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PREFACE

The Swiss Global Atmosphere Watch (GAW-CH) Programme is ten years old. Based on the recommendations of the first national GAW Conference in 1993, the needs and priorities for the GAW related activities at the national level were defined. Subsequently, a steering committee established a comprehensive GAW Programme in Switzerland, which became operational in 2001, after a set-up phase of six years.

During the last decade, the GAW Programme of the World Meteorological Organisation (WMO) was confirmed as a crucial component in the global environmental monitoring network and is considered as a pillar for other global programmes. Since the beginning, the Swiss GAW Programme was defined as an integral part of the WMO/GAW Programme. Thus, the contributions of GAW-CH to the global programme and the international co-operation played a very important role in driving the Swiss activities. An appropriate balance between services, operational monitoring and research activities has been felt to be mandatory in order to fulfil the long-term monitoring of our atmosphere.

The WMO/GAW perspective requested convincing the partners and the decision makers that atmospheric chemistry measurements need as much attention as meteorological parameters in order to understand the long-term evolution of the atmosphere. It was challenging to bring all national key players active in the field of atmospheric chemistry and physics to be involved in a common programme and to get important financial contributions from the government for supporting the planned activities. This is an important achievement and provides an example for future engagements related to GAW or to similar environmental programmes.

The Swiss GAW Programme allowed establishing a strong collaboration between all national research institutions and federal offices involved in atmospheric observations and analyses. Particularly, the co-operation between institutions in charge of the operational measurements and research oriented laboratories was very fruitful and absolutely decisive for the high quality of the collected data. In addition, the Swiss GAW Programme had a stimulating effect on the scientific community and was very successful in triggering complementary projects in the field of atmospheric research and climate change.

The results of the Swiss GAW Programme were prominently presented at two national GAW Conferences in 1998 and 2002 that gave a perspective and prospective view on the numerous scientific and technical developments. The outcome of the programme is embodied by the data submission to the GAW World Data Centres, the establishment of World Calibration as well as Quality Assurance and Science Activity Centres, the effective participation to GAW working groups, the scientific publications in peer reviewed journals as well as the contributions to international conferences and to public media.

During the last decade, the depth, breadth and quality of the long term observations undertaken at the high alpine research station Jungfraujoch in the fields of radiation, aerosols as well as reactive and greenhouse gases could be raised to a level that justified the Jungfraujoch to obtain the status of a global GAW station. Thus in February 2005, the Jungfraujoch became the twenty-third site in the network of the global GAW stations of WMO.

Although the national GAW Conferences also allowed checking whether the programme was performing according to the defined goals, it is now the first time that the Swiss GAW Programme undergoes a review by a group of international experts. According to the mandate to the reviewers, they shall evaluate whether the GAW-CH activities are in line with the GAW objectives and whether they were conducted efficiently. Close national and international collaboration, as well as appropriate synergies between monitoring and research duties constitute additional reviewing criteria. Therefore, the reviewers' recommendations will contribute assessing and optimizing the ongoing activities and adjusting them to future challenges.

The decision to start the Swiss GAW Programme based on the requirements and requests of WMO in the mid-nineties has proved to be a pioneer initiative at a moment when the need of an integrated environmental approach was not felt as strong as nowadays. Hopefully, the judgement of the experts will help to keep the momentum of the first decade and to set the future priorities in an adequate way. We are confident that based on their recommendations, the partners of the programme are willing to continue their effort and the politicians are ready to reinforce their commitment to guarantee the actual level of funding.

The present report gives an overview of all activities within and (sub)-programmes of the Swiss GAW Programme. It will serve to give to the reviewers the frame of the painting. The oral presentations and discussions during the review will add the colours and the expert's eyes will surely help us complementing the right appropriate paint touch.

Zurich and Payerne, March 2005 Gerhard Müller and Pierre Viatte

THE WMO GLOBAL ATMOSPHERE WATCH (GAW) PROGRAMME

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1 INTRODUCTION

The Global Atmosphere Watch (GAW) Programme of the World Meteorological Organization (WMO) was established in 1989. It is focused upon the role of atmospheric chemistry in global change (GAW, 2001, 2004). Details of the programme can be found at the GAW website (http://www.wmo.ch/web/arep/gaw/gaw_home.html). Consisting of a partnership of managers, scientists and technical expertise from 80 countries, GAW is coordinated by the WMO Secretariat in Geneva and the Working Group on Environmental Pollution and Atmospheric Chemistry (WG-EPAC) of the Commission for Atmospheric Science (CAS). The Swiss GAW programme is a major contributor to the WMO/GAW programme with a large research effort within the country as well as data management, quality assurance, training and network infrastructure support for global activities.

WMO/GAW involves research and observations contributing to international conventions in which atmospheric chemistry processes are important. For the Vienna Convention for the Protection of the Ozone Layer and its Montreal Protocol on Substances that Deplete the Ozone Layer, GAW supports the WMO/UNEP quadrennial Scientific Assessment of Ozone Depletion and the WMO /UNEP triennial meeting of the Ozone Research Managers of the Parties to the Convention. It also produces regular Ozone Bulletins during the Antarctic depletion season. GAW has been actively involved in supporting the United Nations Framework Convention on Climate Change (UNFCC) through contributions to the Strategic Implementation Plan of the Second Report on the Adequacy of the Global Observing Systems for Climate by the Global Climate Observing Strategy (GCOS). This plan was recently accepted by the Parties to the Convention. Essential Climate Variables (ECVs), defined in the implementation plan include greenhouse gases, ozone and aerosols. GAW is recognized as the lead international programme responsible for these variables.

WMO/GAW has taken the lead in a scientific assessment of the past, present and future state of global air composition observations, the measurement requirements and priorities in the next 15 years for Integrated Global Atmospheric Chemistry Observations (*IGACO*, 2004). The IGACO Atmospheric Chemistry Theme Report produced for the partners of the Integrated Global Observing Strategy (IGOS) recommends an approach for integration of ground-based, aircraft and satellite observations of 13 chemical species in the atmosphere using atmospheric forecast models that assimilate not only meteorological observations but also chemical constituents. Socio-economic issues related to climate change, ozone depletion/ UV increase and air quality benefit by having such a system in place. IGACO is a blueprint for the next generation GAW activities.

2 GOALS

The focus, goals and structure of GAW are outlined in detail in the Strategic Implementation Plan (*GAW,* 2001) and an addendum (*GAW,* 2004). MeteoSwiss chaired the group developing this plan. Recognizing the need to bring scientific data and information to bear in the formulation of national and international policy, the GAW mission is threefold:

a. Systematic monitoring of atmospheric chemical composition and related physical parameters on a global to regional scale

b. Analysis and Assessment in support of environmental conventions and future policy development

c. Development of a predictive capability for future atmospheric states.

3 APPROACH

3.1 GAW Monitoring

The components of the GAW monitoring programme are summarized in Figure 1. Global GAW networks focus on six measurement groups: greenhouse gases, UV radiation, ozone, aerosols, major reactive gases (CO, VOCs, NO_y and SO_2), and precipitation chemistry. The GAW Station Information System (GAWSIS) was developed and is maintained by the Swiss GAW programme. It is the host of all GAW metadata on GAW Country Programme managers, station descriptions and measurement activities. According to GAWSIS, there are 23 Global, 640 Regional and 73 Contributing stations operating or submitting data to a GAW World Data Centre. GAW Scientific Advisory Groups (SAGs) for each of the six measurement groups establish measurement standards and requirements while calibration and quality assurance facilities ensure valid observations. Five GAW World Data Centres collect, document and archive data and quality assurance information and make them freely available to the scientific community for analysis and assessments. Note the linkages of GAW to contributing partner networks and to satellite observations that contribute to the global air chemistry observations system.

3.2 GAW Urban Research Meteorology and Environment (GURME)

GURME promotes development of air quality forecasting capabilities of WMO members and links to urban environmental issues. In 1999, the GAW Urban Research Meteorology and

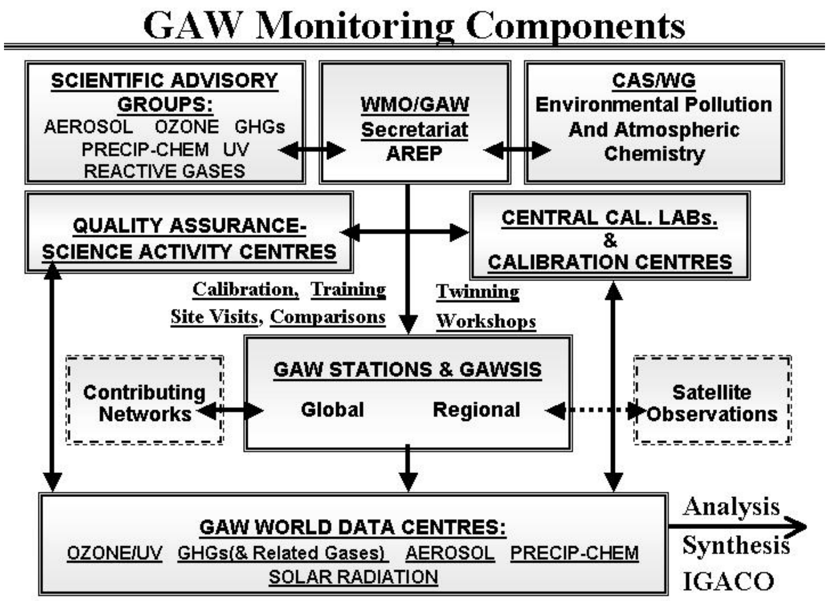

Figure 1: Components of the WMO/GAW Global Monitoring Programme.

Environment (GURME) project was added to GAW by the thirteenth WMO Congress in response to the requests of the WMO members many of whom have responsibilities in the study and management of urban environments. The aim is to enhance capabilities in air chemistry and meteorology of urban pollution. This is done by the coordination and focussing of present activities, as well as initiation of new ones. Through a series of workshops, the Scientific Advisory Group (SAG GURME) and the GAW office has developed guidelines to assist in effectively dealing with urban pollution matters. These are outlined in *GAW* (2003a) and describe in detail on the GAW website. Pilot projects that demonstrate how WMO Members can successfully expand their activities into urban environment issues, showcase new technologies and develop illustrative examples. have been initiated in Beijing, Moscow and three Latin American cities (see *GAW website*). In addition, a pilot project on the use of passive samplers for urban measurements has been conducted involving several cities.

4 RESULTS

In the past decade, the emphasis of GAW on standardization, calibration, quality assurance, data archiving/analysis and building global air chemistry monitoring networks has resulted in major advances.

