instrument on board METOP, the European meteorological polar platform launched in 2006. Several algorithms have been designed for the ozone products, which are currently validated.

In addition, Météo-France is contributing to the EUMETSAT's Ozone Monitoring Satellite Application Facilities hosted by the Finnish Meteorological Institute. This facility delivers ozone and minor constituents’ products derived from the GOME-2 and HIRS instruments on board METOP. The derivation of ozone columns in the lower stratosphere from METEOSAT Second Generation and for METOP/HIRS is the specific contribution of Météo-France.

**Aircraft**
The two French research aircrafts have been renewed for an ATR 42 and a Falcon 20, both have started operating in early 2006. France is also running since 1993 in cooperation with other European institutes and with support of the European Commission, the MOZAIC programme of in situ ozone, water vapour and NOy (since 2002) measurements on in-service commercial aircraft, from which tropospheric ozone climatology are derived at a number of airport worldwide.

**Balloons**
The French contribution to stratospheric balloon activities is twofold: CNES balloon operations in France, Sweden and Brazil for a number of European and international scientists, and development of scientific instruments designed for ozone related research at French laboratories.
The balloons used during the past several years include large open stratospheric balloons carrying heavy (500-600 kg) payloads for few hours (20 flights/year), small flexible and cheaper balloons which could be flown more frequently particularly in the Arctic in the winter for studying fast chemical changes (20 flights/year) and long duration balloons of two types: Infra-Red Montgolfier carrying 60 kg at 25 km flown for few weeks in the Arctic or in the tropics, and constant level super-pressure balloons carrying 20 kg at 19 km for few weeks.

Stratospheric chemistry instruments developed in France include: a FTIR (LPMA) for measuring profiles of long lived, reservoir and radical species; a tuneable diode laser system (SPIRALE) for the in-situ measurement of nitrogen and chlorine compounds; a star occultation UV-Visible spectrometer (AMON) for the night-time measurement of O3, NO2, NO3 and OCIO; an aerosol particle counter (STAC) and several light weight instruments flown more frequently on small balloons together with other European instruments at a variety of sites: the SAOZ UV-visible spectrometer for O3, NO2, BrO and OCIO by solar occultation; the SALOMON moon occultation version; the SDLA diode laser for in-situ CH4, CO2 and water vapour; and the Rumba meteorological payload for long duration balloons.

Most recent balloon campaigns relevant to stratospheric dynamics and chemistry were:

- an ESA-CNES ENVISAT validation campaigns of 5 large balloon flights in Teresina, Northern Brazil in June-July 2005;
- a VORCORE project of 20 long duration constant level balloons in September 2005 in Antarctica for studying the dynamics of the stratospheric polar vortex.

Data interpretation, exchange and archival
The data are analysed through many cross-exchanges with international scientists and particularly Europeans within cooperative projects. French institutes have also developed a full set of models ranging from Lagrangian, 3-D chemical transport (CTM), contour advection, meso-scale and chemistry climate models (CCM). The simulations of the ozone layer in the 21st century by the LMDz-Reprobus CCM have been involved in the last WMO ozone assessment published in 2007. While the experimental data as well as the results of simulation relevant to European projects are archived into the NILU data base available through appropriate protocols, all French space and field data relevant to the stratosphere are archived into a newly built national data base ETHER.

RESULTS FROM OBSERVATIONS AND ANALYSIS

A number of studies are being conducted based on the above observational data frequently in collaboration with foreign scientists and particularly European institutes within projects supported the European Commission. Among those studies, two are highlighted here as an illustration:

Figure 1 shows the results of the yearly evaluation of total ozone loss in the Arctic stratosphere since 1993 from the SAOZ ground based network illustrating the large inter-annual variability of the ozone destruction in relation with the meteorology of the vortex.

Figure 2 shows the validation of ozone profiles retrieved from GOME satellite observations by ground-based lidar measurements performed within NDACC. The satellite ozone profiles were retrieved from neural network algorithms [Iapaolo et al., 2007].
Figure 1: Estimation of amplitude of chemical stratospheric ozone reduction the Arctic during the winter season from the measurements of the SAOZ network. Left: minimum ECMWF temperature north of 60°N at 475 K and 550 K; Right ozone chemical reduction after subtraction of the contribution of transport using a 3D CTM model. [Goutail et al., 2005].

Figure 2: Relative difference between ozone profile measurements from NDACC ground-based lidars and the GOME satellite instrument. The GOME ozone profiles were retrieved with two versions of neural networks (NN1 et NN2).

DISSEMINATION OF RESULTS

Data reporting
The SAOZ (ozone / NO$_2$) and ozonesondes data are made available in near real time to WMO, WOUDC and the ESA and EC databases at the Norwegian Institute for Air Research (NILU). All NDACC relevant data are deposited, after reprocessing, in the NDACC archive centre. In addition
all French space and field data relevant to the stratosphere are archived into the ational data base ETHER.

Relevant scientific papers


FUTURE PLANS

NDACC ground-based observations will be continued at OHP, Reunion Island, Dumont d’Urville and Concordia as well as at the SAOZ stations. The coming NDACC relevant project is the implementation of the high altitude (2500 m asl) Maido station at Reunion Island planned to host most of the instruments presently installed at the campus of the University of La Reunion. The analysis, interpretation and modelling of most of French stratospheric ozone relevant ground-based, satellite, aircraft and balloon observational projects are part of the SCOUT-O3 EU FP6 project (2004-2009) supported by the European Commission and coordinated by the University of Cambridge (UK). The harmonization of data and satellite observations validation are performed within the GEOMON FP6 project (2007-2011).
Ozone-monitoring and ozone-research in Germany is distributed over numerous institutions. Generally, research is carried out at university institutes or research centers (MPI, DLR, FZ-Karlsruhe, FZ-Jülich). Many institutes are deeply involved in the regular monitoring of ozone by several satellite instruments. Ground based long-term observations are provided by DWD and AWI, UV-monitoring by BfS, UBA and DWD. Table 1 gives an overview of the institutes and their activities.

Table 1: Institutes involved in ozone/UV research (R), development (D), modeling (MD), monitoring (MT), quality assessment /quality control (QA/QC).

<table>
<thead>
<tr>
<th>Institute</th>
<th>Location</th>
<th>Field</th>
<th>Keywords</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forschungszentrum Jülich, <a href="http://www.fz-juelich.de/">www.fz-juelich.de/</a></td>
<td>Jülich</td>
<td>R, QA/QC, MD</td>
<td>Calibration O₃-Sonde, JOSIE, ClaMS</td>
</tr>
<tr>
<td>MPI f. Meteorologie (DKRZ), <a href="http://www.dkrz.de/">www.dkrz.de/</a></td>
<td>Hamburg</td>
<td>R, MD, MT, QA/QC</td>
<td>ECHAM</td>
</tr>
<tr>
<td>DLR, DLR/DFD, <a href="http://www.dlr.de/pa/">www.dlr.de/pa/</a></td>
<td>Oberpfaffenhofen</td>
<td>R, MD, MT, QA/QC</td>
<td>GOME, ECHAM, Air-Traffic</td>
</tr>
<tr>
<td>IAP Kühlungsborn, <a href="http://www.iap-kborn.de/">www.iap-kborn.de/</a></td>
<td>Kühlungsborn</td>
<td>R, D, MT</td>
<td>Middle Atmosphere, Alomar,</td>
</tr>
<tr>
<td>Bundesamt f. Strahlenschutz (BfS) <a href="http://www.bfs.de/">www.bfs.de/</a></td>
<td>Salzgitter</td>
<td>MT</td>
<td>UV</td>
</tr>
<tr>
<td>Umweltbundesamt (UBA), <a href="http://www.umweltbundesamt.de/">www.umweltbundesamt.de/</a></td>
<td>Berlin</td>
<td>MT</td>
<td>Air quality</td>
</tr>
<tr>
<td>Uni Bremen, IUP, IFE, <a href="http://www.iup.physik.uni-bremen.de/index.html">www.iup.physik.uni-bremen.de/index.html</a></td>
<td>Bremen</td>
<td>R, D</td>
<td>GOME, SCIAMACHY, MICROWAVE</td>
</tr>
<tr>
<td>Uni Heidelberg, <a href="http://www.physik.uni-heidelberg.de">www.physik.uni-heidelberg.de</a></td>
<td>Heidelberg</td>
<td>R, QA/QC</td>
<td>DOAS</td>
</tr>
<tr>
<td>IMK, Forschungszentrum and University Karlsruhe <a href="http://www-imk.fzk.de">www-imk.fzk.de</a></td>
<td>Karlsruhe, Garmisch-Partenkirchen (IfU)</td>
<td>R, D, MD, MT, QA/QC</td>
<td>FTIR, ENVISAT, LIDAR, CARIBIC, MIPAS</td>
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<tr>
<td>Uni München (LMU) <a href="http://www.meteo.physik.uni-muenchen.de/">www.meteo.physik.uni-muenchen.de/</a></td>
<td>München</td>
<td>R, MD</td>
<td>UV, STAR</td>
</tr>
<tr>
<td>Uni Hannover, Inst. f. Meteorologie <a href="http://www.muk.uni-hannover.de">www.muk.uni-hannover.de</a></td>
<td>Hannover</td>
<td>R</td>
<td>UV</td>
</tr>
</tbody>
</table>
OBSERVATIONAL ACTIVITIES

German agencies are heavily involved at various levels in ongoing satellite measurements of ozone. IMK has co-developed the MIPAS instrument onboard ENVISAT, and is routinely deriving atmospheric profiles of ozone, temperature and many chemical compounds from the MIPAS data. IUP Bremen is a leading partner for the SCIAMACHY instrument on ENVISAT, and for GOME and GOME-2, both for instrument and algorithm development and advanced data processing. DLR is providing much of the ground-processing for several satellite missions and also hosts the World Data Centre for Remote Sensing of the Atmosphere (WDC-RSAT).

Germany’s Meteorological Service (DWD) is running a comprehensive ground-based measurement program at the Observatories Hohenpeissenberg and Lindenberg, monitoring the ozone vertical distribution and total ozone columns on a regular and long-term basis (Table 2). Special efforts are put into high quality and long-term consistency. The time series cover up to 41 years for column measurements of ozone (Dobson since 1967 and Brewer since 1981) and ozone profile measurements (balloon-sonde since 1967) and 21 years for stratospheric LIDAR observations up to 48km. Data are regularly submitted to the data centers at Toronto, Thessaloniki, NILU, and NDSC. In addition to the observational UV-network of the BFS (Table 2), DWD continues to measure UV-B radiation for research and development purposes.

