

## GERMANY

In accordance with Decision VCV/3: Recommendations of the fifth meeting of the Ozone Research Managers to the Parties of the Vienna Convention at Geneva in 2002, the following significant research and monitoring activities have been carried out since 2002 in Germany.

Ozone-monitoring and related research in Germany is distributed over numerous institutions. Usually, there is no distinct separation between research and development, monitoring and quality control. In general, research is carried out at university institutes or at research centers (MPI, DLR, FZ-Karlsruhe, FZ-Jülich). Regular long-term monitoring of ozone outside the planetary boundary layer is provided by DWD and AWI, UV-monitoring by BfS, UBA and DWD. Surface ozone is monitored by authorities at the national and federal level. Surface ozone will not be discussed further in this report.

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

Institute	Location	Field	Keywords
Deutscher Wetterdienst, <a href="http://www.dwd.de/en/FundE">www.dwd.de/en/FundE</a>	Hohenpeissenberg, Lindenberg	MT, R, QA/QC	Regional Ozone Center, DCC, NDSC, GAW
Alfred Wegener Institut für Polar u. Meeresforschung, <a href="http://www.awi-potsdam.de/">www.awi-potsdam.de/</a> <a href="http://www.awi-bremerhaven.de/">www.awi-bremerhaven.de/</a>	Potsdam, Bremerhaven	R, MT, D	Neumayer, Ny Ålesund, MATCH
Forschungszentrum Jülich, <a href="http://www.fz-juelich.de/">www.fz-juelich.de/</a>	Jülich	R, QA/QC, MD	Calibration O <sub>3</sub> - Sonde, JOSIE, ClaMS
MPI f. Meteorologie (DKRZ), <a href="http://www.dkrz.de/">www.dkrz.de/</a>	Hamburg	R, MD	ECHAM
DLR, DLR/DFD, <a href="http://www.dlr.de/">www.dlr.de/</a> <a href="http://www.wdc.dlr.de/index.html">www.wdc.dlr.de/index.html</a>	Oberpfaffenhofen	R, MD, MT, QA/QC	GOME, ECHAM, Air-Traffic
IAP Kühlungsborn, <a href="http://www.iap-kborn.de/">www.iap-kborn.de/</a>	Kühlungsborn	R, D, MT	Middle Atmosphere, Alomar,
Bundesamt f. Strahlenschutz (BfS) <a href="http://www.bfs.de/">www.bfs.de/</a>	Salzgitter	MT	UV
Umweltbundesamt, <a href="http://www.umweltbundesamt.de/">www.umweltbundesamt.de/</a>	Berlin	MT,	Air quality
Uni Bremen, IUP, IFE, <a href="http://www.iup.physik.uni-bremen.de/index.html">www.iup.physik.uni-bremen.de/index.html</a>	Bremen	R, D	GOME, SCIAMACHY, MICROWAVE
Uni Köln, Inst. f. Meteorologie, <a href="http://www.uni-koeln.de/math-nat-fak/geomet/">www.uni-koeln.de/math-nat-fak/geomet/</a>	Köln	R, MD	EURAD,
FU Berlin, Inst. f. Meteorologie , <a href="http://strat-www.met.fu-berlin.de/">strat-www.met.fu-berlin.de/</a>	Berlin	R, MT	Stratosphere
Uni Frankfurt, Inst. f. Meteorologie, <a href="http://www.rz.uni-frankfurt.de/IMGF/meteor/klima/">www.rz.uni-frankfurt.de/IMGF/meteor/klima/</a>	Frankfurt	R, MT	CFC's
Uni Mainz, MPI f. Chemie , <a href="http://www.atmosphere.mpg.de/enid/2_html">www.atmosphere.mpg.de/enid/2_html</a>	Mainz	R, MD	ECHAM/CHEM
Uni Heidelberg, <a href="http://www.uphys.uni-heidelberg.de/">www.uphys.uni-heidelberg.de/</a>	Heidelberg	R, QA/QC	DOAS
IMK, Forschungszentrum und Universität Karlsruhe <a href="http://www-imk.physik.uni-karlsruhe.de/">www-imk.physik.uni-karlsruhe.de/</a>	Karlsruhe, Garmisch- Partenkirchen (IfU)	R, D, MD, MT, QA/QC	FTIR, MIPAS, ENVISAT,
Uni München (LMU)	München	R, MD	UV, STAR
Uni Hannover, Inst. f. Meteorologie <a href="http://www.muk.uni-hannover.de">www.muk.uni-hannover.de</a>	Hannover	R	UV