4.1 Progress in Establishing Calibration, Quality Assurance and Data Analysis Facilities

Table 1 summarizes the major facilities related to quality assurance and archiving in GAW for the GAW target variables outlined in the Strategic Plan. Those facilities supported by the Swiss GAW programme are grey shaded. Over 80% of these facilities have been established under GAW while the rest that were incorporated into GAW in 1989 have been strengthened. In addition to these facilities, 7 regional calibration centres for total ozone are in operation.

As mentioned above, GAWSIS was developed in the last 5 years to fill a serious gap in documenting the past and present state of the GAW networks for the target variables. More details of progress in GAWSIS are given elsewhere in these workshop proceedings.

4.2 Pgress in Building and Defining the GAW Monitoring Network

There are GAW Global, Regional and Contributing stations that support the monitoring of GAW target variables in each of the six groups. Global and Regional stations are operated by a WMO Member and are defined by Technical Regulations adopted by the WMO Executive Council in 1992 (*EC XLIV,* 1992) as well as the GAW Strategic Implementation Plan (*GAW,* 2001; 2004). Contributing stations are those that conform to GAW measurement guidelines, quality assurance standards and submit data to GAW data centres.

Table 1: Overview of the GAW World Central Facilities (as of December 2003). The World Central Facilities have assumed global responsibilities, unless indicated (Am: Americas; E/A: Europe and Africa; A/O: Asia and the South-West Pacific). From the addendum to the GAW Strategic Implementation Plan (*GAW,* 2004).

Species	QA/SAC	World Calibration Centre	Central Calibration Laboratory (CCL, Reference Standard)	World Data Centre
CO_2	JMA (A/O)	CMDL	CMDL	JMA
CH_4	EMPA (Am, E/A) JMA (A/O)	EMPA (Am, E/A) JMA (A/O)	CMDL	JMA
N_2O	UBA	IMK-IFU	CMDL	JMA
CFCs				JMA
Total Ozone	JMA (A/O)	CMDL[1], MSC[2], MGO[3]	CMDL[1], MSC[2]	MSC
Ozone Sondes	FZ-Jülich	FZ-Jülich	FZ-Jülich	MSC
Surface Ozone	EMPA	EMPA	NIST	JMA
Precipitation Chemistry	ASRC-SUNY	ASRC-SUNY	ISWS	ASRC-SUNY
CO	EMPA	EMPA	CMDL	JMA
VOC	UBA	IMK-IFU		JMA
SO_2				JMA
NO_x				JMA
Aerosol		IfT (Phys. Properties)		JRC
Optical Depth		PMOD/WRC	PMOD/WRC[4]	JRC
UV Radiation	ASRC-SUNY (Am)	SRRB (Am)		MSC
Solar Radiation		PMOD/WRC	PMOD/WRC	MGO
^{85}Kr, ^{222}Rn		EML		JMA
^{7}Be, ^{210}Pb		EML		EML

ASRC-SUNY Atmospheric Sciences Research Centre, State University of New York (SUNY), Albany NY, USA, hosting the World Data Centre for Precipitation Chemistry (WDCPC)

BSRN Baseline Surface Radiation Network, Federal Institute of Technology (ETH), Zürich, Switzerland

CMDL Climate Monitoring and Diagnostic Laboratory, National Oceanographic and Atmospheric Agency (NOAA), Boulder CO, USA

EML Environmental Measurements Laboratory, Department of Energy (DoE), New York City NY, USA

EMPA Swiss Federal Laboratories for Materials Testing Research and ResearchTesting, Dübendorf, Switzerland

FZ-Jülich Forschungszentrum Jülich, Jülich, Germany

IMK-IFU Institut für Meteorologie und Klimatologie Atmosphärische Umweltforschung, Forschungs-zentrum Karlsruhe in der Helmholtz-Gemein-schaft, Garmisch-Partenkirchen, Germany

ISWS Illinois State Water Survey, Champaign IL, USA

IfT Institute for Tropospheric Research, Leipzig, Germany

JMA Japan Meteorological Agency, Tokyo, Japan, hosting the World Data Centre for Greenhouse Gases (WDCGG) and the Quality Assurance/Science Activity Centre for Asia and the South-West Pacific

JRC Environment Institute, Ispra, Italy, hosting the World Data Centre for Aerosols (WDCA)

MGO A.I. Voeikov Main Geophysical Observatory, Russian Federal Service for Hydrometeorology and Environmental, St. Petersburg, Russia, hosting the World Radiation Data Centre (WRDC)

MSC Meteorological Service of Canada – formerly Atmospheric Services (AES), Environment Canada, Toronto, Canada, hosting the World Ozone and UV Data Centre (WOUDC)

NIST National Institute for Standards and Testing, Gaithersburg MD, USA

PMOD/WRC Physikalisch-Meteorologisches Observatorium Davos/World Radiation Centre, Davos, Switzerland

SRRB Surface Radiation Research Branch of NOAA's Air Resources Laboratory, Boulder CO, USA

UBA German Environmental Protection Agency, Berlin, Germany

[1] Dobson only
[2] Brewer only
[3] Filter instruments
[4] Precision Filter Radiometers (PFR)

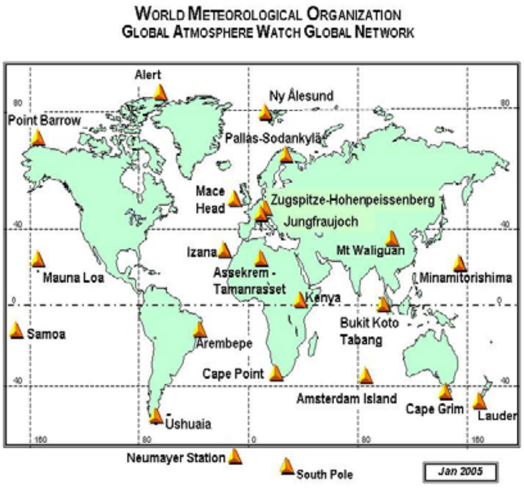

Figure 2: Global stations in the GAW network.

They are mostly in partner networks that fill major gaps in the global monitoring network. The difference between a Global and a Regional GAW station lies in the facilities available for long term measurements, the number of GAW target variables measured, the scientific activity at the site and the commitment of the host country. Switzerland has recently added Jungfraujoch as the 23rd Global station to the GAW global network (Fig. 2) this is one step closer to the goal of 30 stations stated in the Technical Regulations. The Jungfraujoch station clearly fills all requirements and is a unique high altitude station in Europe. Switzerland also contributes 6 other stations to the GAW network.

To monitor global distributions and trends of a particular variable with sufficient resolution to answer outstanding gaps in understanding of environmental issues such as ozone depletion requires not only Global but also Regional and Contributing stations. The GAW ozone vertical profiles network with balloon sondes (Fig. 3) is a good example of how global coverage is achieved through co-operation with contributing partners, namely the NASA/SHADOZ network. Swiss GAW contributes substantively to this network in developing the GAW Standard Operating Procedures for EC- sondes and in maintaining not only a long term balloon sonde station at Payerne but also in Kenya.

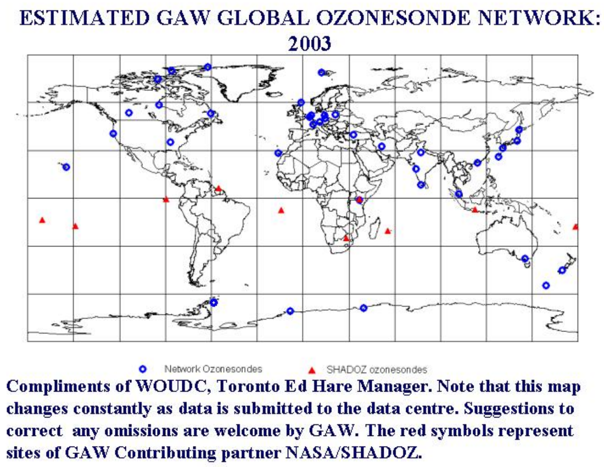

Figure 3: GAW Global network for ozone vertical profile measurements. Blue dots are GAW sites and red triangles are NASA/SHADOZ sites. Kenya is a shared site.

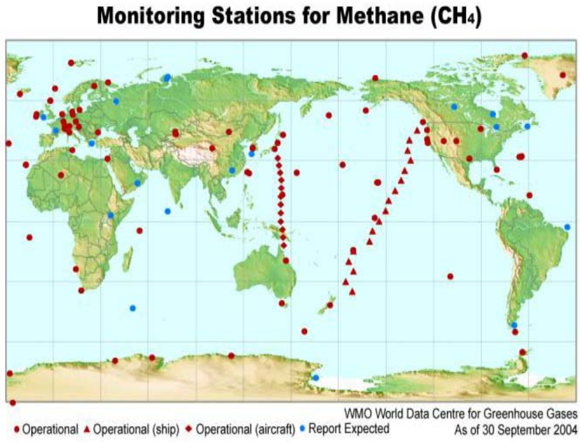

Figure 4: The GAW surface methane network. Support for calibration, audits and maintenance advice are provided by the GAW World Calibration Centre for methane of the Swiss GAW programme.

There are similar global networks for other variables such as total column ozone, surface ozone, carbon dioxide, methane, nitrous oxide, aerosol variables, reactive gases and precipitation chemistry that involve different combinations of the three types of stations and network configurations (e.g. *GAW*, 2003a). The GAW network for global methane observations (Fig. 4), when compared to the ozone network, illustrates such differences. The World Calibration Centre for Methane at EMPA in Dübendorf, Switzerland works to ensure that stations in the network have calibrations linked to the GAW world reference standard maintained by NOAA/CMDL in Boulder, to visit sites offering advice and training.

Aerosols play a major role in all atmospheric chemistry issues. The GAW SAG for aerosols chaired by a member of the Swiss GAW programme has published a measurements guideline (*GAW,* 2003b) that recommends five core aerosol variables to be measured in a global network: aerosol optical depth, aerosol mass in 2 size ranges, aerosol chemistry in 2 size ranges, aerosol scattering and aerosol absorption. It also suggests a more comprehensive measurement programme for selected sites such as the Global stations. GAW is currently in the process of building the global aerosol network. The Swiss GAW programme has played a key role. In March 2004, the GAW Aerosol SAG led by Prof. Urs Baltensperger, C. Wehrli and the GAW office organized an Experts Workshop on column aerosol optical properties. It was held at the GAW World Optical Depth Research Centre (WORCC) in Davos which operates a calibration centre and a global reference network of GAW Precision Filter Radiometers (PFRs) for the purpose of linking the diverse AOD measurements. The workshop addressed two questions: (i) what is the current status of the global long-term network of aerosol optical depth stations operated by WMO members and partners (e.g. NASA AERONET) and (ii) how can these diverse efforts be coordinated more effectively to everyone's benefit? A WMO/GAW report of the workshop conclusions and recommendations will be followed up with an Experts Meeting.