Table 2: Operational network for long-term measurements of ozone and UV.

<table>
<thead>
<tr>
<th>Type of observation</th>
<th>Location</th>
<th>Org.</th>
<th>Instrument</th>
<th>Type/No.</th>
<th>Start</th>
</tr>
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<tr>
<td>Total Ozone Column</td>
<td>Hohenpeissenberg</td>
<td>DWD</td>
<td>Dobson</td>
<td>No. 104, No. 064</td>
<td>1967</td>
</tr>
<tr>
<td></td>
<td>Hohenpeissenberg</td>
<td>DWD</td>
<td>Brewer</td>
<td>No. 010</td>
<td>1983</td>
</tr>
<tr>
<td></td>
<td>Hohenpeissenberg</td>
<td>DWD</td>
<td>Microtops</td>
<td>No. 3128, No. 3785</td>
<td>1996</td>
</tr>
<tr>
<td></td>
<td>Lindenberg</td>
<td>DWD</td>
<td>Dobson</td>
<td>No. 071</td>
<td>1964</td>
</tr>
<tr>
<td></td>
<td>Lindenberg</td>
<td>DWD</td>
<td>Brewer</td>
<td>No. 030, No. 078</td>
<td>1987</td>
</tr>
<tr>
<td>Calibration</td>
<td>Hohenpeissenberg</td>
<td>DWD</td>
<td>Dobson</td>
<td>No. 064</td>
<td>1999</td>
</tr>
<tr>
<td>Ozone Vertical Profile</td>
<td>Hohenpeissenberg</td>
<td>DWD</td>
<td>LIDAR</td>
<td>Brewer-Mast</td>
<td>1967</td>
</tr>
<tr>
<td></td>
<td>Hohenpeissenberg</td>
<td>DWD</td>
<td>Ozonosonde</td>
<td>ECC (since 1992)</td>
<td>1974</td>
</tr>
<tr>
<td></td>
<td>Lindenberg</td>
<td>DWD</td>
<td>Ozonosonde</td>
<td>ECC</td>
<td>1990</td>
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<tr>
<td>Ny Alesund (Svalbard)</td>
<td>AWI</td>
<td>Ozonosonde</td>
<td>ECC</td>
<td>1992</td>
<td></td>
</tr>
<tr>
<td>Ny Alesund(Svalbard)</td>
<td>AWI</td>
<td>LIDAR</td>
<td>DIAL</td>
<td>1991</td>
<td></td>
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<tr>
<td>Neumayer (Antarctica)</td>
<td>AWI</td>
<td>Ozonosonde</td>
<td>ECC</td>
<td>1992</td>
<td></td>
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<tr>
<td>Garmisch</td>
<td>FZK</td>
<td>LIDAR (Troposphere)</td>
<td>DIAL</td>
<td>1988</td>
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<td>Calibration</td>
<td>Jülich</td>
<td>FZJ</td>
<td>Ozonosonde</td>
<td>1999</td>
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<tr>
<td>UV</td>
<td>Garmisch</td>
<td>FZK</td>
<td>Bentham DTM 300</td>
<td>1994</td>
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<td></td>
<td>Hohenpeissenberg</td>
<td>DWD</td>
<td>Brewer MK II</td>
<td>No. 010</td>
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<td>DWD</td>
<td>Brewer MK IV</td>
<td>No. 078</td>
<td>1995</td>
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<td>DWD</td>
<td>Brewer MK III</td>
<td>No. 118</td>
<td>1996</td>
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<td>DWD</td>
<td>Bentham DM 150</td>
<td>2000</td>
<td></td>
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<td>Lindenberg</td>
<td>DWD</td>
<td>Spectro 320D</td>
<td>2002</td>
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<td></td>
<td>Dortmund</td>
<td>BAuA</td>
<td>Bentham DM150</td>
<td>1993</td>
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<td>Kulmbach</td>
<td>LIU</td>
<td>Bentham DM150</td>
<td>1993</td>
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<td></td>
<td>München</td>
<td>BTS</td>
<td>Bentham DM150</td>
<td>1993</td>
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<td></td>
<td>Langen</td>
<td>BTS</td>
<td>Bentham DM150</td>
<td>1993</td>
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<td>Schauinsland</td>
<td>BTS</td>
<td>Bentham DM150</td>
<td>1993</td>
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<td></td>
<td>Sylt</td>
<td>CAU</td>
<td>Bentham DM300</td>
<td>1995</td>
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<td></td>
<td>Zingst</td>
<td>BTS</td>
<td>Bentham DM150</td>
<td>1993</td>
<td></td>
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<tr>
<td></td>
<td>Zugspitze</td>
<td>FZK</td>
<td>Bentham DTM300</td>
<td>1995</td>
<td></td>
</tr>
</tbody>
</table>

The Alfred Wegener Institute for Polar and Marine Research (AWI) operates two fully equipped polar stations in the Arctic (Koldewey/Ny-Ålesund), and Antarctic (Neumayer) and temporary onboard of RV POLARSTERN. The Neumayer meteorological observatory is a radiation and climate monitoring station and an air chemistry observatory. The new station (Neumayer III) will replace Neumayer II to continue the long-term observations. Since 1992 vertical ozone balloon soundings are part of the regular observations. These measurements continue the sounding record from the former station Georg Forster, beginning in 1985. Measurements of surface radiation as part of a global observation network to detect long-term changes in the Earth’s radiation budget and their impacts on climate (BSRN) are included.
The full suite of NDACC measurements are routinely performed at the primary station Koldewey/Spitsbergen. This includes ozone-soundings by ECC-sondes, Lidar, microwave, DOAS, FTIR and UV-spectrometers. In addition, the same radiation measurements as at Neumayer-Station are performed as part of the BSRN.

IMK (Forschungszentrum and University of Karlsruhe) contributes with ground based remote sensing observations by FTIR- and mm-wave spectrometers and LIDAR instruments. With the tropical mm-wave spectrometer station in Merida, Venezuela, 4700 m asl, FZK-sites cover tropical, sub-tropical, mid- and polar latitudes. Within the NDACC, FTIR spectrometers are operated by IMK at Kiruna (Sweden), at Izaña on Tenerife Island (Spain) and at the Zugspitze mountain. Several ozone- and climate-related species have been measured with this technique for about 15 years. The stratospheric aerosol content is monitored since 1976 with a LIDAR which is part of the NDACC at the Garmisch site.

Measurements of ozone and ozone relevant species by IMK have been performed for many years by ground-based, balloon and airborne observations. Since the successful launch of the ENVISAT satellite in 2002, the retrieval of MIPAS-ENVISAT data beyond ESA standard products with the KOPRA-RCP processor developed at IMK provides high quality data sets on a global scale for O3, HNO3, NO, NO2, N2O5, HNO4, CIONO2, ClO, HOCI, COCl2, CFCs, water vapour, atmospheric tracers as N2O, CH4, CO, and SF6, and cloud particle properties of PSCs relevant for the polar ozone loss.

A new container with many new instruments has been developed for measurements on board a passenger aircraft Airbus A340-600 of Deutsche Lufthansa AG. It measures regularly the distribution of ozone and other trace gases in the tropopause region within the CARIBIC project (Civil Aircraft for the Regular Investigation of the atmosphere Based on an Instrument Container) since 2005. This project with many European partners is co-ordinated by Max Planck Institute for Chemistry in Mainz. [http://www.caribic-atmospheric.com/](http://www.caribic-atmospheric.com/)

**Calibration activities**
The World Calibration Center for Ozone Sondes (WCCOS) at FZ Jülich continues to improve and standardize the quality of ozone-soundings with balloon sondes. Under the auspices of WMO/GAW the Assessment of Standard Operating Procedures for Ozone Sondes (ASOPOS) has been preparing a final document in 2008 with recommendations for standardization of sonde operation.

The Regional Dobson Calibration Centre for WMO RA VI Europe (RDCC-E) at the Meteorological Observatory Hohenpeissenberg (MOHp) in close co-operation with the Solar and Ozone Observatory at Hradec Kralove (SOO-HK, Czech Republic) has been responsible for second level calibration and maintenance service of approximately 30 operational Dobson spectrophotometers in Europe since 1999. Included are the two Dobsons, at the Antarctic stations Halley Bay (British Antarctic Survey BAS) and Vernadsky (Ukraine).

In the past 9 years 18 intercomparisons (15 at MOHp, 2 at LKO, Arosa in Switzerland, and 1 at INTA, El Arenosillo in Spain) were organized, performed and evaluated under the lead management of RDCC-E. Altogether 57 Dobsons, some of them 2 or 3 times, from 21 countries got a complete calibration service. 15 instruments were completely upgraded. RDCC supports the establishment of the Regional Dobson Calibration Centre for WMO RA I Africa, run by the South African Weather Service. SOO-HK provided valuable contributions to the comprehensive RDCC-E tasks like training courses for operators, technical support during campaigns, soft- and hardware developments and free distribution.

**RESULTS FROM OBSERVATIONS AND ANALYSIS**
The trend measurements at the IMK sites exhibit declining trends of the chlorine reservoirs in the stratosphere since the mid 90ies as a response to the Montréal protocol. In addition, the long-term record of the stratospheric aerosol loading shows that current background levels are still at
historical low values. Trend analyses of the long ozone records at Hohenpeissenberg (Dobson, sonde, lidar) reveal increasing stratospheric ozone since the late nineties of the last century. While the ozone increase in the upper stratosphere can be taken as a first sign of a beginning ozone recovery from man-made chlorine, this is not the case for the total ozone column and for ozone in the lower stratosphere where dynamical factors play a major role in the recently enhanced levels. The strongest recent increase is found at about 14 km (+7.0% per decade for the period 1994-2007).

THEORY, MODELLING, AND OTHER RESEARCH

State of the art chemistry climate models are used in Germany to simulate and understand the past evolution of the ozone layer, and to predict the future. German activities are well interfaced to international programmes like the SPARC-CCMVAL activity. ECHAM related model development takes place at MPI-Mainz, MPI-Hamburg, FU Berlin, and at DLR. Models have been used to simulate the decadal trends from 1960 to 2020 and have contributed significant results to the IPCC/TEAP report (2005), the WMO Scientific Assessment of Ozone Depletion (2006), Germany was involved in the preparation of the Fourth Assessment Report of IPCC (2007). Beyond a reasonable reproduction of mean parameters and long-term variability characteristics there are many apparent features of episodic similarities between simulation and observation.