## MONITORING

Germany's Meteorological Service (DWD) is running a very intense measurement programme 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 38 years for ozone measurements up to 30 km altitude (balloon-sonde and Dobson-spectrometers) and 18 years for upper stratospheric LIDAR observations. 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. Both institutes provide the public with UV-information including daily forecasts of the UV-index (see below).

The Alfred Wegener Institute for Polar and Marine Research (AWI) is very active in atmospheric research. It operates two fully equipped polar stations in the Arctic (Ny-Ålesund/Koldewey - NDSC primary station), and Antarctic (Neumayer) and temporary onboard of RV POLARSTERN. The Neumayer meteorological observatory is designed as a radiation and climate monitoring station and an air chemistry observatory. In the next years a new station (Neumayer III) will replace Neumayer II to continue the long-term observations. This includes 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). 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.

The full suite of NDSC measurements are routinely performed at the primary station Koldewey. 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- spectrometers and LIDAR instruments within the NDSC and WMO-GAW networks to trend assessments. With a new tropical mm-spectrometer station in Merida, Venezuela, 4700 m asl, FZK-sites cover tropical, sub-tropical, mid- and polar latitudes. Within the NDSC, FTIR spectrometers are operated by IMK at Kiruna (North of Sweden) and at Izaña on Tenerife Island and a primary NDSC station at the Zugspitze. Several ozone- and climate-related species are measured with this technique since about 10 years. The stratospheric aerosol content is monitored since 1976 with a LIDAR which is part of the NDSC at the Garmisch site.

Two major satellite instruments onboard the European ENVISAT satellite, MIPAS and SCIAMACHY, are initialized and supported by groups at IUP/IFE, University of Bremen, and IMK, Karlsruhe. DLR/DFD is routinely retrieving and processing the data from a number of satellite instruments, among them GOME, SCIAMACHY, and MIPAS. In order to improve the utilization of data, the World Data Center for Remote Sensing of the Atmosphere (WDC-RSAT) was established.

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.

WDC-RSAT grew out of the Atmos Users Center (AUC) of the German Remote Sensing Data Center which was established to provide the European atmospheric satellite data user community with direct and easy access to measurements and derived data products from a wide range of sensors.

In addition to providing sensor data and analysis products of the atmosphere, WDC-RSAT offers various services such as the assistance of scientific field campaign planning by e.g.

analyzing the overall atmospheric state. 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.