5 FUTURE PLANS

The GAW monitoring programme will evolve in the next decade to reflect the needs of users of a globally coordinated atmospheric chemistry network. It is essential that the groundwork laid in the past 16 years for global ground-based and aircraft monitoring systems is maintained and strengthened. This is no mean feat considering the pressures on WMO Members. In the next decade, technological advances in measurement methodology and data exchange will shape the evolution of GAW monitoring. Merging ground-based in situ and remote sensing observations with routine aircraft and satellite measurements through the use of “smart interpolators” that are under development by the research and modelling community is at once a daunting and exciting challenge. WMO/GAW is the designated lead in the implementation if an Integrated Global Atmospheric Chemistry Observations (IGACO) strategy (Fig. 5) within which the next generation GAW will evolve to meet the observational need and challenges of climate change, ozone depletion, air quality and long range transport of air pollution.

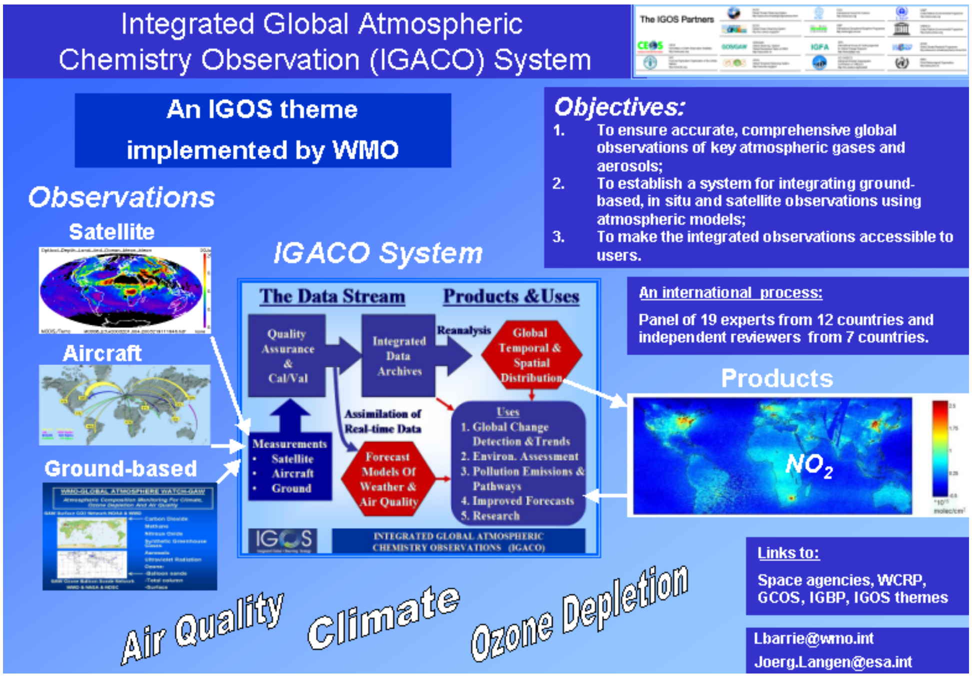

Figure 5: A schematic of the IGACO partners, system and links societal needs and issues.

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GENERAL ASPECTS AND INTERNATIONAL SERVICES

THE SWISS GLOBAL ATMOSPHERE WATCH (GAW-CH) PROGRAMME: GENERAL ASPECTS AND INTERNATIONAL SERVICES

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1 INTRODUCTION

Established in 1989 by the World Meteorological Organization (WMO) as a major priority programme, the Global Atmosphere Watch (GAW) Programme is one of the most important contributions to the study of environmental issues in the post-UNCED (United Nations Conference on Environment and Development, 1992) period (*Barrie,* 2005 – this volume). GAW is considered to be the atmospheric chemistry component of the Global Climate Observing System (GCOS).

The mission of the Global Atmosphere Watch is to make reliable, comprehensive observations of the chemical composition and selected physical characteristics of the atmosphere in order to provide the scientific community with the means to predict future atmospheric states, and to organize assessments in support of formulating environmental policy. The goals and implementation strategies are defined in the Strategic Plan (*WMO*, 1997; *WMO*, 2001).

In order to fulfil these goals, WMO expressed the need to strengthen the role of the national meteorological and hydrological services (NMHSs) with respect to atmospheric chemistry monitoring and research activities. WMO recommended that all members give the same priority to atmospheric chemistry measurements as to other meteorological parameters and encouraged the NMHSs to ensure that chemical composition observations become an integral part of atmospheric observations.

GAW is based on voluntary contributions by the member countries and the scientific community. The achievement of the objectives of the Strategic Plan therefore depends entirely on the close and continuous participation of member countries. Therefore, it became important

- to support and encourage the operation of GAW stations on the basis of commitments by Member countries,
- to increase the number of participating countries, particularly those that may contribute to central facilities, services and expert groups.

In 1994, the Swiss Global Atmosphere Watch Programme GAW-CH was launched through a decision of the Swiss Government aiming to support

- the UN Climate Convention on Climate Change, 1992 (Global Climate Observing System),
- the Vienna Convention for the Protection of the Ozone Layer (1985),

by establishing a Swiss contribution to the GAW Programme of WMO.

The Swiss government allocated 3.8 Mio CHF to the build-up of the GAW-CH programme during the years 1995-98, as well as regular contributions of more than 1 Mio CHF per year for the follow-up activities. About half of the funding has been dedicated to international activities in favour of the global GAW programme, the other half was used for national level GAW related monitoring and research activities. They are described in a separate section of this report (*Viatte and Müller,* 2005 – this volume).

This contribution concentrates on more general aspects of the Swiss GAW programme and its international activities

2 GENERAL GOALS

The main goal fixed by the Swiss GAW community was to reinforce its international contributions and co-operation especially in relation with

- calibration,
- quality assurance,
- capacity building.

The international services should be

- established in sectors where the Swiss participants have a strong and special experience,
- maintained on a long-term,
- in line with the needs and priorities of GAW as stated in its strategic plan.

From the beginning, it was felt important that members of the Swiss GAW community participate at the established Scientific Advisory Groups (SAG) which have the task to organise and co-ordinate GAW activities for the various parameter types, to contribute to the elaboration of the guiding documents of GAW and to assist the secretariat in its management and leadership role.

Finally, the international contributions and the international co-operation were expected to be driving forces also for the national activities.

3 APPROACH

The first step of the Swiss GAW programme (GAW-CH) has been to establish a strong collaboration between MeteoSwiss, as the lead institution of this programme, and the various federal offices and national research institutions involved in atmospheric observations and analyses.

For co-ordination and leadership of the programme a national steering committee (Landesausschuss GAW-CH) was established. It meets twice a year and is supported by a secretariat at MeteoSwiss (Koordinationsstelle GAW-CH) acting as national focal point for WMO as well.

The set-up phase of GAW-CH, which started in 1995, was two years longer than planned and ended in 2000. It was followed by a consolidation phase of four years which was extended until the end of 2006.

It was clear from the beginning that GAW-CH had to undergo reviews on a regular basis. Jointly with the Swiss Agency for the Environment, Forests and Landscape (BUWAL), MeteoSwiss therefore organized various meetings of the Swiss GAW community (*Müller,* 1994; *Jeannet et al.,* 1999; *Jeannet and Ruffieux,* 2002). These conferences reviewed the status of the ongoing work and defined needs and priorities for future activities. This year, and for the first time, the Swiss GAW programme has the chance to profit from an independent review by international experts.

4 RESULTS

Most of the Swiss international services (Figure 1) started already in the mid nineties; they are defined on the basis of contracts between MeteoSwiss and the partner institutions concerned – most of them without time limit:

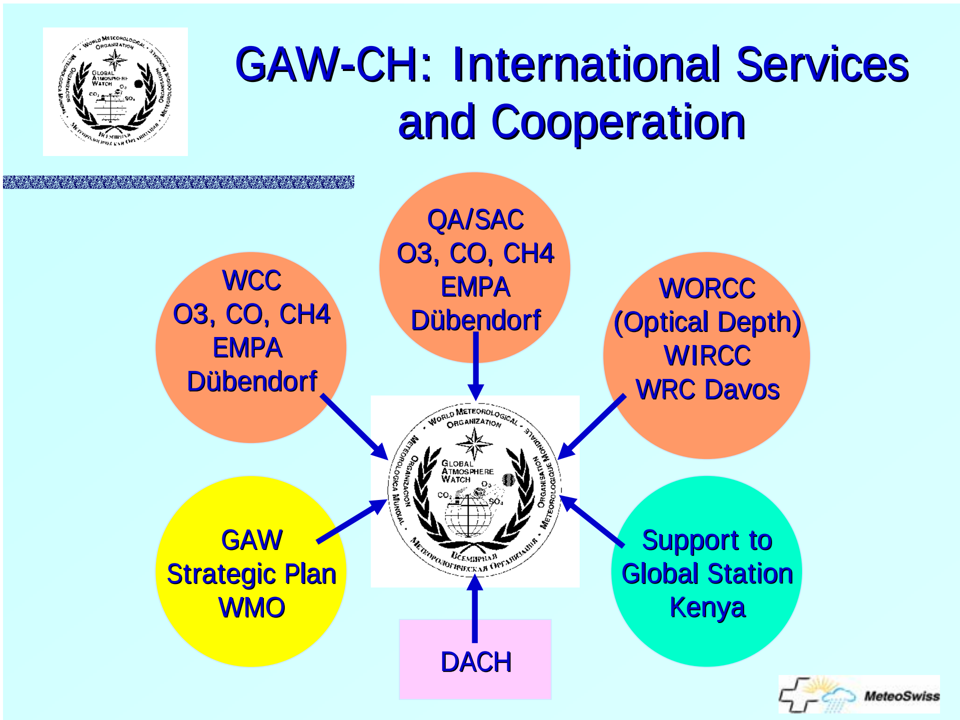

Figure 1: Services and Co-operations in the framework of the Swiss GAW Programme GAW-CH in favour of the global GAW Programme of the World Meteorological Organisation (WMO).