Downward-transport of NOx-rich mesospheric air into the polar winter stratosphere and its effect on the stratospheric ozone budget was one of the foci of the MIPAS-Envisat related IMK work. Scientific studies based on the observations of the Arctic and Antarctic winters 2002 to 2004 and the results of several CTMs and CCMs showed that NOx transport from the higher atmosphere, from high latitudes, or locally produced NOx due to solar proton events reduces considerably the stratospheric polar winter ozone which can, under certain circumstances, outweigh the impact of heterogeneous chemistry. One of the major results of MIPAS-ENVISAT with respect to polar ozone loss has been the retrieval of a global picture of PSC occurrence in the Antarctic during the last polar winters and comparison with chemistry-climate model simulations. Balloon-borne observations allowed further analysis of the composition of PSC particles, ground based studies analyzed ozone loss in several winters.

At Forschungszentrum Jülich (FZJ) various research activities related to stratospheric ozone are carried out with special emphasis on model simulations. All these studies significantly improved the knowledge on chemical ozone loss processes especially in the arctic (see 4.3 relevant scientific papers).

A number of studies on the chemistry of the ClO/Cl2 O2 were conducted, based on both laboratory and field observations. Further, the potential impact of ClOx radical complexes on polar stratospheric ozone loss processes was investigated.

Chemical ozone loss was analysed by simulation in chemistry climate models. Observed chemical ozone loss in the Arctic is still not fully reproduced by models, and towards the vortex edge still tends to be underestimated in the Antarctic.

Chemical ozone loss and related processes were deduced from observations for the first time in the Antarctic winter 2003 based on Improved Limb Atmospheric Spectrometer (ILAS)-II observations; both the setup phase of the polar vortex and the conditions in the established vortex were analysed.

The sensitivity of Arctic ozone loss to enhanced stratospheric H2O was investigated. Further, strongly enhanced Arctic ozone loss in the years following the eruption of Mt. Pinatubo was deduced; these results are important in view of proposed geo-engineering schemes.

In several studies, the chemical ozone depletion in the Arctic vortex has been reproduced rather successfully with the CLaMS model. Based on these studies CLaMS was also employed to investigate the strength and weaknesses of the Match method to deduce polar ozone loss; ozone
loss at lower altitudes seems to be overestimated. Further, a ClaMS study reveals that ozone loss
driven by nitrogen oxides and triggered by stratospheric warmings can play a major role.

MATCH campaigns, coordinated by AWI, and funded by the EU and national institutes, have been
carried out for more than ten successful years, most recently in the past winter 2007/2008. These
campaigns have been instrumental for our current understanding of the chemical ozone loss in the
Arctic.

The IUP at the university of Bremen is the PI institute for the SCIAMACHY instrument aboard the
ENVISAT satellite. Research is made in the field of ozone and ozone relevant trace gas analysis
using Fourier Transform Spectroscopy (FTS) and other methods, aerosol analysis, satellite data
retrieval and scientific support including validation for the GOME and SCIAMACHY projects.

The Atmospheric Chemistry Department of the Max Planck Institute for Chemistry in Mainz has a
research focus on ozone and the role of radicals in photo-oxidation mechanisms which play a
central role in the self-cleansing capacity of the atmosphere. Computer models are developed to
simulate the interactions of chemical and meteorological processes, and investigate the influences
of atmospheric composition changes on climate.

DISSEMINATION OF RESULTS

The International Council for Science (ICSU) World Data Centre for Remote Sensing of the
Atmosphere (WDC-RSAT) is hosted by the Cluster for Applied Remote Sensing at the German
Aerospace Centre (DLR-CAF). The primary focus of WDC-RSAT is the provision of data which are
primarily gathered from satellite based sensors. Higher level data and information products are
also generated from the data through assimilation into numerical models of the atmosphere and of
its interaction with the biosphere. Additionally offered is a service contributing to validation of
atmospheric measurements through application, for example, of a 3D trajectory model such that
satellite data can be better matched with correlative measurements. http://wdc.dlr.de/

Data reporting
Data from nearly all institutes mentioned above are regularly submitted to the data centers at
Toronto, Thessaloniki, NILU and NDACC.

Information to the public
BfS and DWD provide the public with UV-information including daily forecasts of the UV-index and
warnings. The daily UV-forecasts for clear sky and cloudy conditions are available for free on a
global scale: http://orias.dwd.de/promote/index.jsp
Since 1994 DWD regularly distributes the Ozonbulletin des Deutschen Wetterdienstes on current

Relevant scientific papers
Blum, U., F. Khosrawi, G. Baumgarten, K. Stebel, R. Müller, and K. H. Fricke: Simultaneous lidar
observations of a polar stratospheric cloud on the east and west sides of the Scandinavian mountains


Dameris, M.; V. Grewe, M. Ponater, R. Deckert, V. Eyring, F. Mager, S. Matthes, Ch. Schnadt, A. Stenke, B.
Steil, Ch. Brühl, M. Giorgetta: Long-term changes and variability in a transient simulation with a
chemistry-climate model employing realistic forcing. Atmospheric Chemistry and Physics, 5, S. 2121 –
2145, 2005.

Brühl, M. P. Chipperfield, E. Cordero, M. Dameris, M. Deushi, V. E. Fioletov, St. M. Frith, R. R. Garcia,
A. Gettelman, M. A. Giorgetta, V. Grewe, L. Jourdain, D. E. Kinnison, E. Mancini, El. Manzini, M.
Plummer, E. Rozanov, M. Schranner, Th. G. Shepherd, K. Shibata, R. S. Stolarski, H. Struthers, W.
Tian, M. Yoshiki: Assessment of temperature, trace species, and ozone in chemistry-climate model


PROJECTS AND COLLABORATION

German institutions participate in a number of international and EU funded research projects, special measurement campaigns and modeling studies, such as CAWSES and SCOUT-O3. They also play a major role in ESA and EUMETSAT projects.

FUTURE PLANS

IMK develops new instruments for the German research aircraft HALO and co-ordinates the HALO demo mission POLESTRACC which concentrates on the polar ozone chemistry. In addition, IMK act as a capacity builder as a new FTIR ground-based station in Ethiopia will be build up in order to measure total ozone and other ozone relevant substances with high quality at a tropical station.

FZJ/ICG-1and IMK together with European partners take the initiative for a new ESA satellite mission PREMIER (PRocess Exploration through Measurements of Infrared and millimeter-wave Emitted Radiation) – to understand processes that link trace gases, radiation, chemistry and climate in the atmosphere.

GLORIA (GLObal Radiance Limb Imager for the Atmosphere) is an imaging Fourier-spectrometer under development for the German research aircraft HALO and for satellites. From 2009 onward it will provide a large number of atmospheric parameters with high resolution.

NEEDS AND RECOMMENDATIONS

- Continuing high-quality measurements of total ozone and ozone profiles by satellites on the global scale and by ground-based systems at selected stations have to insured for the next decades. Without such high-quality data it would become impossible to follow the expected recovery of the ozone layer from man-made halogens, and to understand the substantial cooling of the stratosphere and warming of the troposphere that are expected over the next decades from man-made climate change.
- The complex system of ozone, atmospheric chemistry and dynamics is still not fully understood. Continued research is needed to better understand the underlying processes and to explain the discrepancies between model predictions and observations.
- The release of observational data to the data centers should be accelerated.
- Quality Assurance/Quality Control activities like calibration centers should be supported to maintain the high quality standards of the ground stations, which is necessary for satellite validation and ozone monitoring incl. trend analyses.
- The release of observational data to the data centers should be accelerated.

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HUNGARY

OBSERVATIONAL ACTIVITIES

In Hungary monitoring and research of ozone and UV-B solar radiation are mostly performed by the Hungarian Meteorological Service (HMS) in the Observatory of Atmospheric Physics in Budapest. HMS has long term data series and scientific experiences in this field. The operative column measurements of ozone and the high resolution UV spectra measurements were carried out by Brewer spectrophotometer without any data loss during this two year period. Results of measurements were inserted into the data base.

HMS runs a broad band UV radiometer network consisting of four stations. This network performed continuous, proper measurements and data measured were archived in the data base. There are seven UV-B radiometers operated by the ten regional environmental inspectorates as well. There is an intention to combine these two networks.

HMS satisfied the international data reporting commitments.

CALIBRATION

Monthly routine tests of the Brewer spectrophotometer towards the three standard source of radiation given by the manufacturer were carried out. Tests towards inner sources of radiation as well as tests controlling mechanic and electronic characteristics of the spectrometer were also carried out and archived. Test results show no problem.

In May, 2007 biannual calibration of the Brewer spectrophotometer towards the world standard Brewer operated by the International Ozone Service in Canada. During the calibration all parameters indicated good performances. Only one minor modification had to be done with one of the parameters.

Calibration of network detectors of the broad band UV radiometer network was carried out in both years. Before each calibration the national reference detector was checked towards the Brewer spectrophotometer.

The national reference detector was calibrated in the World Radiation Centre (Davos, Switzerland) in the framework of COST 726 action ("Long term changes and climatology of UV over Europe").

UV FORECAST

In 2006 and 2007 daily 24 hour forecast of the maximal UV-B dose was prepared in the period of 1 May to 30 September. The forecasted values were visualised on maps on the website operated by the Hungarian Red Cross (www.napsugarzas.hu). Result of a development in 2007: not only the forecasted values but the hourly values measured on that day can be seen as well on the website in near-real-time manner.

INTERNATIONAL CO-OPERATION

(1) COST 726 ("Long term changes and climatology of UV over Europe"): The program started in 2004 and is going to finish in 2009. HMS participated in three important activities in this EU action during the last two years:
(i) Co-operation in writing the paper: Practical Guide to Operating Broadband Instruments Measuring Erythemally Weighted Irradiance. This work accomplished successfully, the publication was issued at the beginning of 2007.
(ii) Calibration of broad band UV detectors in the World Radiation Centre, Davos.
The Working Group 4 of COST 726 together with the WMO Scientific Advisory Group for UV Measurements is developing the Standard Operating Procedure (SOP) for the broad band UV measurements. Main goal of the Working Group to harmonise the work of national and regional networks doing erythemally weighted UV radiation measurements. In this activity calibration of UV detectors designated as regional reference towards the WRC’s reference is essential. HMS took part in calculation of calibration related to each detector.

(iii) HMS produced and made available the homogenised global radiation data series of Budapest for the modelling work of COST 726 (restoration of UV data series for the past).