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

Type of observation	Location	Org.	Instrument	Type	Start
<b>Total Ozone Column</b>	Hohenpeissenberg	DWD	Dobson	No. 104, No. 064	1967
	Hohenpeissenberg	DWD	Brewer	No. 010	1983
	Hohenpeissenberg	DWD	Microtops	No. 3128, No. 3785	1996
	Lindenberg	DWD	Brewer	No. 078	1992
	Potsdam	DWD	Dobson	No. 071	1964
	Potsdam	DWD	Brewer	No. 030	1987
	Potsdam	DWD	Brewer	No. 118	1996
<b>Calibration</b>	Hohenpeissenberg	DWD	Dobson	No. 064	1999
<b>Ozone Vertical Profile</b>	Hohenpeissenberg	DWD	Ozonesonde	Brewer-Mast	1967
	Hohenpeissenberg	DWD	LIDAR (Stratosphere)	DIAL	1987
	Lindenberg	DWD	Ozonesonde	ECC (since 1992)	1974
	Ny Ålesund (Spitzbergen)	AWI	Ozonesonde	ECC	1990
	Ny Ålesund (Spitzbergen)	AWI	LIDAR	DIAL	1991
	Neumayer (Antarctica)	AWI	Ozonesonde	ECC	1992
	Garmisch	FZK	LIDAR (Troposphere)	DIAL	1988
<b>Calibration</b>	Jülich	FZ	Ozonesonde		
<b>UV</b>	Garmisch	FZK	Bentham DTM 300		1994
	Hohenpeissenberg	DWD	Brewer MK II	No. 010	1991
	Lindenberg	DWD	Brewer MK IV	No. 078	1991
	Potsdam	DWD	Brewer MK II	No. 030	1993
	Potsdam	DWD	Brewer MK III	No. 118	1996
	Potsdam	DWD	Bentham DM 150		2000
	Potsdam	DWD	Spectro 320D		2002
	Dortmund	BAuA	Bentham DM150		
	Kulmbach	LfU	Bentham DM150		
	München	BfS	Bentham DM150		1993
	Langen	BfS	Bentham DM150		1993
	Schauinsland	BfS	Bentham DM150		1993
	Sylt	CAU	Bentham DM 300		1995
	Zingst	BfS	Bentham DM150		1993
	Zugspitze	FZK	Bentham DTM 300		1995

## RESEARCH AND DEVELOPMENT

The German Ministry of Education and Science (BMBF) has been funding a number of ozone and UV-research programmes. These programmes were conducted in close cooperation with partners from Europe and abroad, and include laboratory studies, modeling and the evaluation of existing data. They substantially improve the understanding of the ozone layer, especially at northern high and mid-latitudes. The AFO 2000 Programme, in particular the KODYACS project has investigated the links between long-term ozone depletion and climate change. KODYACS combined substantial modeling efforts (ECHAM/CHEM) with analysis of existing long-term measurements.

Apart from ongoing ozone related research activities, DLR-IPA is involved in two major EU-funded projects: DLR-IPA is coordinator and one of the main contributors for the international TROCCINOX project. TROCCINOX is aimed at improving the knowledge about trace gases (including water vapor) and particles (ice crystal and aerosols) in the upper troposphere and lower stratosphere in connection with tropical deep convection as well as large scale upwelling motions. A major focus is on production of NO<sub>x</sub> by lightning (LNO<sub>x</sub>) in tropical thunderstorms. In two major international campaigns (January to March 2004, and January to March 2005), several aircraft,

including Brazilian Bandeirante, DLR-Falcon and Russian high-altitude Geophysica were deployed over Brazil, and on transfer flights across the Atlantic.

DLR-IPA and the Atmospheric Chemistry Department of the Max Planck Institute for Chemistry in Mainz are partners in the SCOUT-O3 project. SCOUT-O3's aim is to provide predictions about the evolution of the coupled chemistry/climate system, with emphasis on ozone change in the lower stratosphere and the associated UV and climate impact. In cooperation with FU-Berlin, DLR-IPA is leading SCOUT-O3 activity 1, which will generate ozone, climate and UV predictions with various state-of-the-art models. DLR-IPA is also involved in the major international SCOUT-O3 tropical thunderstorm campaign, November/December 2005 in Darwin (Australia), and in measurement and modeling activities for surface UV. IUP-Uni Bremen is one of the leading institutes in the scientific design of the GOME and the SCIAMACHY instruments. Algorithms for retrieving trace gas amounts from the instruments' raw data are developed in cooperation with German Remote Sensing Data Center (DFD), the Smithsonian Astrophysical Observatory (Harvard, Cambridge/MD, USA), the University of Heidelberg (Germany), the Koninklijk Nederlands Meteorologisch Instituut (KNMI, The Netherlands), and other institutes from the GOME Science Advisory Group.