- **World Optical Depth Research and Calibration Centre** (WORCC) at the Physikalisch-Meteorologisches Observatorium/World Radiation Centre (PMOD /WRC) in Davos: Since the seventies, the WRC is responsible for the world-wide homogeneity of the meteorological radiation measurements. Based on the existing knowledge, since 1995 the PMOD is also operating the WORCC. In this function, it developed Precision Filter Radiometers (PFR) for the measurement of optical depth and defined procedures to ensure world-wide homogeneity of optical depth measurements by transfer standards and data quality control algorithms. PFRs have been supplied to a dozen of GAW stations all over the world and are now in routine operation. At present, based on a recommendation of the Commission for Atmospheric Sciences (CAS) and the Commission for Instruments and Methods of Observation (CIMO) of WMO, the PMOD is building up a **World Calibration Centre for long-wave radiation**.

- **World Calibration Centre (WCC) and Quality Assurance /Science Activity Centre** (QA/SAC) for Surface Ozone, carbon monoxide and methane at the Swiss Federal Laboratories for Materials Testing and Research (EMPA) in Dübendorf: In 1996 EMPA started the WCC for surface ozone for Europe and Africa as a joint project with MeteoSwiss. Later, Carbon Monoxide (1997) and Methane (2000) activities have been integrated. In 1998 the responsibility of the WCC was enlarged from Europe/Africa to the world-wide network. EMPA's activities include capacity building in addition to the audits and inter-comparison campaigns. As support to the Secretariat of WMO, EMPA has been establishing a meta-data information system (GAWSIS) which became available on the Internet by the end of 2001. In addition, a project was started aimed to the use and dissemination of ESA (European Space Agency) and NASA (National Aeronautic and Space Administration) satellite information on atmospheric constituents.
- **Support to the global GAW station of Kenya**: The station of Kenya is one of the new very important global GAW stations. MeteoSwiss and EMPA regularly performed trainings and audits for the measurements at Mt Kenya and Nairobi. In order to maintain the unique ozone sonde station at the Kenyan Meteorological Department (KMD) in Nairobi, MeteoSwiss also contributed to the funding of consumables for the ozone soundings. The sounding data are controlled at MeteoSwiss in Payerne and submitted to the international data centres SHADOZ (Southern Hemisphere ADitional OZonesondes) and WOUDC (World Ozone and UV Data Centre). The relocation of the revised Dobson instrument D18 for ozone total column measurement at Nairobi from the university to the KMD observatory is in preparation.
- **Co-operation DACH** (Germany-Austria-Switzerland) for a globally relevant alpine data set, involving the German global GAW station of Zugspitze/Hohenpeissenberg (2960 m/985 m asl), the Austrian regional GAW station of Sonnblick (3016 m asl) and the Swiss regional GAW station of Jungfraujoch (3580 m asl). The co-operation started in 1995. A common data archive was established at the German weather service (DWD). Studies of the spatial representativeness of the data lead to the development of filters for extracting data with extended spatial representativeness (*Fricke et al.,* 2000). Because of various operational problems, the co-operation was reduced to single research activities later on. At the beginning of 2005, Jungfraujoch has officially changed its status from a regional to a global GAW station.
- **Strategic Plan for GAW**: MeteoSwiss and EMPA had the chance to take leading roles in the preparation and renewal of the GAW strategic planning which is a contribution to the implementation of the WMO Long-Term Plan (*Müller,* 2002). A first edition of the plan covered the period 1997-2000 (*WMO,* 1997). A second edition guides the programme through the years 2001-2007 (*WMO,* 2002); its implementation plan has been up-dated in 2004 for the years 2005-07 (*WMO,* 2004).

5 FUTURE PLANS

It is planned to continue the operation of all the Swiss centres. Some of them will have additional features:

- WORCC: The SAG for aerosols strongly suggests a transition from the trial phase to a viable long-term operation. In the global Aerosol Optical Depth (AOD) network, the operational WORCC should be the apex for the measurement traceability pyramid, including technical support and a data processing hub for the precision filter (PFR) network. It should also be the training centre for the global AOD network. For these new requirements additional funding is needed; the details still need to be specified.

- WCC, QA/SAC (EMPA): The development and maintenance of the meta-data information system GAWSIS at WMO will be carried on. The QA/SAC has started by the end of 2004 a 20man-months add-on programme to assure the ongoing operation of the Mount Kenya global GAW station; the programme includes validation, analysis and submission of carbon monoxide data.

MeteoSwiss has the intention to continue its special support to the global station in Kenya. Consumables like ozone sondes, balloons and sensing solutions have to be regularly provided. WMO has established a special trust fund to cover this topic.

The future of the DACH co-operation seems to be rather open and will strongly depend on the quality of the coming joint research activities. However, it remains to be an excellent opportunity for regular networking between the participants.

MeteoSwiss is also prepared to take over the responsibility for the preparation of the next edition of the strategic plan for the years after 2007.

6 RESOURCES

During the **set-up phase,** from 1995 to 2000, globally 6.3 Mio CHF have been spent from the GAW-CH budget. About 2.8 Mio CHF (44%) have been devoted to international services (Table 6.1), the other part was used for the national monitoring and research programme.

In the period 2001-04, during the **consolidation phase** -which has already operational character-, the expenses from the GAW-CH budget amounted to 4.5 Mio CHF. The portion spent for the international services (Table 6.2) is the same as before (44%=2.0 Mio CHF). The remaining part is devoted to the national research and monitoring activities.

The overall costs for the international services (Table 6.3) for the **whole 10 years period 1995-2004** were 6 Mio CHF, 4.8 Mio CHF (80%) coming from the GAW-CH budget and 1.2 Mio CHF (20%) being brought in by the contributing institutions.

Table 6.1: Resources allocated to the international services (per year, averaged over the initiation phase, 1995-2000).

	From GAW-CH Budget		From contributing institutions	
	Personnel (person years per year)	Non-salary expenses (kCHF per year)	Personnel (person years per year)	Non-salary expenses (kCHF per year)
Scientists	2.3		0.5	
PhD students	-		-	
Technicians	0.2		0.5	
Total	2.5	187*	1.0	54
Total (kCHF/y)	253	187*	96	54

* Includes contributions to projects/programmes not described in this report.

Table 6.2: Resources allocated to the international services (per year, averaged over the consolidation phase, 2001-2004).

	From GAW-CH Budget		From contributing institutions	
	Personnel (person years per year)	Non-salary expenses (kCHF per year)	Personnel (person years per year)	Non-salary expenses (kCHF per year)
Scientists	2.9		0.5	
PhD students	-		-	
Technicians	0.2		0.3	
Total	3.1	143*	0.8	21
Total (kCHF/y)	372	143*	76	21

* Includes contributions to projects/programmes not described in this report.

Table 6.3: Resources allocated to the international services (per year, averaged over the entire period, 1995-2004).

	From GAW-CH Budget	From contributing institutions
Initiation	440	150
Consolidation	515	97
Total (kCHF/y)	469	128

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WORLD OPTICAL DEPTH RESEARCH AND CALIBRATION CENTRE (WORCC)

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1 INTRODUCTION

Growing recognition of the importance of aerosols in the Earth's radiation budget and hydrological cycle has led to a steady increase of scientific interest in aerosol physical, chemical and optical properties over the last decades. The column integrated extinction coefficient or aerosol optical depth (AOD*)* is the ultimate common denominator that links satellite retrievals, chemical transport models and ground-based observations in intercomparisons and validation experiments. Ground-based AOD is derived by passive remote sensing technique from spectral irradiance (sunphotometers) or radiance (sky-scanning radiometers) measurements.

Sunphotometer measurements were collected by the Background Airpollution Monitoring program, (BAPMoN, with turbidity data archive located at NCDC/NOAA in Asheville) since 1972. Increasing doubts about the quality and usefulness of these data led to a detailed review of the NCDC archive in 1992 by a WMO group of experts, who concluded that the instrumentation, protocols and algorithms used were seriously flawed and should no longer be employed in the Global Atmosphere Watch program.

In response to recommendations by two WMO expert workshops in the early 90-ties, Switzerland has offered to establish and operate a World Optical depth Research and Calibration Centre (WORCC) supporting the implementation of a new AOD program in GAW.

2 GOALS

The WORCC was started at PMOD/WRC on 1. January 1996, based on a mandate that was formulated during the GAW QA/SAC meeting at Garmisch-Partenkirchen in 1995 and listed the following tasks:

1. Development of an accurate radiometric reference for spectral solar irradiance measurements.
2. Development of procedures to ensure worldwide homogeneity of AOD observations.
3. Development of new instrumentation and algorithms for AOD observations, including quality control procedures.
4. Implementation of a trial phase network at GAW stations to test new instrumentation, methods and procedures.
5. Training of station operators in AOD observations.

3 APPROACH

The next paragraphs give an outline of the approach taken to fulfil the tasks listed under the corresponding numbers of chapter 2.

1. The spectral radiometric reference at WORCC is based on a silicon trap detector that is traceable to the cryogenic radiometer of Physikalisch-Technische Bundesanstalt (PTB) Berlin. Sunphotometers are calibrated in terms of their extraterrestrial signal, which can be obtained by classic extrapolation methods or from their radiometric response combined with an accurate solar spectrum or by *in situ* measurements from stratospheric balloons. All 3 methods are used at WORCC (*Wehrli,* 2000).
2. The strategy to achieve worldwide homogeneity of AOD observations is to implement a calibration hierarchy within individual networks and to link different networks by intercomparison of representative instruments at overlapping network sites or during dedicated campaigns.
3. Instrument development is based on long experience of PMOD with terrestrial and space-borne filter radiometers and recent advances in interference filter coating technology. A precision filter radiometer (PFR) was designed with emphasis on instrumental stability and quality control features and a series of instruments was built for deployment in the trial network. Algorithms for AOD, based on current WMO recommendations and scientific literature, and PFR specific quality control procedures were implemented in software at station level and at WORCC for central processing. A generic data transfer format was devised that includes sufficient meta data for self-consistent processing of measurements.
4. Implementation of a global trial network is based on a selection of GAW stations that were proposed by the scientific advisory group on aerosols (SAG/Aerosol) and negotiated by intermediation of the WMO secretariat. Collaborating GAW stations are contributing the sun tracking facility and a limited amount of manpower for routine maintenance, while MeteoSwiss and PMOD/WRC sponsors the PFR instruments.
5. Automated instrumentation and data transmission have largely eliminated the need for technical training of station personnel. Quality control procedures implemented in on-site software and diagnostic feedback from WORCC processing facility are used to ensure reliable AOD observations. Additional instructions and training for GAW station technicians are provided through the GAWTEC facility at Schneefernerhaus.

4 RESULTS

The concept, achievements and results of WORCC have been presented at various scientific conferences and meetings over the last few years and are now well known within the international AOD community.