(2) EU FP7 framework program:
HMS participated in the work of a consortium consisting of 11 institutes from 9 countries elaborating a proposal for the tender in autumn 2007 in the framework of EU FP7 „Quantification of changing surface UV radiation levels and its impact of human health“. The preparation work started at the end of 2007 and the proposal was submitted in due time (25 02 2008) with the title „UV radiation at European level and its impact on human health: an European UV atlas“.

OTHER ACTIVITIES

In 2006 collaboration of experts from different fields (atmospheric physics, dermatology, ophthalmology, biophysics, radiation biology, sociology, public health, labour safety) having relation to UV radiation intensified. First the work was organised in an academic working group. However, according to the rules of the Hungarian Academy of Sciences does not enable operation of an interdisciplinary working committee, it is possible only for certain disciplines. After a longer preparation period HMS houses the working committee.

The first relevant work is professional secondment of the related activities of the Hungarian Red Cross. One of them is education on the right protection forms against the harmful UV radiation. There were many presentations on this topic and an instructor CD was made for schools.

Another one is a summer program, operation of two UV radiation first aid stations at the Lake Balaton by the Hungarian Red Cross for two moths. The personal UV dosimeters used experimentally here were calibrated by HMS.

Experts from HMS attended the „10th Biennial Brewer Users’ Group Workshop“ in Northwich (Cheshire, UK) in June, 2007. This biannual event deals not only with the Brewer spectrophotometer, but general UV spectrometric és spectroscopic theoretical and technical questions as well.

PUBLICATIONS


PRESENTATIONS

Tóth Z.: Az ultraibolya sugárzás egzakt méréstechnikája

Tóth Z.: Elektromágneses sugárzások biológiai hatékonysága, különös tekintettel az
ultraibolya tartományra
OMSZ belső továbbképzés, 2007. okt. 3. és 17.

Tóth Z.: A légköri ózon és a biológiai lag hatékony ultraibolya sugárzás kapcsolata

Tóth Z.: Mennyire káros a káros ultraibolya sugárzás?
Bajai Városi Könyvtár előadás sorozata, Baja, 2007. nov. 28.

****
INDIA

INTRODUCTION

India ratified the Vienna Convention for the protection of ozone layer on June 19, 1991 and the Montreal Protocol on Substances that Deplete the Ozone Layer on September 17, 1992. The Copenhagen, Montreal and Beijing Amendments were also ratified on 3rd March 2003. The India Country Programme was prepared in 1993 chalking out a strategy to phase-out production and consumption of Ozone Depleting Substances (ODSs).

Atmospheric ozone monitoring started in India since 1928 when Dr. Royds made total ozone measurements in Kodaikanal with Dobson photoelectric ozone spectrograph as part of the first world-wide ozone measurements organized by Prof. G. M. B. Dobson. The first Dobson Spectrophotometer was acquired by India Meteorological Department (IMD) in 1940. The Indian ozone observational and research programme are as follows:

OBSERVATIONAL ACTIVITIES

Column measurements of ozone and other gases/variables relevant to ozone loss
Total ozone measurements are being carried out at 6 stations by the IMD. Present network of six Dobson and two Brewer spectrophotometers are stationed at Srinagar, New Delhi, Varanasi, Pune and Kodaikanal.

At all stations, routine measurements of total ozone are made (upto a maximum of six times per day) by trained personnel. Whenever, conditions permit, Umkehr observations are also made form these stations to compute the vertical distributions of ozone. Later, two Brewer Ozone Spectrophotometers were procured. One (#89) was installed at National Ozone Centre, IMD, New Delhi and other (#94) at Kodaikanal. It has an advantage over the Dobson Spectrophotometer because it is semiautomatic. Besides, it could also measure SO₂, NO₂ and UV-B.

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

Vertical Ozone Distribution: The development of an Indian ozonesonde was taken up in 1963. The first successful sounding was carried out in September, 1964. The sondes were subsequently intercompared in WMOIII03C. Further, comparisons were also held in West Germany in 1970 and 1980; in 1991 (Canada) and 1996 (Germany). Since early 1970, fortnightly soundings were attempted at New Delhi, Pune, Thriruvanathapuram, Dakshin Gangotri and Maitri (Antarctica). A large number of vertical profiles of ozone, water vapor and nitrogen dioxide have been obtained and average profiles for Delhi were derived. The data obtained by this method was compared with balloon, rockets and LIMS satellite data. The system has been successfully operated during 13th, 14th and 16th Indian Antarctica Expedition and measured ozone height profiles in the Antarctica conditions both normal and ozone hole period. A similar high tech LHS with wide band (1GHz) acousto-optic spectrometers as back-end has also been developed and designed for operation at NPL, New Delhi sponsored by Indo-French Centre for Advanced Research.

The Laser Heterodyne System (LHS) and mm wave radiometer: This system monitors the 10 micron ozone line in absorption mode against the Sun. The mm wave radiometer observes the 101 GHz ozone line in emission mode. This instrument has the advantage over LHS that it can be operated round the clock under all weather conditions as it does not require direct sun light. The line profiles in both the experiments are inverted to obtain the Ozone height distribution. The ozone height profiles over Delhi and Maitri have been generated for a limited period using these techniques. The laser heterodyne spectrometer due to its ultra high spectral resolution and quantum limited sensitivity, can resolve the individual spectral lines completely even Doppler broadened absorption lines in the upper stratosphere. In view of the above a major project has been undertaken to design, develop and set up the most sophisticated CO₂ laser heterodyne system to get on line profiles of various trace species in the atmosphere including ozone over Antarctica as well as at NPL, New Delhi. The system developed earlier has been modified by using wide band (1GHz) acousto-optic spectrometers for the first time to improve the height resolution, accuracy.
and better spectral resolution. This is the first system of its kind on the global scale to use 1 GHz Acousto - optic spectrometer for laser heterodyne system to resolve the line completely with a very high spectral resolution and that is also in Antarctic environment. This HI-TECH system has been successfully set up and operated at Maitri, (70° 46’ S, 11° 44’ E) an Indian Antarctic station during 1993-94 and again during 1994-95 and ozone height profiles were obtained on cloud less clear days. The absorption line profiles obtain from Laser heterodyne system was used to retrieve the height profiles of ozone using inversion technique (an in house developed software to retrieve height profiles with inverse solution of radiative transfer equation).

**Surface Ozone Measurements**: During the 70s, the electrochemical surface ozone measurement system was successfully developed. The system is successfully operating at New Delhi, Pune, Kodaikanal, Thiruvananthapuram, Nagpur, Srinagar, Dakshin Gangotri and Maitri.

Surface ozone is being measured over New Delhi, an urban site, a region of intensive anthropogenic activity since 1997. Temporal variation studies on surface ozone at NPL, New Delhi during July, 1997 to December, 2007 shows that in all year’s winter and monsoon months attains low values of ozone than the critical value (NAAQS – 1 Hour average -120 ppbv). Where as during summer and post monsoon months ozone values attains critical value, which alarming poor air quality in these seasons.

**Measurement of Minor Constituents**: In addition to surface ozone, monitoring of NOx, CO, CH₄, NMHC, aerosols and meteorological parameters has also been carried out at the same site on a continuing basis to help in interpreting surface ozone variations. The Differential Absorption Lidar (DIAL) facility is also being used from time to time to monitor surface ozone, water vapour, ethylene and ammonia.

**UV measurements**

**Broadband measurements**
Measurements of UVB started in India around 1980 by independent scientists around India. Since its inception, the care of these instruments has changed hands several times and future funding is in jeopardy. The instruments were banded into a more formal network under the Indian Middle Atmospheric Programme (IMAP) in 1982-83. The IMAP program ended in 1989 and funding has continued for all stations except Jodhpur since then under ISRO-UGC. The six instruments originally included Jodhpur, Pune, Visakhapatnam, Mysore, New Delhi and Trivandum. The instruments are filter based instruments which measure four wavelength bands with 10 nm FWHM. The center wavelengths are roughly 280, 300 and 310 nm. For the moment, Dr. S. C. Chakravarty of the Space Science Office, ISRO and B. H. Subharay are keeping the program running.

Regular measurement of UV-B radiation by filter photometer were started in 1979 at National Physical Laboratory, New Delhi. At present under Indian Middle Atmospheric Programme (IMAP) a chain of 7 stations have been established for routine measurement of global UV-B radiation at 280, 290, 300 and 310nm.

**UV-Biometer**: The measurement of Minimum Erythermal dose in the UV-B range started at Delhi in 1995 January and is continuing.

**Narrowband filter instruments**
India started using Narrowband filter instruments for measurement of radiation from July 1957 at 21 principal and 22 ordinary stations where continuous recording of global and defused solar radiances and bright hours of sunshine are measured. UV-A, UV-B and UV-Total measurement has also been introduced at all the stations to study the impact of climate on human health, agriculture productivity, ozone depletion etc.

**Spectroradiometers**
The spectral measurements in the UV-B range at ½ nm interval started in 1989 and is continuing. The UV network is likely to expand and coordinate with international programme.
**Calibration activities**
The network instruments are calibrated against the National Standard at regular intervals. The National Standard is in turn, inter-compared against World standard in WMO organized International Intercomparisons. India participated in such comparisons held at Belsk (1974), Boulder (1977), Melbourne (1984) and Japan (1996). IMD, New Delhi is the National Ozone Centre for India and the Regional Ozone Centre for the Regional Association-II (Asia) of the World Meteorological Organization (WMO).

UV measuring instruments have been calibrated by using monochromators and wherever possible by using brewer spectrophotometer.

**RESULTS FROM OBSERVATIONS AND ANALYSIS**
The major findings are as follows:

1) Though the latitudinal variation of trends for Dobson and satellite data are similar for Dobson data over India gives small positive trend at the subtropical and equatorial regions, which is a significant finding. Extension of trend analysis using neural network over the period 1991-2001 has been done to predict ozone over Delhi.

The Stratospheric Ozone profiles obtained from Jharia from north India are found more lower then those lines to south. The low stratospheric Ozone according to study may be because of O₂, CO, CH₄ etc on regular basis at Maitri. Two years continuous observation of CO₂ hourly average concentration revealed that average yearly value of 368.43 ppm in 2002 and 369.72 ppm in 2003 indicating anthe coal fires containing gases such as methane, oxides of sulphur and carbon.

NPL has established a semi-automatic gas chromatograph for monitoring green house gases such as C increase of 1.3 ppm. This corresponds to growth rate of 0.35% per year.

2) Analysis of long term total ozone data from the Indian stations have not shown any trend.