IUP-Uni Bremen substantially contributes to the NDSC and operates a number of relevant systems at the KOLDEWEY Arctic station in cooperation with AWI. The building of a new tropical station (Merida, Venezuela, 4700 m asl) in cooperation with FZ Karlsruhe and AWI is in progress. They are also contributing to another arctic station on the Greenland ice-shelf (at 3200 m asl) in cooperation with DPC, Kopenhagen, Uni Bordeaux, Uni Leeds and NSF USA (EU-Project).

At IMK (Forschungszentrum and University of Karlsruhe) measurements of ozone and ozone relevant species have been performed for many years by ground-based and airborne observations. Since the successful launch of the ENVISAT satellite, the retrieval of MIPAS-ENVISAT data beyond ESA standard products with the KOPRA-RCP processor developed at IMK provides data sets on a global scale of NO, NO<sub>2</sub>, N<sub>2</sub>O<sub>5</sub>, HNO<sub>4</sub>, ClONO<sub>2</sub>, ClO, many other chlorine species, atmospheric tracers, other atmospheric parameters like photolysis rates and cloud particle properties (PSC, SVC). Main results are a detailed analysis of mixing effects during the Antarctic vortex split period in 2002, a global picture of PSC occurrence in the Antarctic, and the chemical effects of the strong solar storm events in fall 2003 and Arctic winter 2003/2004, showing ozone loss of 30% in about 50 km altitude. Balloon-borne observations allowed further analysis of the composition of PSC particles, ground based studies analyzed ozone loss in several winters. A new container with many new instruments has been developed for measurements on board a passenger aircraft Airbus A340-600 of Deutsche Lufthansa AG to measure regularly the distribution of ozone and other trace gases in the tropopause region.

The Lidar observation at Garmisch shows that the stratospheric aerosol load has relaxed after the eruption of Mt. Pinatubo. Current background levels are comparable to that observed in the seventies. Possible contributions from air traffic can therefore be excluded. Around 1995/1996 the Zugspitze and Jungfraujoch solar FTIR observations of total HCl and ClONO<sub>2</sub> have monitored the Cl<sub>y</sub>-turnover as a response to the Montréal protocol.

At Forschungszentrum Jülich various research activities related to stratospheric ozone are carried out including in-situ and remote observations and model simulations. In-situ observations of stratospheric water vapor and halogen oxides (ClO, Cl<sub>2</sub>O<sub>2</sub>, BrO) are made from aircraft and balloon platforms. Remote observations of various chemical species from aircraft (M55-Geophysica) are performed with the IR spectrometer CRISTA-NF. 3-dimensional simulations with respect to chemical ozone loss and the ozone budget are performed with the Lagrangian CTM CLaMS. Also different methods for diagnosing chemical ozone loss from available observations have been developed and are applied.

Under the coordination of Forschungszentrum Jülich (FZJ) the European IAGOS (Integration of Routine Aircraft Measurements into a Global Observing System) project (<http://www.fz-juelich.de/icg/icg-ii/iagos/>) started in the beginning of 2005 with the preparation of a

distributed infrastructure for observations of atmospheric composition (e.g. ozone) on the global scale from commercial in-service aircraft. Commercial aircraft are complementary to satellite, balloon borne and ground based observations and can constitute an important component in a future integrated global observation system to watch the atmosphere for global or regional changes in the frame of the WMO/IGACO-(Integrated Global Atmospheric Chemistry Observations) theme. The IAGOS-initiative goes beyond the European MOZAIC (Measurement of Ozone by Airbus In-Service Aircraft) project (<http://www.aero.obs-mip.fr/mozaic/>), where five Airbus A340 long range passenger aircraft are equipped with automated instrumentation to measure comprehensive climatologies of the large scale distribution of ozone between surface and 12 km altitude since 1994. FZJ has been involved in MOZAIC from very beginning (coordination by CNRS in France). In total, more than 25,000 long-haul flights have been accomplished between 1994 and 2004 for O<sub>3</sub> measurements, yielding more than 100,000 hours of data from the tropopause region and 40,000 tropospheric profiles over many cities.

Long-term measurements of stratospheric CFC12 have been conducted by the University of Frankfurt and FZ Jülich. Since 1978 they have studied the evolution of this important source gas by regular balloon soundings.