Currently, the PFR network consists of 9 GAW stations located from the tropics to the polar region and from sea level to above 3500 m, with 5 of them in continuous operation since more than 4 years and 6 sites that are co-located with other networks. Further expansion is foreseen at 4 GAW stations, and more than 20 additional PFR systems are operated by national weather services in Europe. PFR measurements at GAW stations are transmitted monthly to WORCC for quality control and evaluation. Data quality is assured through continuous on-site calibration at those (5) stations where reliable results by this method can be obtained, and by exchange of instruments at the remaining sites. AOD results are submitted as hourly averages to the World Data Centre for Aerosols (WDCA) in Ispra up to 2003, all other data are available on request from WORCC.

A field comparison of 4 networks co-located at Bratt's Lake, Canada (*McArthur,* 2003) has demonstrated agreement of current AOD programs well within the uncertainty of 0.02 optical depths, which is the goal required in GAW. Additional, unpublished, intercomparisons at Mauna Loa (AERONET) yield even better results, while comparisons with national networks at Lindenberg (DWD) and at Riory (JMA) have confirmed the Canadian results. Thus the worldwide homogeneity of ground-based AOD observations has been demonstrated.

Course lectures on theory, instrumentation, calibration and data evaluation for AOD were given in 2003 and 2004 for the participants of GAWTEC courses in aerosol measurements.

The original goals or tasks of WORCC and their implementation were critically reviewed by SAG/Aerosol in March 2004 and acknowledged as being completely reached. WORCC was considered as a major, cost-effective contribution towards a global AOD network.

5 FUTURE PLANS

In a WMO expert workshop on "Global surface networks for column aerosol optical properties", hosted by WORCC in March 2004 at Davos, 90 stations with long-term (4+ years, >50% coverage) AOD observation programs were identified. About half of these are operated by national weather services affiliated with GAW, while the other half is associated with the NASA/AERONET project. The working group session concluded that current international coordination of global AOD networks was inadequate and that the preferred remedy was a federation of networks under the WMO/GAW umbrella. Common data policy agreements, technical standards and expansion strategies need to be developed by a standing sub-committee of SAG/Aerosol consisting of representatives from the networks, the data archives and the calibration centre.

In the minutes of their March 2004 meeting, the SAG/Aerosol strongly recommends the transition of the PFR network from the trial phase to an operational phase. The SAG fully endorses the continued operation of WORCC, but also recognized that current funding and staffing level of WORCC is critical to maintain its functions and to become the mechanism for providing long-term traceability of AOD observations in GAW partner networks. The SAG thus has encouraged GAW to cooperate with MeteoSwiss in order to develop a strategy for viable long-term operations of WORCC. Alternative resources sought by WORCC (participation in EU-FP6 program or in future opportunities) can alleviate the situation for limited periods only, but not provide a firm base for sustainability.

Continued assurance of data quality within the existing PFR network and its future expansion will remain a major task of WORCC; continued operation and maintenance of the PFR network will need an investment in filter replacements.

According to the SAG review on behalf of MeteoSwiss (letter of 16. November 2004 to GAW-CH), the envisaged new role of the PFR network is to serve as a gateway for network intercomparisons at its collocation sites, and of WORCC to become the apex of the traceability pyramid and the data processing hub for the GAW/PFR network.

The provision of calibration services for an extended, heterogeneous GAW network will require the development and test of new methods of comparison and interpolation between dissimilar wavelengths. Alternative types of radiometers, as are used by other networks, need to be available at WORCC, but represent a significant investment of typically 25k€ per radiometer.

Recent initiatives for integrated programs like GMES or AIROS, and strategies like PARAGON or IGACO, have expressed the need for near real-time access to relevant atmospheric concentrations, including aerosol properties. Lag time for PFR measurements vary from a few days to several weeks and data are processed at WORCC on a monthly basis with annual delivery to the WDCA. The dataflow could be sped up by additional efforts in network architecture (direct internet access to station data) and process automatisation (software development at WORCC), at least for quality-controlled data. Quality assurance requires instrument re-calibration, updated evaluation and statistical tests, and is thus applicable *a posteriori* only, typically after one year.

WORCC will continue to play an active role in the coordination and homogenisation of global AOD networks by participation in working groups and organization of instrument comparisons.

6 RESOURCES

Table 6.1: Resources of WORCC (per year, averaged over the initiation phase, 1995-2000).

	From GAW-CH Budget		From PMOD/WRC	
	Personnel (person years per year)	Non-salary expenses (kCHF per year)	Personnel (person years per year)	Non-salary expenses (kCHF per year)
Scientists	0.83		-	
PhD students	-		-	
Technicians	0.15		0.10	
Total	0.98	40*	0.10	15
Total (kCHF/y)	112	40*	10	15

- Includes additional funding for the instrumentation of the global trial network.

Table 6.2: Resources of WORCC (per year, averaged over the consolidation phase, 2001-2004).

	From GAW-CH Budget		From PMOD/WRC	
	Personnel (person years per year)	Non-salary expenses (kCHF per year)	Personnel (person years per year)	Non-salary expenses (kCHF per year)
Scientists	0.90		-	
PhD students	-		-	
Technicians	0.15		0.05	
Total	1.05	35	0.05	6
Total (kCHF/y)	120	35	5	6

Table 6.3: Resources of WORCC (per year, averaged over the entire period, 1995-2004).

	From GAW-CH Budget	From PMOD/WRC
Initiation	152	25
Consolidation	155	11
Total (kCHF/y)	153	19

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WORLD CALIBRATION CENTRE FOR SURFACE OZONE, CARBON MONOXIDE AND METHANE (WCC-EMPA)

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1 INTRODUCTION

The objective of the Global Atmosphere Watch programme (GAW) is to provide reliable long-term observations of compounds which are relevant for atmospheric chemistry or climate change. Comparable data sets from different stations of a network are of crucial importance when it comes to questions of e.g. global trends or changes of the chemical composition of the atmosphere. Several central facilities ensure comparability and traceability of measurements within GAW. The Central Calibration Laboratories (CCLs) are providing reference standards for a specific parameter, and World Calibration Centres (WCCs) ensure traceability of individual measurements to these GAW references. An overview of GAW central facilities with definitions of their responsibilities can be found in GAW Report No. 142 (*WMO*, 2001).

The World Calibration Centre for Surface Ozone, Carbon Monoxide and Methane (WCC-EMPA) was established in 1996 (*Buchmann,* 1996) and started with the parameter surface ozone. Carbon monoxide and methane were included in 1998 and 2000 (*Buchmann et al.,* 1999). Since 2000, QA/SAC Switzerland is also hosted by Empa and close collaboration resulted in a common mission statement:

The mission of WCC-EMPA and QA/SAC Switzerland is to improve and maintain the quality and public access of surface ozone, carbon monoxide and methane data measured at Global Atmosphere Watch stations, primarily through inter-comparison and calibration of instrumentation, one-to-one training and workshops, as well as continuous operational support, in order to contribute to the scientific basis of our understanding of climate change.

2 GOALS

The following are the primary goals and define the scope of WCC-EMPA:

- to ensure full traceability of surface ozone, carbon monoxide and methane measurements at ‘global GAW stations’ to the designated reference
- to solve instrument and/or measurement problems at stations
- to improve technical know-how at stations through on-site training
- capacity building aimed at improving data quality and availability

3 APPROACH

WCC-EMPA is performing approximately four system- and performance audits per year at global GAW stations. Traceability of measurements to the GAW reference is audited through inter-comparisons with travelling standards. As an example the traceability chain for surface ozone is illustrated in Figure 1. Instrument calibration can be provided when necessary. Each audit involves careful calibrations of the travelling standards before and after an inter-comparison. Details of surface ozone traceability and the performance audit concept can be found in *Klausen et al.* (2003). A similar calibration scheme applies for carbon monoxide and methane audits.

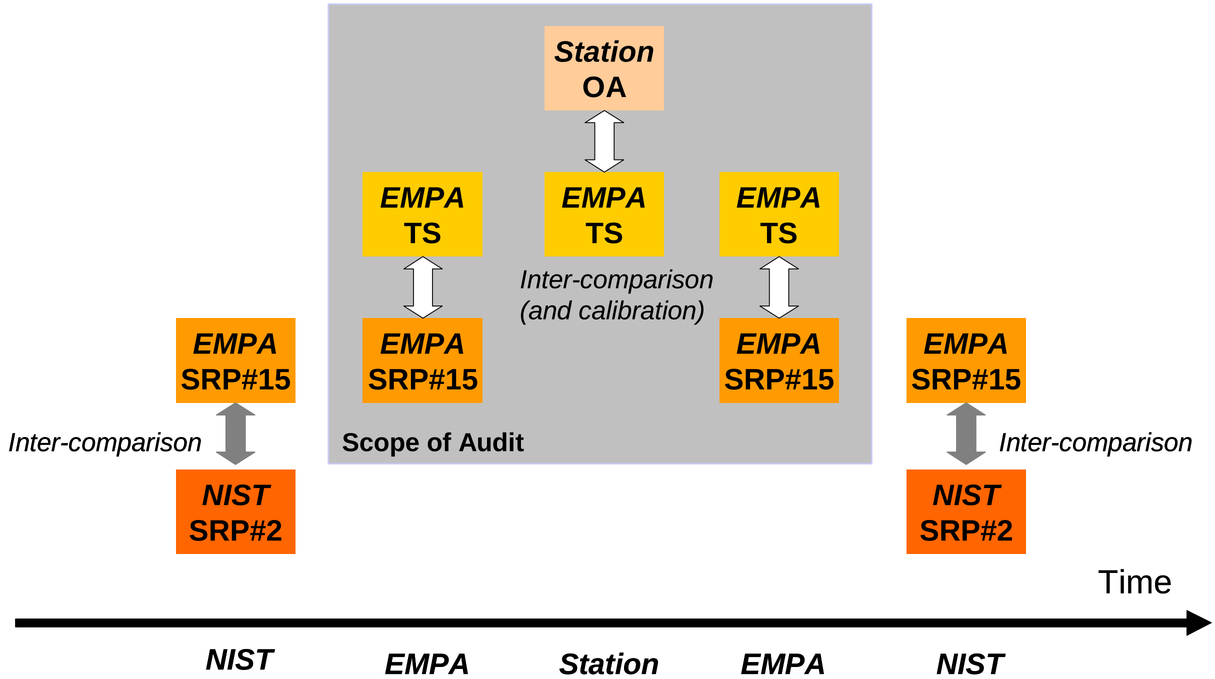

Figure 1: Traceability chain for surface ozone. The scope of each audit includes a direct inter-comparison of the on-site analyser (OA) with the WCC-EMPA travelling standard (TS). The TS is calibrated before the audit with the WCC-EMPA standard reference photometer (SRP#15), and the calibration is confirmed after the audit by a further inter-comparison. Traceability of SRP #15 to the GAW reference (SRP#2) is assured by regular direct inter-comparisons of SRP#15 with SRP#2 and other SRPs.