**THEORY, MODELLING, AND OTHER RESEARCH**
Impact studies of UV rays on plants, animals and human beings were conducted in Jawaharlal Nehru University, Banaras Hindu University etc. which were published in national and international journals. Central Radiation Laboratory, Pune has also been conducting radiation studies at 45 stations. India also maintains one weather monitoring station at Maitri, Antarctica with a facility for measurements of global and diffuse solar radiation using pyranometers and of optical depth using a sunphotometer.

**DISSEMINATION OF RESULTS**
Results of the studies are disseminated through electronic media/website of respective institutions and query services.

**Data reporting**
The total ozone data and Umkehr data (vertical profile of Ozone) are being regularly sent in WMO format to the World Ozone Data Centre (W03DC) Canada, and are being regularly published by the Centre.

**Information to the public**
The information on ozone concentration and other constituents are placed in the website of India Meteorological Department.
Relevant scientific papers

Nandita D Ganguly, Department of Physics, St.Xavier’s College, Ahmedabad. “Low level of stratospheric ozone near the Jharia coal field in India”.

Dr. B. C. Arya, Scientist-F Radio and Atomspheric Sciences Division, “Report on NPL’s activities related to Ozone and other trace gases.


“UV-B flux increase during Coronal Mass Ejection” by Saumitra Mukherjee and Anita Mukherjee, Jawaharlal Nehru University, New Delhi; 4th (Virtual) Thermospheric/Lonospheric Geospheric Research (TIGER) Symposium.

“Possible Biological Effects by UV-radiation Newly Detected from Internally Administered Radioisotopes” by M. A. Padmanabha Rao, 114, Charak Sadan, Vikaspuri, New Delhi, India

“Modernization of Radiation Network” by R. D. Vashishtha & M. K. Gupta of India Meteorological Department, Pune, India

“Air quality monitoring in Chennai, India in the summer of 2005” by Mr. M. Pulikesi etal.

“Low level of stratospheric ozone near the Jaharia coal field in India” by Ms. Nandita D Ganguly.

PROJECTS AND COLLABORATION

Ministry of Science and Technology, under its atmospheric programme, is developing projects for monitoring of ozone and minor constituents including various greenhouse molecules such as Carbon Dioxide (CO2), Methane (CH4), Nitrous Oxide (NOx).

Indian Middle Atmospheric Programme (IMAP), operating since 1982, has provided an umbrella for integrating all Indian efforts on ozone research. Rocket Programmes in collaboration with ex-USSR were stepped up during this period with payloads from Physical Research Laboratory, Ahmedabad and the National Physical Laboratory, Delhi. These, along with balloon and ground based measurements, have well characterized the ozonesphere over India.

Indo-Russian collaborative programme on variations in ozone and aerosol content in tropics/extratropical troposphere and stratosphere are being studied.

A collaborative programme with Ultraviolet International Research Center, Finland has been launched to monitor the UV radiations.

FUTURE PLANS

a) Continuous monitoring of ozone profile over the country.

b) Study on atmospheric chemistry in relation to ozone layer depletion and climate change.

c) To participate in the international intercomparisons of Dobson Spectrophotometer, Brewer Spectrophotometer and Ozonesonde.

d) To develop biological system to monitor UV-B.

e) To continue research on impact of UV-B on human health and eco-systems.

f) To develop climatic models to predict the climatic change over India.
NEEDS AND RECOMMENDATIONS

- In accordance with the decision of the Meeting of Parties to the Vienna Convention, present activities need to be continued to monitor ozone concentration and UV radiations.
- Research activities relating to impact of UV radiations on life and its supporting system need to be conducted.
- The Ozone Research Managers meeting may recommend to the Meeting of Parties for taking decisions to request Parties to provide adequate support to continue the present activities and to carry out future plans.
- Developed countries may consider to have bilateral assistance programme with developing countries to strengthen ozone and UV-monitoring and research system.
- UNEP networking system may also include ozone and UV monitoring activities in their agenda.

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ISLAMIC REPUBLIC OF IRAN

OBSERVATIONAL ACTIVITIES

This report contains the updated information on the ozone and UV observation and research activities, which have been pursued in Iran through the past two years since the 6th meeting of the WMO/UNEP Ozone Research Managers.

For the past three decades, the Meteorological Organization (MO) and Geophysics Institute of the University of Tehran have been taking over and performing UV-B and ozone monitoring and research activities in Iran.

Research and monitoring activities are based mainly on and through continuous cooperation and exchange of information between these centers and other research entities, i.e. the universities and related research institutes.

In spite of long history of atmospheric observation and research, the country still lacks sufficient capacity to effectively realize its objectives in the field of ozone and UV observation and networking, which forms only part of the country's atmospheric research and monitoring platform.

Column measurements of ozone and other gases/variables relevant to ozone loss (e.g. Dobson, Brewer, DOAS, FT-IR)

There exist three stations in which the ozone measurement facilities are installed and in use.

The following stations are operating under the supervision of the Meteorological Organization (MO) and the Geophysics Institute of the University of Tehran:

1) Geophysics
2) Firoozkooh
3) Esphahan

Data on the above stations are provided in the Table 1.

Table 1: Stations active in the ozone and UV measurement and monitoring activities in Iran

<table>
<thead>
<tr>
<th>Station</th>
<th>Type</th>
<th>Coordinates</th>
<th>Measurement facilities</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Synoptic</td>
<td>Latitude</td>
<td>Longitude</td>
</tr>
<tr>
<td>Geophysics</td>
<td>Yes</td>
<td>35° 44’ N</td>
<td>51° 33’ E</td>
</tr>
<tr>
<td>Firoozkooh</td>
<td>Yes</td>
<td>35° 43’ N</td>
<td>52° 34’ E</td>
</tr>
<tr>
<td>Esphahan</td>
<td>Yes</td>
<td>32° 47’ N</td>
<td>51° 72’ E</td>
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</table>

Firoozkooh Station

Of the above stations, Firoozkooh has not reportedly been active in the field of stratospheric ozone measurements for the past two years. Surface ozone outside urban area has been measured at Firooz-kooh. The station is a reference station and official connected to the World Meteorological Organization’s (WMO) Global Atmospheric Watch (GAW).

Esfahan and Geophysics stations are mainly involved in the ozone and UV observations and have been cooperating with Firoozkooh station and the Meteorological Organization in surface ozone measurement activities.

Esphahan ozone station

This station is recognized by an international 336 codes and is connected to the global networking system. Total ozone is being measured using Dobson system since January 2000. Since April 2000, Brewer ozonometric equipment was installed and has been operating at Esphahan station.
This system measures total ozone in vertical column in an area of 1 cm\(^2\) by attracting solar and sky radiation. In addition, the system measures UV-B, SO\(_2\) and NO\(_2\). Esphahan station is recognized by an OIFM code and measures on a daily basis the upper atmospheric conditions between 11 to 12 GMT. This measurement includes vertical pressure, temperature, humidity, wind speed and direction. This station is also equipped with radiosonde (RS80) and hydrogen balloon (Totex 600gr) in order to study the Upper atmosphere.

**Geophysics institute station**
The institute is mainly responsible for total ozone monitoring, data recording and processing, networking with World Ozone and Ultraviolet Radiation Data Center (WOUDC) and conducting research, training and public awareness campaigns on stratospheric and surface ozone. The center is equipped with a Dobson photo-spectrometer and ancillary data processing and analysis hardware and software systems. The institute has been in cooperation with Tehran Municipality in air pollution monitoring activities through the established network of pollutants monitoring stations.

As of 2000, total ozone has been measured using Dobson system for 30 minutes (from 8am to 7pm). Results of the measurements are regularly calibrated using satellite data. The data recorded at the above stations is being reported to the WOUDC and are available through the center’s web pages.

**Profile measurements of ozone and other gases/variables relevant to ozone loss**
(e.g. ozonesondes, ozone lidar)
Profile measurement of Ozone needs employment of special equipment, which are not available at the existing stations. In order to study the Upper atmosphere, radiosonde (RS80) and hydrogen balloon (Totex 600gr) are in use at Esfahan station. Data recorded by these instruments then is transmitted to the global telecommunication system using a switching system. Esfahan station is connected to the global network of ozone observation and reports the data back to the WOUDC on a regular basis.

**UV measurements**
UV-B is only being measured at Esphahan station. UV is measured at the wavelengths between 320 and 330 nm including UV-B. There are several other locations reported as high risk spots in terms of exposure to UV. UV monitoring in these high risk spots are of utmost importance and need establishment and use of new UV measurement equipment and facilities.

**Broadband measurements**
(e.g. Solar Light, Yankee, Robertson Berger) *(N/A)*

**Narrowband filter instruments**
(e.g. GUV, NILU-UV) *(N/A)*

**Spectroradiometers (N/A)**

**Calibration activities**
Data recorded by the stations is regularly checked for their validation and consistency. In the case of data inconsistency the equipment are sent to the WMO for calibration. Currently monitoring equipment at Geophysics and Esphahan stations are calibrated and are properly in operation.

Equipment installed at the Firooz-kooh station was damaged and not in use for the last two years. In order to maintain the continuity of ozone data series, the station will need to fix the damaged apparatus and to improve its measurement system. This station only records surface ozone data. An strategy is in place to change the stations’ systems to European standards.

Calibration of equipment in Geophysics station has been last made in February 2006 in Japan. In an agreement with the Japanese atmospheric research center, the Dobson apparatus at Geophysics station will be calibrated once in two years. So, the next calibration is due for end of 2008. According to the latest calibration, data collected by the Geophysics equipment has 3% deviation from the satellite data recorded for the same period, which is considerably acceptable.
Equipment at Esfahan Station has been recently calibrated in South Korea and is operating.

RESULTS FROM OBSERVATIONS AND ANALYSIS
(e.g. trend analyses, UV doses (annual, monthly etc.), UV maps)

Figure 1: Comparison between Dobson data and satellite data for 2004.

Figure 2: Monthly variations of total ozone for the years 2002 to 2005.

THEORY, MODELLING, AND OTHER RESEARCH
(e.g. 3-D CTM modeling, data assimilation, use of satellite data, UV effect studies)

Two research units are active and affiliated to the Meteorological Organization as follows:
- Esfahan Ozone and Atmospheric Chemistry Research Center.
- Atmospheric Chemistry and Air Pollution Research Group of the Meteorological Science Research Center.

These centers are linked to the Esfahan and Firoozkooh stations and provide necessary research programmes of assistance for the centers.