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 cold winter 2004/2005. These campaigns have been instrumental for our current understanding of the chemical ozone loss in the Arctic.

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.

The UV-group at the University of Munich investigates different influences on surface UV including modeling and detailed measurements.

## **QA/QC/VALIDATION**

Activities towards improving the quality of balloon-ozone-soundings were continued at the World Calibration Center for Ozone Sondes (WCCOS) at FZ Jülich. In this scope, several JOSIE (Juelich Ozone Sonde Intercomparison Experiment: <http://www.fz-juelich.de/icg/icg-ii/josie>) sonde simulation experiments have been conducted in the laboratory to evaluate the performance of ozone sondes. In April 2004 the WMO/BESOS (Balloon Experiment on Standards for Ozone Sondes) field campaign at the University of Wyoming at Laramie, USA, was held to test the reliability of JOSIE-results in the real atmosphere. The results of JOSIE and BESOS clearly demonstrate that caution has to be exercised in making instrumental changes or in preparing/operating procedures with regard to the sonde performance and hence the interpretation of ozone trends. Under the auspices of WMO/GAW the Assessment of Standard Operating Procedures for Ozone Sondes (ASOPOS) has been initiated and a panel meeting of experts in Jülich (September 2004) critically evaluated operating procedures and is preparing a detailed document with recommendations for standardization of sonde operation.

The Regional Dobson Calibration Center for WMO RA VI Europe (RDCC-E) at the Meteorological Observatory Hohenpeissenberg (MOHp) has been responsible for second level calibration and maintenance of more than 30 operational Dobson spectrometers in Europe since 1999. The close cooperation between MOHp and the Solar and Ozone Observatory at Hradec Kralove (SOO-HK, Czech Republic) guarantees excellent calibrations, training of operators, supply of the community with hard- and software. In the past 6 years 12 intercomparisons were performed with altogether 39 spectrometers from 18 countries. 9 Dobsons were completely refurbished electronically, among them 3 instruments being operated by the British Antarctic Survey at stations at the South Pole and one from Nairobi/Kenya.

The regional standard Dobson No. 064 was calibrated twice towards the primary standards (2002 at Boulder, USA, 2004 at Dahab, Egypt). During the last mentioned campaign DICE near the Red Sea the RDCC-E assisted in the organization and realization of the calibration service for the African network in WMO RA I together with the World Dobson Calibration Center (NOOA, Boulder - USA). In 2005 the staff of the RDCC-A from South Africa visited MOHp to get a training course in Dobson maintenance service.

GAWTEC, the Training and Education Center of the GAW Programme, has been established in July 2001. From the beginning, it was funded by the Bavarian State and supported by WMO. Since 2004, the German Federal Environmental Agency provides significant financial contributions to GAWTEC, which is also a co-operating partner of the German Quality Assurance/Science Activity Center. GAWTEC organizes training courses twice a year for personnel from GAW stations worldwide. It is based at the UFS Schneefernerhaus on the Zugspitze mountain. Experts from UBA, IMK at Garmisch, DWD at Hohenpeissenberg and additional invited experts hold training courses in measurement techniques of GAW-relevant parameters including ozone. Special emphasis is put on quality control, data handling and interpretation. Funding for GAWTEC will be provided at least until the end of 2006.

At the Ground Truthing Facility in Garmisch (IFU/IMK) dedicated validation studies have been performed for the instrument SCIAMACHY onboard ENVISAT by ground-based FTIR observation. Thereby significant deviations between the FTIR NO<sub>2</sub> column amounts and the ESA SCIAMACHY results have been identified.

By IMK observations from the ground based stations in Kiruna and Tenerife have been used for validation of the SCIAMACHY and MIPAS observations on ENVISAT, and the Japanese satellite instrument ILAS-2. For the validation of MIPAS and SCIAMACHY on ENVISAT, balloon borne campaigns with a MIPAS FTIR instrument at several sites and several flights with MIPAS on the Geophysica aircraft have been performed.

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