In addition to instrument inter-comparisons each audit includes a system audit, focusing on the whole measurement system including facilities, QA/QC, data management and data submission.

On-site training aimed at improving data quality and availability is provided mainly at stations in developing countries during the audits.

4 RESULTS

4.1 System and Performance Audits

By the end of 2004 a total of 32 audits at 15 global GAW stations were performed. Ozone was audited in all cases, carbon monoxide in 17 and methane in 9 cases. Figure 2 gives an overview of audits performed by WCC-EMPA, and almost all accessible global stations have received at least one audit since WCC-EMPA was established.

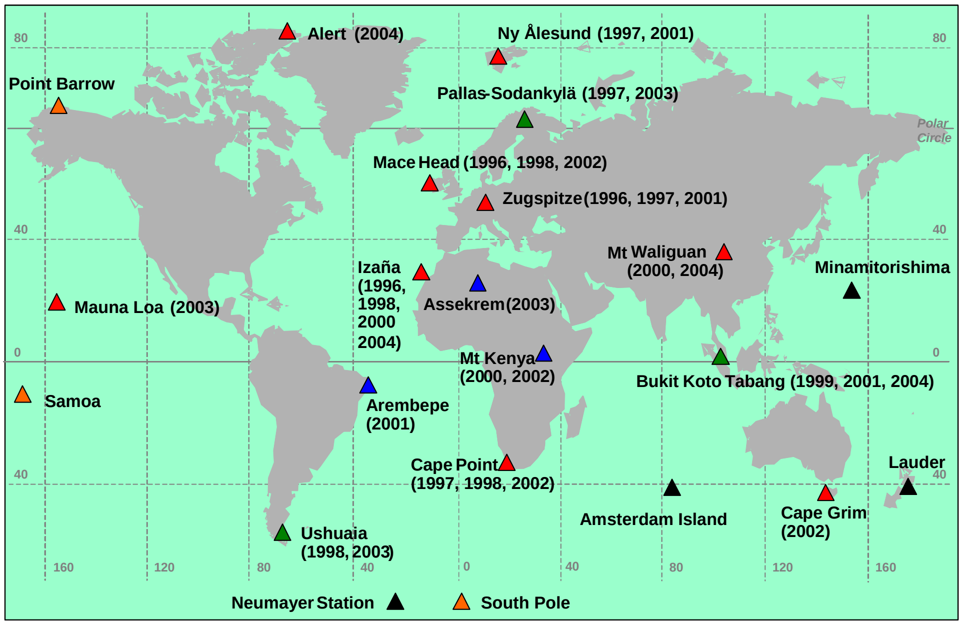

Figure 2: Overview of audits performed at global GAW stations. Red: O_3, CO and CH_4, Green: O_3 and CO, Blue: O_3, Black: not yet audited. Orange: Stations of the NOAA-CMDL network (along with Mauna Loa).

An improvement in reducing measurement bias as a result of repeated audits at a station could be shown for surface ozone (*Klausen et al.*, 2003) and is illustrated in Figure 3. Results of each audit were summarised in a detailed report including recommendations concerning instrumentation, data handling and treatment as well as the general operation of the station. Audit reports were submitted to the audited stations and WMO.

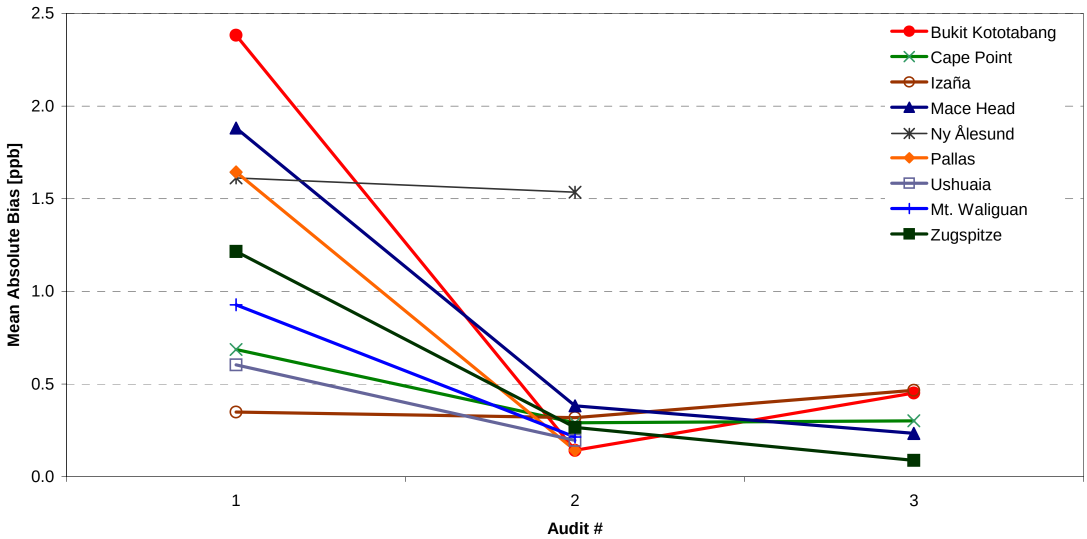

Figure 3: Mean absolute bias of ozone analysers, calculated as the absolute area between regression line and the ideal 1:1 line divided by the maximum concentration in the concentration range 0-100 ppb.

4.2 Capacity Building

GEF stations have been supported with training activities during audits in close collaboration with QA-SAC Switzerland. The support of these stations is ongoing and also includes a small "storehouse" financed with funds from Global Environment Facility (GEF) for urgently needed spare parts to assure long-term operations of these stations.

WCC-EMPA provided twice training in carbon monoxide measurement technique in the framework of the GAW Technical Education Centre (GAWTEC). The aim of these capacity building activities is to improve personal skills of station operators/scientists and to widen the understanding of atmospheric processes.

4.3 Co-operation with Central Calibration Laboratories (CCLs)

WCC-EMPA maintains calibration standards for surface ozone, carbon monoxide and methane. A close collaboration exists with the responsible CCLs (CO and CH4: NOAA-CMDL, O3: NIST). As a result of frequent inter-comparisons between NOAA-CMDL and WCC-EMPA, inconsistencies of the carbon monoxide reference scale were identified and are addressed in the SAG reactive gases. Data accuracy is expected to improve as a result of this work.

5 FUTURE PLANS

Since repeated audits at stations demonstrated an improvement of data quality, we plan to continue system- and performance audits at global stations every two to six years wherever possible. A focus will be on stations in developing countries where more capacity building is needed. These activities will be co-ordinated with QA/SAC Switzerland.

An executive summary of audit results is planned to be made available at the corresponding WDCs. This information will provide data users and the scientific community with information on data quality, which is essential for long-term research activities.

Close co-operation with the CCLs is planned to continue. A special focus will be on the harmonisation of the carbon monoxide reference scale. The SAG reactive gases will be supported in this issue.

6 RESOURCES

Table 6.1: Resources of WCC-EMPA (per year, averaged over the initiation phase, 1995-2000).

	From GAW-CH Budget		From Empa	
	Personnel (person years per year)	Non-salary expenses (kCHF per year)	Personnel (person years per year)	Non-salary expenses (kCHF per year)
Scientists	0.90		0.15	
PhD students	-		-	
Technicians	-		0.15	
Total	0.90	53	0.30	36
Total (kCHF/y)	82	53	30	36

Note: WCC-EMPA activities started in November 1995.

Table 6.2: Resources of WCC-EMPA (per year, averaged over the consolidation phase, 2001-2004).

	From GAW-CH Budget		From Empa	
	Personnel (person years per year)	Non-salary expenses (kCHF per year)	Personnel (person years per year)	Non-salary expenses (kCHF per year)
Scientists	1.00		0.10	
PhD students	-		-	
Technicians	-		-	
Total	1.00	-	0.10	9
Total (kCHF/y)	124	44	12	9

Table 6.3: Resources of WCC-EMPA (per year, averaged over the entire period, 1995-2004).

	From GAW-CH Budget	From Empa
Initiation	135	66
Consolidation	168	21
Total (kCHF/y)	148	48

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QUALITY ASSURANCE / SCIENCE ACTIVITY CENTRE QA/SAC SWITZERLAND

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1 INTRODUCTION

1.1 Mission Statement

The mission of the World Calibration Centre for Surface Ozone, Carbon Monoxide and Methane (WCC-Empa) and the Quality Assurance/Science Activity Centre (QA/SAC Switzerland) is to improve and maintain the quality and public access of surface ozone, carbon monoxide and methane data measured at Global Atmosphere Watch stations, primarily through inter-comparison and calibration of instrumentation, one-to-one training of station staff and continuous operational support, as well as to provide scientific stewardship to stations and to promote and enhance the scientific use of GAW data through workshops, in order to contribute to the scientific basis of our understanding of climate change. This fully supports the overall mission of GAW (*WMO,* 2001).

1.2 Responsibilities

The QA-related responsibilities of GAW Quality Assurance/Science Activity Centres were loosely defined in GAW Report No. 142 (*WMO,* 2001) and include

- the support of the local QA system at individual GAW sites,
- implementation of the GAW Scientific Advisory Groups' (SAGs) guidelines and recommendations,
- the coordination of instrument calibrations and intercomparisons carried out by WCC-Empa, as well as other measurement activities related to standard operating procedures (SOPs),
- training, long-term technical help and the organisation of GAW workshops for station scientists and technicians.

The science-related activities of QA/SACs include all activities that facilitate the development of the scientific component of the GAW program.

QA/SAC Switzerland became operational in March 2000, filling a gap in the organizational structure of GAW and strengthening the overall GAW programme. QA/SAC Switzerland operates in close relationship with WCC-Empa; the WMO/GAW Secretariat; the World Data Centres; the Scientific Advisory Groups; as well as individual stations (Figure 1) (*Klausen et al.,* 2001). QA/SAC Switzerland also interacts with the other QA/SACs (Japan: CO2 and CH4, Asia and South-West Pacific only; Americas: Precipitation, Germany: aerosol physics, N2O, VOCs), however, there is no coordination of activities yet.