Computer software is available at the Iranian Geophysics Centre and Esfahan station for processing and modelling of the atmospheric ozone and photo-chemicals. These facilities have
only been utilized for data processing and analysis. Models developed thus far have only for the simulation and analysis of air pollution in urban areas and so far no model has been developed specifically applicable for Ozone and UV analyses.

The first Iran-Korea joint workshop on climate modelling, Co-hosted by Climatological Research Institute (CRI) and Meteorological Research Institute (METRI) was held on November 16-17 2005. The program consisted of invited and contributed oral presentations from both countries and issues related to the subjects of the workshop were discussed in full. The workshop covered theoretical and applied topics of climate modeling as follows:

- Long Term Forecasting
- Climate Change and Variability
- Extreme Events
- Application of Climate Information
- Tele Connections
- Paleoclimatology

**DISSEMINATION OF RESULTS**

**Data reporting**
(e.g. submission of data to the WOUDC and other data centres)
Firoozkooh and Esfahan Stations are reference stations connected to the global network of atmospheric watch. Total and vertical ozone data in WMO format are being regularly reported to the World Ozone and Ultraviolet Data Center in Canada (WOUDC). The data recorded by the stations also being archived at the related centers. Data on Ozone and UV recorded at Esfahan station is reported to WOUDC in Canada once every two months. The Firoozkooh data is reported to the same center on a monthly basis.

**Information to the public**
(e.g. UV forecasts)
As its routine procedure, the geophysics institute provides assistances to the graduate and post graduate students through their MSc and PhD research programmes on air pollution and atmospheric research. These assistances are in the form of long term meteorological data series and processed information. Reports of the student theses are normally available for use by other researchers.

The long term and daily meteorological and ozone observation data are also available at the websites of the Geophysics Institute and Meteorological Organization as well as at the web-sites of provincial Meteorological Departments for use by researchers and consultants. Information is also provided at the above web-sites for public use. (URLs for the web-sites are: http://geophysics.ut.ac.ir/En/ for Geophysics Institute and http://www.irimet.net/ for Meteorological Organization. Links to provincial Meteorological Departments are available at http://www.irimo.ir/english/OSTAN/index.asp).

**PROJECTS AND COLLABORATION**
(e.g. national projects, international projects, other collaboration (nationally, internationally))

The following research programmes have been completed by the Geophysics research institute:
- The correlation between Total Ozone and troposphere/stratospheric parameters (1991).
- Correlation between tropospheric ozone and ground-base UV (1999).
- Tehran air pollution and atmospheric parameters (2003).
Total Ozone change analysis with respect to the periodic solar activities (1983).
Relationship between the dust pollution and meteorological parameters (2000).
Analysis of interaction between the Total Ozone recorded at a random meteorological station and regional weather systems (1999).
Comparative analysis of Ozone change through an eleven-year period of solar activities (1994).
Study of relation between ozone and humidity.
Measurement of ozone layer changes using Dobson and Brewer photo spectrometer data.
The study of stratospheric/trapospheric exchange by means of ground ozone measurement (1978).
Temporal and spatial variability of Total ozone in Central Plateau of Iran revealed by ground-based instruments (2007).

The Geophysics Institute and Meteorological Organization are in continuous cooperation with other academic and non-academic research units for the study of atmospheric phenomena.

**FUTURE PLANS**
(e.g. new stations, upcoming projects, instrument development)

The Meteorological Organization is planning to renovate the equipment and facilities of Firoozkooh station. Also a number of high risk UV spots are already identified, for which new equipment and facilities will be needed.

The Meteorological Organization and Geophysics Institute are in demand for improvement of their research, observation and data recording and reporting systems through regular UV monitoring and analysis as well as public awareness campaigns.

There is a strong need for scientific research on environmental impacts of increased UV due to the ozone depletion in different parts of country covering effects of UV radiation on:

A). Human health
B). Terrestrial and aquatic ecosystems
C). Biogeochemical cycle
D). Air quality
E). Materials

Development and improvement of "data networking system" is considered by the Meteorological Organization as an important component of the existing ozone/UV monitoring system. Atmospheric Modeling is another area of interest that requires professional training and advanced hardware and software facilities.

A new atmospheric research center is also under construction in esfahan for the purpose that will need advanced equipment and networking systems.

**NEEDS AND RECOMMENDATIONS**

- Development of advanced research programmes on the UV/Ozone analysis and impacts.
- Development of National UV Observation and Monitoring Network.
• Organization of regional and national training workshops for officials and experts from relevant UV/Ozone monitoring organizations and public seminars on ozone/UV changes and its effects on terrestrial life.

• Thematic meetings on UV/Ozone Observation and monitoring will be needed to be included in the UNEP/ROAP networking system. This can be accomplished back to back to the annual network meetings.

• Capacity Building and provision of necessary advanced equipment and facilities to the existing stations including:
  o Equipping Geophysics station with the following instruments:
    o Sky Radiometer (POM-02)
    o Sky radiometer (POM-01L)
    o Grating Sunphotometer (PGS-100)
    o Multichannel Data Logger (PMMS-100)
    o Brewer Spectrophotometer
    o Automation of existing Dobson Photo-spectrometer for improved and precise measurements
    o Renovation of Firoozkooh station
    o Development of new UV monitoring stations in high risk UV spots
    o Provision of upper-atmospheric observation and research facilities to Esfahan and Firoozkooh stations
    o Provision of technical assistance and training to the centers for advanced atmospheric research and modeling

• Systematic calibration of surface and upper-atmospheric ozone measurement instruments at existing stations.

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ITALY

The contributing institutions are:

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<thead>
<tr>
<th>INSTITUTION</th>
<th>Short name</th>
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<tr>
<td>CETEMPS/Dipartimento di Fisica, Universita’ degli Studi dell’Aquila, L’Aquila</td>
<td>CETEMPS/UNIAQ</td>
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<tr>
<td>Università degli Studi di Urbino “Carlo Bo”, Urbino.</td>
<td>UNIURB</td>
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<tr>
<td>Dipartimento di Fisica, Università di Roma “La Sapienza”, Roma.</td>
<td>UNIRM</td>
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<tr>
<td>ARPA Valle d’Aosta (Regional Environmental Protection Agency).</td>
<td>ARPAVDA</td>
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<td>CMCC,INGV, Roma.</td>
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OBSERVATIONAL ACTIVITIES

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

CETEMPS/UNIVAQ: The ozone total columns observed on routine basis at L’Aquila (683 m asl, 43.38°N, 13.31°E) are derived from the balloon ozone-sonde profiles. This database has been used for a comparison with OMI (Ozone Monitoring Instrument, http://www.knmi.nl/omi/) onboard AURA satellite (http://avdc.gsfc.nasa.gov/).

UNIURB: In situ continuous measurements of Ozone Depleting Substances (ODS, Montreal Gases) by Gas Chromatography-Mass Spectrometry at the CNR Atmospheric Research Station “O. Vittori” at Monte Cimone (Northern Apennines, Italy (2165 m asl, 44°11’ N, 10°42’ E) and weekly measurements of the same gases at the ABC-Pyramid Atmospheric Research Observatory (Nepal, 27.95 N, 86.82 E) located in the Himalayas, Khumbu valley, at 5079 m a.s.l.

UNIRM: Total ozone and total nitrogen dioxide observations have been collected since 1992 at Rome (Lat. 41.9°N, Long. 12.5°E, 75m a.s.l) and at Ispra (Lat. 45.8°N, Long. 8.63°E, 240m a.s.l) by using two Brewer MKIV spectrophotometers. Brewer MKIV 067 is located at the Physics Dept. of Sapienza University of Rome. Brewer MIV 066, located at the Environment Institute of the Joint Research Centre, Ispra (Va) until January 2007, was moved to the alpine station of ARPA (Aosta Valley Regional Environmental Protection Agency) at Saint-Christophe, Aosta (Italy), at approximately 100 km east from Ispra. Aerosol optical depth (AOD) retrievals in the UV and visible regions are now available.

ARPAVDA: Total ozone and total nitrogen dioxide measurements have been collected since 2007 in Saint-Christophe (45.74°N, 7.36°E, 570 m a.s.l), Aosta, using the Brewer MKIV spectrophotometer #66. This instrument, owned by Sapienza – University of Rome, was moved from the Joint Research Centre, Ispra (VA), where it has been measuring since 1992. The spectrophotometer is now being operated by ARPA Valle d’Aosta. Estimates of the total ozone content every 30 minutes are available since 2006, retrieved from the Bentham spectroradiometer. The results have been successfully compared with those obtained by the Brewer #66 and OMI satellite data.

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

CETEMPS/UNIAQ: The ozone profiles (balloon-sonde) have been collected since 1994. From 2004 this activity has achieved a routine pace: about 1.5/2 ozone profiles (from ground up to 10hPa altitude) per month (This activity is also part of the commitments included in a Convention between University of L’Aquila/CETEMPS -Centre of Excellence for the integration of remote sensing techniques and modelling for the forecast of severe weather- and Italian Government/Ministry of Environment. The Italian Ministry of Environment (Ministero dell’Ambiente
e della tutela del Territorio) provides the needed resources for the acquisition of the ozone sondes, the maintenance of the radio-sonde system.) The ozone profiles database has been available for the calibration/validation campaign of the MIPAS (Michelson Interferometer for Passive Atmospheric Sounding) instruments onboard ENVISAT. There is an overall agreement between the two techniques (along about 20 spatial and temporal coincident measurements), the main difference (below 10%) are located in the lower stratosphere and troposphere, in the high stratosphere, the agreement is better than 5%.

UV measurements
CETEMPS/UNIAQ: Broadband measurements
UV-A and UV-B (Yankee Environmental Systems) instruments have been operating since 2004.

UNIRM: Spectral UV irradiance (from 290 to 325 nm at 0.5 nm stepwidth) have been measured by Brewer spectrophotometer #067 operational since 1992. Values of erythemal and Vitamin D dose rates are also available. In addition erythemal dose rates and doses are provided by the broadband UV radiometer (model YES UVB-1) operational since 2000.

ARPAVDA: Three UV broadband radiometers (2 KIPP&ZONEN UV-S-AE-T, double band A/E, and 1 Yankee YES UVB-1) have been operating since 2004 at three different sites (Saint-Christophe, 570 m asl, La Thuile, 1640 m asl, and Plateau Rosa, 3500 m asl) to account for the altitude and snow effect. Data are available as 5 minutes averages (sampling time 10 seconds) and transmitted to the elaboration centre by GSM modems. A Bentham double monochromator spectroradiometer has been operating continuously since 2004, measuring the global spectral irradiance in the range 290-500 nm (stepwidth: 0.25 nm, FWHM: 0.54 nm) every 15-30 minutes (scan time: 6 minutes). Global spectral UV irradiance is also measured by the Brewer spectrophotometer (from 290 to 325 nm at 0.5 nm stepwidth). Erythemal and integrated dose rates, along with the UV index, and doses are routinely calculated from the spectral measurements and compared with the broadband measurements.