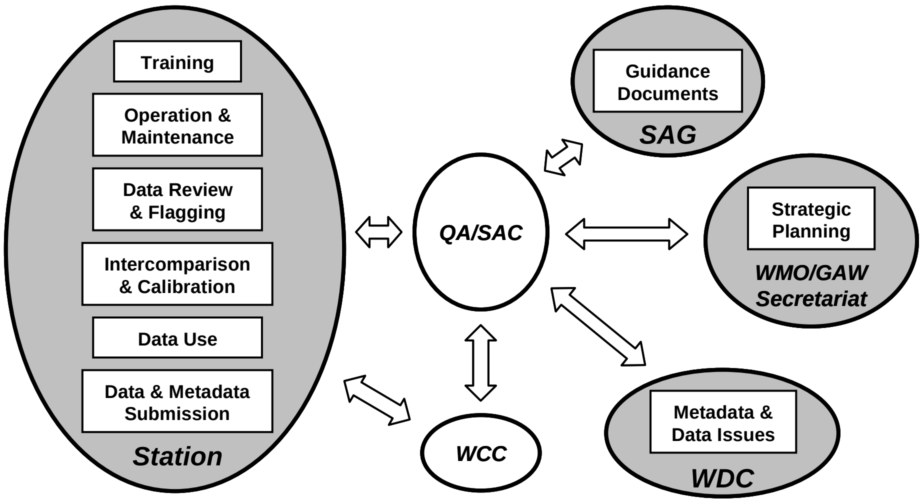

Figure 1. Main areas of interaction between QA/SAC Switzerland and other GAW constituents.

2 GOALS

The following are the primary goals and define the scope of QA/SAC Switzerland:

- to improve the QA system of the GAW program,
- to build capacity for GAW in lesser developed countries
- to support WMO/GAW and the Commission of Atmospheric Sciences (WMO/CAS) in data-related cross-cutting issues and in improving the visibility and quality of the GAW program,
- to promote and enhance the scientific use of GAW data through workshops.

3 APPROACH

The responsibilities of a QA/SAC within the GAW program are broad enough to require specification by the individual host organization. QA/SAC Switzerland operates on an annual basis by agreeing with the head of GAW-CH (Gerhard Müller) on a set of tasks. For the most part, these tasks define milestones for continuing and/or new projects. At the end of each calendar year, progress and achievements are documented in a short report. Major projects and tasks of QA/SAC Switzerland in support of the overall goals of GAW during the last four years include the development of the GAW Station Information System (GAWSIS), the organization of a workshop, co-edition of the GAW Strategic Plan and the further development of selected GEF stations. Results of these activities in response to the goals outlined above are presented in the following.

4 RESULTS

4.1 Improvement of the QA system of the GAW program

QA/SAC Switzerland has developed a methodology for the assessment of the quality of surface ozone measurements (*Klausen et al.,* 2003) and is continually reviewing the QA system of global GAW stations as part of station audits.

4.2 GAWSIS

One of the most visible products of QA/SAC Switzerland is the GAW Station Information System (GAWSIS) that is being developed and maintained in collaboration with the WMO/GAW Secretariat and the GAW World Data Centres. The objective of this databasepowered internet application is to provide comprehensive information on the status of the surface-based GAW observation platforms. GAWSIS is available at http://www.empa.ch/gaw/gawsis.

4.3 Capacity Building

QA/SAC Switzerland has been collaborating closely with the Global GAW stations Mt. Kenya, Bukit Koto Tabang and Assekrem in order to stabilize the operations at these sites. For the former two stations, we have already established in-situ carbon monoxide measurements and we are in the process of doing so in Assekrem. Also, we have improved data management and quality assurance of surface ozone, carbon monoxide and ancillary data from the Mt. Kenya, Bukit Koto Tabang stations and have continually developed and improved tools to facilitate data review and analysis.

Twice now, QA/SAC Switzerland has provided training in CO measurement technicques, data management and analysis in the framework of the GAW Training and Education Centre (GAWTEC), a facility that primarily addresses the needs of station operators/scientists.

All capacity building activities were conducted in close collaboration with WCC-EMPA.

4.4 Support of WMO/GAW and WMO/CAS

QA/SAC Switzerland assisted in the preparation of the second edition of the GAW strategic plan (*WMO,* 2001) as well as its addendum (*WMO,* 2004). We have also assisted in the CAS Working Group on Environmental Pollution and Atmospheric Chemistry (Steering Body of GAW), and have represented GAW in meetings related to GAW data management and the WMO Information System.

4.5 Scientific use of GAW data

QA/SAC Switzerland was instrumental in organizing a regional GAW workshop in Riga, Latvia that provided a platform to exchange ideas for some 75 scientists involved in GAW and specifically addressed the status and needs of GAW in Europe (*Klausen,* 2002; *Klausen and Malone,* 2004).

Our continuous support of countries such as Kenya and Indonesia has also sparked scientific collaboration. First results were presented at the IGAC 2004 in Christchurch, NZ (*Klausen et al.,* 2004) and a project to exploit the measurements at Mt. Kenya station is ongoing.

Project related to the activities of QA/SAC Switzerland include the EU FP5 project SOGE (*Reimann,* 2005), a follow up project in FP6 (SOGE-A) and a project (HALCLIM) with the scope to estimate emissions of Switzerland (*Reimann et al.,* 2004).

5 FUTURE PLANS

We plan to continue with the development and maintenance of GAWSIS with due attention to the ongoing implementation efforts for the Framework for the WMO Information System (FWIS). While the work necessary for development is expected to slowly decrease, maintenance - including regular exchange with users, data providers and the World Data Centres - will remain a significant task.

Assistance of the WMO/GAW Secretariat and CAS in matters concerning the strategic development of GAW and by representing GAW in WMO expert teams will continue.

We plan to continue our collaboration with selected GAW stations, both on a technical level and increasingly concerning the analysis and scientific use of the data, thereby improving data quality at these sites as well as the visibility of these efforts in the scientific literature. We will continue to pursue funding opportunities to extend the scientific scope of these stations and to foster scientific collaboration.

Support of and participation in the work of the SAG Reactive Gases and the SAG Greenhouse Gases will continue, particularly concerning guidelines for measurements of the three mandated variables O3, CO, and CH4. We also hope to contribute actively to further harmonization of QA procedures and network development for these components.

6 RESOURCES

Table 6.1: Resources of QA/SAC Switzerland (per year, averaged over the initiation phase, 1995-2000).

	From GAW-CH Budget		From Empa	
	Personnel (person years per year)	Non-salary expenses (kCHF per year)	Personnel (person years per year)	Non-salary expenses (kCHF per year)
Scientists	0.14		0.014	
PhD students	-		-	
Technicians	-		-	
Total	0.14	-	0.014	-
Total (kCHF/y)	17	-	2	-

Note: The QA/SAC activities started in March 2000 funded with 100 kCHF from the GAW-CH budget.

Table 6.2: Resources of QA/SAC Switzerland (per year, averaged over the consolidation phase, 2001-2004).

	From GAW-CH Budget		From Empa	
	Personnel (person years per year)	Non-salary expenses (kCHF per year)	Personnel (person years per year)	Non-salary expenses (kCHF per year)
Scientists	0.80		0.16	
PhD students	-		-	
Technicians	-		-	
Total	0.80	-	0.16	5
Total (kCHF/y)	108	-	19	5

Table 6.3: Resources of QA/SAC Switzerland (per year, averaged over the entire period, 1995-2004).

	From GAW-CH Budget	From Empa
Initiation	17	2
Consolidation	108	24
Total (kCHF/y)	53	11

Note: The QA/SAC activities started in March 2000 funded with 100 kCHF from the GAW-CH budget.

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DACH CO-OPERATION: A NETWORK OF ALPINE SITES

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1 INTRODUCTION

Identifying and understanding alterations of the atmosphere with respect to natural and anthropogenic changes - an important goal of GAW (*WMO,* 2001) – necessitates long-term research activities. Ambient air trace gas concentrations are known to reflect emissions of pollutants and thus constitute the basis for controlling air pollution. Remote stations albeit near inhabited areas are required to observe a representative air quality for larger areas, without local bias.

Investigating background concentrations and their trends in Central Europe, **DACH**, a joint co-operation between the German (DWD), the Austrian (ZAMG) und the Swiss (MeteoSwiss) Meteorological Agencies was established. The co-operation focuses on the three remote GAW- sites located in the Alps, which are surrounded by the heavily industrialized central Europe: Zugspitze/Hohenpeissenberg (**D**, 2650m/ 985m asl), Sonnblick (**A**, 3106 m asl) and Jungfraujoch (**CH**, 3580m asl). Additional project partners are the Austrian and the German Federal Environmental Agencies and the Swiss Laboratory for Materials Science and Research (Empa).

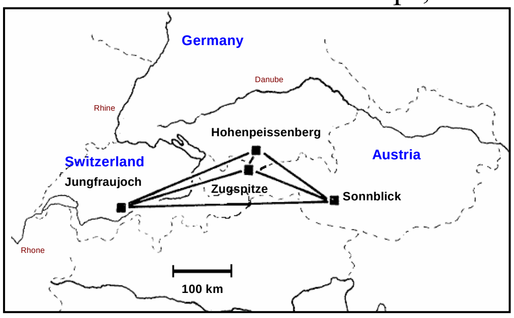

Figure 1: Stations of the DACH – co-operation.

2 GOALS

The goals of the DACH co-operation are:

- to investigate spatial representativeness of GAW data series of Central Europe in order to determine background concentrations
- to early detect potential changes of the atmosphere in mid-Europe by analysing trends of the background concentration
- to understand alpine meteorological and chemical processes for a consequential implementation of the overall goal of GAW (*WMO,* 2001)

3 APPROACH

High-quality long-term measurements are provided from the alpine stations. Although the stations have different regions of influence, their remote and elevated location let us expect a substantial part of the recordings being representative for the alpine area or a larger region. All regional influence caused by a region smaller or different from the common alpine region is regarded as local influence and thus suppressed by filtering the corresponding data points. The remaining observations are regarded as background and analysed especially for trends of carbon monoxide (CO) and nitrogen oxides (NO_x) (*DACH,* 2002; *Weiss et al.,* 2005).

Filter functions based on statistics, meteorological data or auxiliary chemical measurements have been developed to distinguish background from local pollution at the stations. A combined trend analysis of the DACH stations was the result (*DACH,* 2002).

Process oriented filters are defined to flag local meteorological events which may lift polluted air to the remote station. These events require specific filters for each station. They have been developed based on the experience of the station operators and on statistical analysis (*Fricke et al.,* 2000; *Forrer et al.,* 2000; *Kaiser and Nemeth,* 2000).