Calibration activities
UNIRM: The absolute calibration of Brewer 067 is made by the IOS inc. (International Ozone Service) almost every year. Furthermore, UV measurements are intercompared with the travelling standard spectroradiometer B5503 from PMOD/WRC (Physikalisch-Meteorologisches Observatorium Davos, World Radiation Center) every two years. The YES radiometer participated into the broadband radiometer inter-comparison at PMOD/WRC at Davos (Switzerland) in August 2006.

ARPAVDA: The ozone calibration of Brewer #66 is performed by the IOS inc. (International Ozone Service) almost every two years. UV measurements of the Brewer spectrophotometer and Bentham spectroradiometer are intercompared with the travelling standard QASUME from the PMOD/WRC (Physikalisch-Meteorologisches Observatorium Davos, World Radiation Center) every two year.

The Bentham spectroradiometer is calibrated every month by a local operator by means of 2/3 calibration lamps (portable field calibrators, 200W, from Schreder CMS). The lamps are calibrated by the PMOD/WRC and represent a calibration triad. Cross-calibration between the spectroradiometer and the spectrophotometer are regularly performed. The broadband radiometers spectral response function and cosine response are measured every year in a specialized laboratory (Scheder CMS, Austria). Absolute calibration is performed by ARPA with reference to the double monochromator spectroradiometer, following the international guidelines (Ann Webb, Julian Gröbner, Mario Blumthaler, A Practical Guide to Operating Broadband Instruments Measuring Erythemally Weighted Irradiance) and calculating a calibration matrix (ozone-solar zenith angle). The YES radiometer participated into the COST-726 broadband radiometer intercomparison at PMOD/WRC at Davos (CH) in August 2006, giving satisfying results.
RESULTS FROM OBSERVATIONS AND ANALYSIS

CETEMPS/UNIVAQ: Ozone trend analyses: The extended ozone profile database (2004-2007) has got the quality-standards for being used in a preliminary analysis concerning the possible trends of the ozone content in the different atmospheric region. In summary, such studies show that: there is not any significant trend in the lower troposphere; the same in the higher troposphere and in the lower stratosphere (these data have a larger standard deviation); on the other hand in the middle stratosphere [20-25km], it is evident a small decreasing in the ozone content (about 10+/−5DU/decade) which is consistent with other kind of observations (i.e., IPCC’s Special Report on Safeguarding the Ozone Layer and the Global Climate System, 2005)

UNIURB: ODS: Atmospheric trends of ODS and allocation of Source regions.

UNIRM: Surface UV radiation: A climatological characterization based on the time series of UV index was carried out. The mean of maximum UV index is (7.2±0.2) at Ispra and (8.9±0.4) at Rome under clear sky conditions. High exposure category (6< UV index < 7) is more frequent at Rome (32%) than at Ispra (26%). Very high UV indexes (≥ 8) occur only at Rome.

ARPAVDA: Surface UV radiation: The UV indexes measured in the three stations are published in real-time on the web site www.uv-index.vda.it using the colour scale recommended by the WMO. UV doses are calculated. Extreme UV indexes occur in the Alps of Valle d’Aosta: close by 9 at Aosta and La Thuile, during summer, and higher than 12 at Plateau Rosa, because of the coupled effect of altitude (3500 m asl) and snow cover (perennial snow is always present on the glacier).

THEORY, MODELLING, AND OTHER RESEARCH

CETEMPS/UNIVAQ: Stratospheric and tropospheric Ozone: Research and assessment studies on stratospheric ozone have been made using a global chemistry-transport model (ULAQ-CTM) and a chemistry-climate coupled model (ULAQ-CCM), both including an interactive module for calculation of aerosol formation and growth. Both models have been validated with satellite and aircraft data and then used for future projections of the ozone layer and changes of the ozone radiative forcing on climate. The above models have also been adapted and used for studies of tropospheric ozone and its precursors, as well as for future trends of tropospheric O3. CETEMPS/UNIAQ modelling activities have also contributed to the UNEP/WMO/IPCC: Scientific Assessment of Ozone Depletion: 2006; Chapter 5: Climate-Ozone Connections, Review Ed. D. Albritton, 49 pp., Geneva, Switzerland, 2007; and to UNEP/WMO/IPCC: Scientific Assessment of Ozone Depletion: 2006; Chapter 6: The Ozone Layer in the 21st Century.

UNIRM: Comparison with Ozone and UV satellite data: The daily mean ozone values from Brewer spectrophotometer #067 showed a good agreement with OMI ozone data retrieved by means of both OMI-TOMS 5 (bias=−1.8%) and OMI-DOAS (bias=−0.7%) algorithms. The comparisons between satellite-based and ground-based UV data showed that, on average, OMI UV products exceed ground-based UV measurements by more than 20%. This may be attributed to the fact that the satellite instrument does not effectively probe the boundary layer, where the extinction by the aerosols can be important, mainly in an urban site as Rome.

Assessment of solar UV exposure in the Italian population: In the last four years several campaigns are carried out focused on quantifying the solar UV exposure in Italian populations such as sunbathers, skiers and vine growers searching a possible relation among biological markers of individual response to UV exposure. Preliminary results were showed during national conferences. Recent results were submitted to international journals. The variability of calibration curves of polysulphone dosimetry was widely studied during several ad hoc field campaigns at different middle latitude sites (urban, semi-rural and rural sites) and in any season of the year. It was concluded (Casale et al., 2006) that a careful quantification of the polysulphone calibration curve under the same atmospheric conditions of exposure of population groups is recommended in the personal UV measurement programmes.
**ARPAVDA:** Radiative transfer models (e.g. LibRadtran) are routinely used for the forecasts of the UV index in cloudless conditions and for quality control. The forecasts are daily published on the UV website [www.uv-index.vda.it](http://www.uv-index.vda.it) in the form of WMO-compliant maps of Aosta Valley. The standard libRadtran model was modified to take into account some effects typical of a mountain region (effective albedo, altitude and “cutted” atmospheric profiles) and compared with a 3D model, giving satisfying results (±1 UV index maximum difference). A near-real time UV map of Aosta Valley is computed every 15 min accounting for cloud amount, using satellite data from Meteosat Second Generation. The daily mean and instantaneous measurements from Brewer spectrophotometer showed an agreement with OMI ozone data (daily mean and overpass values), similar to that observed and published for other mountain sites. The bias is about -3%, the correlation index is 0.99 and the RMS is 3.5%.

**CMCC/INGV:** Global Modelling of Stratospheric Ozone: The anthropogenic perturbation of the atmospheric composition is at the origin of global environmental changes of the Earth System. Within this context, our research objectives are aimed at identifying and quantifying the connections between ozone evolution and climate change, by using and developing global numerical models with interactive meteorology and chemistry. In particular we are working with the MAECHAM general circulation models of the troposphere, stratosphere and mesosphere, as well as with one of its version coupled to a stratospheric ozone chemistry model [the MAECHAM4CHEM chemistry climate model (CCM), and its further evolution, the ECHAM5/MESSy1]. CCMs include the full representations of dynamical, radiative, and chemical processes in the atmosphere and their interactions. We have been part of the MAECHAM4CHEM model team that has contributed to the coordinated simulations of past ozone evolution and scenarios of future ozone projection of the last ozone assessment (WMO, 2007). In the last few years, we have been part of several international teams and co-authored a number of publications aimed at analyzing various aspects of the modelling of stratospheric ozone with comprehensive global numerical models: - the evaluation of inter-annual variations in total ozone and lower stratospheric temperature in the MAECHAM4CHEM model has been addressed; -the comparison of long term evolution of upper stratospheric ozone of the MAECHAM4CHEM model with selected observational stations within the Network for the Detection of Stratospheric Change (NDSC); - the assessment of the simulation by a number of CCMs of stratospheric temperature, tracer, and ozone in the recent past and of stratospheric ozone projection in the 21st century; - and the evaluation of the solar cycle and temperature in CCMs.

**Modelling of shortwave radiative transfer in Atmospheric Global Models.** The spectral resolution of the shortwave radiation parameterization used in the Middle Atmosphere (MA) ECHAM5 model has been increased from 4 to 6 bands, in order to improve the representation of ozone absorption in the stratosphere.

**DISSEMINATION OF RESULTS**

**Data reporting**

**CETEMPS/UNIVAQ:** The multi-annual UV and ozone profile data can be freely used on request at CETEMPS. Model data for international data centres.

**UNIRM:** Daily total ozone are submitted to international datacentres at the end of every year.

**ARPAVDA:** Every measurement is published in real time on the website of ARPA. Daily total ozone and B-files are submitted daily to the WOUDC.

**CMCC/INGV:** Preparation of numerical data from the MAECHAM4CHEM model for submission to the British Atmosphere Data Centre (BADC) data centre, within the procedures for the last ozone assessment (WMO, 2007).

**Information to the public**

**CETEMPS/UNIVAQ:** An annual report concerning the stratospheric ozone and surface UV levels is yearly compiled within the existing Convention between CETEMPS/UNIAQ and Italian
Government/Ministry of Environment. The observational procedures and their scientific content are widely exploited along continuous on-site visiting activities (secondary schools, university students, foreign scientists) and press releases.

**ARPAVDA:** UV forecasts for clear sky are published daily on the ARPA website and on national newspapers (La Stampa, regional page). The recommended solar protection factors and the erythemal times are reported for some site of Aosta Valley and different phototypes.

**Relevant scientific papers**

**CETEMPS/UNIVAQ:**


**UNIURB:**


**UNIRM:**


**ARPAVDA:**


CMCC/INGV:

PROJECTS AND COLLABORATION

CETEMPS/UNIVAQ:
National projects:
Convention between CETEMPS/UNIAQ and Italian Government/Ministry of Environment.

International projects:
EC-SCOUT-O3; SPARC-CCMVal; EU-ACCENT; AEROCOM; HTAP; WMO Assessments; IPCC Assessments.

UNIRM:
International collaborations
Australian Sun and Health Research Laboratory, Queensland University of Technology, Institute of Health and Biomedical Innovation, Brisbane, Australia; ARPA Valle d’Aosta; Management Committee Member of COST Action 726 “Long term changes and climatology of UV radiation over Europe”.

ARPAVDA:
National projects
Agire POR: exchange program promoted by the Italian economy ministry between ARPA Valle d’Aosta and ARPA Basilicata; ARPA Piemonte, Forecast and Environmental Monitoring Area, University of Rome (La Sapienza), University of Turin, Institute of Atmospheric Sciences and Climate (ISAC-CNR, Italy), Italian Air Force, Weather Service

International collaborations
General Joint Research Centre (JRC), Institute for Health and Consumer Protection (ICHIP), Physical and Chemical Exposure Unit, Ispra (VA), Italy; Physikalisch-Meteorologisches Observatorium Davos, World Radiation Center (PMOD/WRC), Davos, Switzerland; World Ozone and Ultraviolet Radiation Data Centre, Meteorological Service of Canada, Toronto, Ontario, Canada; Deutsches Zentrum fuer Luft- und Raumfahrt (DLR), Institut fuer Physik der Atmosphaere, Oberpfaffenhofen, Germany; Department of Medical Physics, Innsbruck Medical University, Innsbruck, Austria; Deutscher Wetterdienst, KU3, Human Biometeorology, Freiburg, Germany; EUMETSAT, Darmstadt, Germany; Royal Netherlands Meteorological Institute (KNMI), Atmospheric Composition, Climate Research, De Bilt, The Netherlands.
CMCC/INGV: International collaborations
EC-SCOUT; WMO Assessments; SPARC-CCMVal;

FUTURE PLANS

CETEMPS/UNIVAQ: Development of global models (increased horizontal resolution, upgrade of hydrocarbon chemistry for tropospheric ozone).
Re-establishment of an ozone DIAL (Differential Absorption Lidar) to extent the temporal coverage of the ozone profile monitoring.

UNIRM: Further development of UV sensors for the assessment of human UV exposure; investigation on total ozone UV irradiance trend.

ARPAVDA: Further research on solar photometry and aerosol optical depth (AOD) measurements.

CCM/INGV: Development of the investigation concerning the impact of ENSO on Stratospheric Temperature and Ozone. Global Modelling of Climate Change and Ozone: it is planned to incorporate the MAECHAM5 stratosphere resolving model in the coupled atmosphere ocean general ocean model (AOGCM) available at CMCC. The first objective will be to evaluate the coupled model with the stratospheric resolving atmosphere by a climate control simulation.

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JAPAN

OBSERVATIONAL ACTIVITIES

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

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

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

Concentrations of ozone-depleting substances and other constituents are monitored by the Center for Global Environmental Research (CGER) of the National Institute for Environmental Studies (NIES) and by JMA. The locations of the monitoring sites are listed in Table 2. The CGER of NIES monitors halocarbons (CFCs, CCl4, CH3CCl3 and HCFCs), HFCs, surface ozone, CO2, CH4, CO, N2O, NOx, H2, the O2/N2 ratio, and aerosols at remote sites (Hateruma and Ochiishi). JMA measures the surface concentration of ozone-depleting substances (CFCs, CCl4 and CH3CCl3) and other constituents (surface ozone, CO2, N2O, CH4 and CO) at Ryori, a GAW Regional Station in northern Japan. Monitoring of the concentration of surface ozone, CO2, CH4 and CO is also carried out at Minamitorishima (a GAW Global Station) and Yonagunijima (a GAW Regional Station in the Ryukyu Islands).

The Ministry of the Environment (MOE) operationally observes the concentration of halocarbons (CFCs, CCl4, CH3CCl3, halons, HCFCs and CH3Br) and HFCs at remote sites (around Wakkanai and Nemuro) and at an urban site (Kawasaki).

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

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

JMA also observes CFCs, CO2, N2O and CH4 in both the atmosphere and seawater of the western Pacific on board the Ryofu Maru and Keifu Maru research vessels.

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

Ground-based and sonde measurements
Since October 1990, the CGER of NIES has been measuring the vertical profiles of stratospheric ozone over Tsukuba (where NIES is located) with an ozone laser radar (ozone lidar). This is accepted as a complementary measurement by the Network for the Detection of Atmospheric Composition Change (NDACC). The lidar ozone profiles were assessed by comparison with JMA ozone sonde data and Stratospheric Aerosol and Gas Experiment II (SAGE II) ozone profiles, and
were registered in the NDACC database. The CGER began measuring vertical profiles of ozone with millimeter-wave radiometers in September 1995 at Tsukuba and in March 1999 at Rikubetsu. JMA has been observing the vertical ozone distribution by KC (KI solution and carbon electrode) ozone sonde at three sites in Japan (Sapporo, Tsukuba and Naha) and at Syowa Station in Antarctica. The KC ozone sonde is an electrochemical instrument that has been used in Japan since it was developed by JMA in the 1960s. Observations are conducted once a week.

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

**UV measurements**

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

**Spectroradiometers**
JMA observes surface UV-B radiation with Brewer spectrophotometers at Sapporo, Tsukuba and Naha in Japan and at Syowa Station in Antarctica. The observations were started in 1990 at Tsukuba and in 1991 at the other sites.

**Calibration activities**
JMA began operation of the Quality Assurance/Science Activity Centre (QA/SAC) in Tokyo and the Regional Dobson Calibration Centre (RDCC) in Tsukuba in accordance with the GAW Strategic Plan 2001–2007 to contribute to the assessment and improvement of the quality of ozone observations in Regional Associations II (Asia) and V (South-West Pacific) of the World Meteorological Organization (WMO). The Regional Standard Dobson instrument (D116) is calibrated against the World Standard instrument (D083) every three years. Recent intercomparison with the World Standard was conducted in 2007 at NOAA/CMDL in Boulder, Colorado, USA. The Dobson instruments used for observation at domestic sites are also calibrated against the Regional Standard every three years. As an activity of the RDCC, JMA held a campaign of Dobson Intercomparison at Tsukuba with participation from India, Iran, Pakistan, the Philippines and Thailand in March 2006. As an activity of the QA/SAC, JMA dispatched an expert to the Republic of Korea to install an automated observation system to the Dobson instrument and to instruct operators at Yonsei University, Seoul from July to August 2006.

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

Trend analyses were carried out for total ozone at three sites (Sapporo, Tsukuba and Naha), eliminating the variation component of solar activity and quasi-biennial oscillation (QBO). The results show that total ozone mainly decreased in the 1980s and no significant trends or slight increasing trends have appeared since the mid-1990s, although total ozone varies year by year. Trends for vertical profiles were examined using Umkehr and ozone sonde measurements. At all sites in Japan, reduced ozone levels are seen in two ranges at altitudes of about 20 and 40 km. On the other hand, an increasing trend is seen at altitudes of less than 15 km at Naha.
Increasing trends are seen in erythemal UV measurements at three sites in Japan since the beginning of JMA’s UV radiation observation in the early 1990s. As the total ozone was at its lowest level around the early 1990s and no significant trends or slight increasing trends are seen in the total ozone after the mid-1990s, the cause of the above increasing trends in erythemal UV radiation since 1990 cannot be attributed to ozone changes.

THEORY, MODELLING AND OTHER RESEARCH

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

CCSR/NIES CCM is based on a spectral atmospheric general circulation model (CCSR/NIES AGCM). A new version of this CCM with T42 horizontal resolution has been developed that includes bromine chemistry and atmospheric sphericity effects. It was used to simulate global distribution and time evolution of the stratospheric ozone layer for the recent past and future under a future scenario with the concentration of greenhouse gases and ozone depletion substances recommended by CCMVal for the simulation. The results were published in the WMO Ozone Assessment Report 2006 and scientific journals. NIES has also developed a three-dimensional chemical transport model (CTM) in which temperature and wind velocity data are assimilated into the calculated fields in CCSR/NIES AGCM using a nudging method. The model was used to investigate the effects of atmospheric sphericity on stratospheric chemistry and dynamics in the Antarctic, ozone destruction outside the Arctic polar vortex due to polar vortex processing, and N2O distributions in the Northern Hemisphere in early and late Arctic polar vortex breakup years. The results were published in scientific journals.

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

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

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

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

DISSEMINATION OF RESULTS

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

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

Information to the public
An Annual Report on the state of the ozone layer, surface UV-B radiation and atmospheric concentrations of ozone-depleting substances is published for the public by the MOE.

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

Relevant scientific papers
The MOE supports research on global environmental changes (including ozone layer depletion) through the GERF, and their results are published in Annual Summary Reports.

PROJECTS AND COLLABORATION

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

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

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

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

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

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

A Superconductive Submillimeter-Wave Limb-Emission Sounder (SMILES) is being designed for installation in the Japanese Experiment Module (JEM) on the International Space Station (ISS) as a collaborative project between the Japan Aerospace Exploration Agency (JAXA) and the National Institute of Information and Communications Technology (NICT). The system’s detailed design and manufacturing of the proto-flight model (PFM) for JEM/SMILES are complete, and a launch scheduled in 2009 by the H-II Transfer Vehicle (HTV) is aimed at. The mission objectives are: i) space demonstration of a superconductive mixer and a 4-K mechanical cooler for submillimeter limb-emission sounding, and ii) global observations of atmospheric minor constituents in the stratosphere (O₃, HCl, ClO, HO₂, HOCl, BrO, O₃ isotopes, HNO₃, CH₃CN, etc), contributing to the atmospheric sciences. The SMILES observation is characterized by its focus on the variation of radical species in the stratosphere and the impact of such variations. Based on its high sensitivity in detecting atmospheric limb emission in the submillimeter wave range, JEM/SMILES will make measurements on several radical species crucial to ozone chemistry (normal O₃, isotope O₃, ClO, HCl, HOCl, BrO, HO₂ and H₂O₂). The SMILES will also try to observe the isotopic composition of ozone.

NEEDS AND RECOMMENDATIONS

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

To predict future changes in the ozone layer more precisely, integration between stratospheric and climate models is desirable. The interactions between climate change and ozone layer depletion and changes in the ozone layer in the post-CFC period due to emissions of CH₄, H₂ and N₂O need to be assessed. Studies on chemical and dynamical processes including the formation of PSCs and denitrification mechanisms, cross-tropopause transport and the ozone budget near the tropopause region should also be continued. Reevaluation of chemical reaction data including photochemical data for stratospheric modeling is urgently required to resolve discrepancies between observations and model calculations.
To detect the variations and long-term trends in ground-level UV radiation, a systematic calibration program and a well-coordinated monitoring network should be established.

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