Statistical filters are applied to the data series to determine the background values on the assumption that higher CO concentrations are caused by local pollution. Within a moving window, a certain defined percentage of the half hourly measurements are flagged to distinguish the "background" from local influences. The moving percentage filter is characterized by two filter parameters, the percentage ***a,*** which is flagged within the moving window of length ***w***. To find the optimum parameters for this background filter, the correlation between the stations after filtering has been compared for different filter parameter values. The concurrently measured monthly means have been de-seasonalized and regressed against each other. The optimum filter parameter values are defined as those where the explained variance R^2, averaged over all pairs of stations, maximizes. Thus, the optimum background filter flags identify the common background of all the stations. (Weiss et al., 2005). The underlying hypothesis is that the various remote sites exhibit the best correlation between their readings if only background air is considered.

4 RESULTS

4.1 Filter performance: process versus statistical filtering

To determine the CO background of all stations, an optimum moving percentage filter is suggested, while for the NO_x background determination, an application of a station specific process oriented filter is more appropriate. Unlike process filtering of the NO_x data, process filtering of the CO data has a small effect on the CO mean concentrations and no effect at all on its long-term change. The reason for this relative insensitivity of CO with respect to the process oriented filters is the longer lifetime of CO. The main variability in CO concentrations is caused by other processes than those recognized by process oriented filters. The statistical filter, on the other hand, had been found useful to apply prior to CO trend analysis. The optimum percentage flagged as background, applying the moving percentage) filter to enhance the CO background, varies between 10% and 50% (Fig. 2).

4.2 Frequency of background observations

The regression analysis of all pairs of stations indicates the amount of data which can be considered as background. According to this analysis, using the maximum average variance, about 30% for Hohenpeissenberg (D) and Sonnblick (A) data, and about 50% for Jungfraujoch (CH) and Zugspitze (D) data are considered as background.

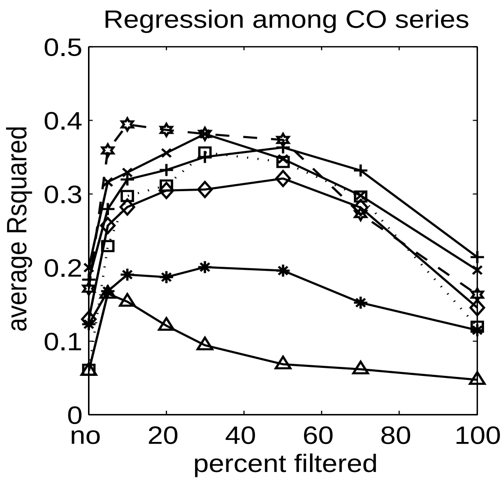

Figure 2: Average explained variance (R^2) for the correlation of CO data between different remote stations as a function of 'percent filtered' (see text). The time-window was kept fixed at 20 days. For each station, the data are correlated to all the others yielding an R^2 each.. The averaged explained variance R^2 is displayed for each station:

◊	Jungfraujoch,	x	Mace Head,
□ ···	Sonnblick,	+	Zugspitze,
∗	Hohenpeissenberg,	✻ --	Chaumont,
Δ	Rigi		

4.3 Trend analysis

The trend analysis of CO background time series (see Fig. 3 for details) shows no trend for period A (1995-1996), while period B (1997-1998) indicates a significant positive trend, followed by a significant negative trend during period C (1999-2001) and finally a positive trend for period D (2002-2003). Especially for stations at lower altitudes, the trends of unfiltered observations (small symbols in Fig. 3) deviate distinctly from the combined background trend.

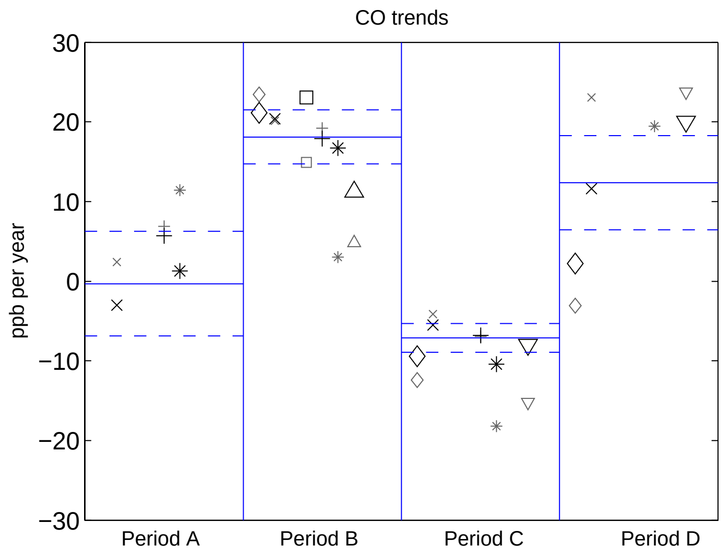

Figure 3: Linear CO trends estimated for the individual station, unfiltered series (small symbol) and their (filtered) background series (large symbols) as well as a combined background trend (solid line) and its standard deviation (dashed line). To obtain the background, the time-window was set to 20 day and the optimum percent of values was chosen.

◊ Jungfraujoch, x Mace Head, □ Sonnblick, + Zugspitze, *Hohenpeissenberg, Δ Chaumont, ▼ Rigi.

Period A: 01/1995-12/1996, B: 01/1997-12/1998, C: 01/1999-12/2001, D: 01/2002-12/2003.

The resulting CO-background trends (*Weiss et al.,* 2005) correspond well with those found earlier (*Novelli et al,* 2003), who attributed the increase in 1997-1998 to a hemispheric increase in biomass burning. We conclude that our observations are caused by a regional (European) trend in CO emissions in addition to a hemispheric background trend.

Data-series from high alpine mountain stations usually necessitate discrimination between background concentration and special pollution events for further scientific interpretation. The process filters, developed in this project, have been introduced in our other research activities at the high alpine station Jungfraujoch (*Zellweger et al.,* 2000; *Rinsland et al.,* 2000; *Zellweger et al.,* 2003; *Reimann et al.,* 2004 and 2005).

5 FUTURE PLANS

The DACH-collaboration will continue with different projects in variable team compositions, each focusing on a particular question.

In this context, the process oriented **filters** will be **improved,** considering meteorological processes. In particular, trajectory information will be used to detect periods where boundary layer air is advected to the sites.

A new focus is the scientific work on the feasibility to model the **area of influence of stations** by using trajectories and Lagrangian particle dispersion models (LPDM) based on numerical wind fields of the national Metoffices. A first approach is based on trajectory statistics and the mixing heights determined by the numerical wind fields of DWD (DACH-project MISCHTRA).

In collaboration with MeteoSwiss, Empa has modified the DWD-LPDM in order to run it in a backward mode at CSCS Manno. This allows to model areas of influence (footprints) which will provide additional information about the representativeness of measuring sites. Footprints in combination with measured data will increase the potential for data analysis, which is highly desirable and will be of advantage to GAW sites.

6 RESOURCES

Table 6.1: Resources of DACH (per year, averaged over the initiation phase, 1995-2000).

	From GAW-CH Budget		From Empa	
	Personnel (person years per year)	Non-salary expenses (kCHF per year)	Personnel (person years per year)	Non-salary expenses (kCHF per year)
Scientists	0.45		0.22	
PhD students	-		-	
Technicians	-		-	
Total	0.45	2.6	0.22	2.8
Total (kCHF/y)	42	3	26	3

Note: Empa started DACH activity in 1996, GAW-CH contribution started in 1997.

Table 6.2: Resources of DACH (per year, averaged over the consolidation phase, 2001-2004).

	From GAW-CH Budget		From Empa	
	Personnel (person years per year)	Non-salary expenses (kCHF per year)	Personnel (person years per year)	Non-salary expenses (kCHF per year)
Scientists	0.20		0.10	
PhD students	-		-	
Technicians	-		-	
Total	0.20	0.70	0.10	0.50
Total (kCHF/y)	21	1	12	1

Table 6.3: Resources of DACH (per year, averaged over the entire period, 1995-2004).

	From GAW-CH Budget	From Empa
Initiation	45	29
Consolidation	22	13
Total (kCHF/y)	35	23

Note: Empa started DACH activity in 1996, GAW-CH contribution started in 1997.

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OZONE RADIOSONDE MEASUREMENTS, NAIROBI KENYA

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1 INTRODUCTION

Balloonborne electrochemical concentration cell (ECC) ozone sondes today are the most accurate *in situ* means of observation for ozone profiles in the troposphere and lower stratosphere. While the number of observation sites in the northern hemisphere is quite high, this is by far not the case in the tropical region and southern hemisphere.

This MeteoSwiss contribution to the GAW international program refers to the work involved at the Kenyan Meteorological Institute (KMD) in Nairobi for: coordinating ozone/PTU launches, supplying equipment on site (sondes, calibration bench, and additional equipment), performing regular data analysis (quality assurance and quality control) before providing the validated measurements to the central data base (NASA-SHADOZ and the World Ozone and UV Data Centre in Toronto, Canada).

This work started a decade ago, was initialized by a development phase involving MeteoSwiss experts and the KMD radiosonde team on site in Nairobi, and is nowadays accompanied by a yearly visit of MeteoSwiss experts with a control of the ozone ECC standard operating procedure, as well as trainee/apprenticeship for the KMD's operators of the ozone team on site.

2 GOALS

The GAW general guidelines that sustain this action are summarized as follows: to develop and maintain systematic atmospheric observations in support of the spirit of the Vienna Convention; to provide, in line with the objectives of GAW, a long-term record of ozone (and other atmospheric constituents) in a tropical region, and to detect ozone loss and its eventual recovery in the stratosphere. Our specific task in this project is a sustainable effort in supporting the KMD ozone team in order to ensure the weekly ozone profiling from Nairobi.

3 APPROACH

The vital roles of ozone in the atmosphere have demonstrated the need for precise long-term measurements as well as a quantification of the short-term vertical variability of ozone. However, very limited measurement programs have been conducted in Africa. In the past 15 years there has been considerable interest in enhancing tropical ozone observations for several reasons, in particular:

- In the free troposphere ozone is radiatively active, so changing concentrations over time are cause for concern. There is inadequate coverage in ozone profile observations to determine ozone trends in the tropics (*Thompson,* 2003).
- The tropics are a region of intense interaction between natural and anthropogenic processes affecting ozone. Sufficient data for determining relative roles of the chemical and dynamical complexities affecting ozone are lacking.

- Tropical ozone profile data are needed to evaluate new satellite ozone products and to suggest approaches to satellite retrievals from new instruments on the AURA spacecraft.

Methods of observation: The ozone sonde measurements are made with electrochemical concentration cell (ECC) ozone sondes, in which air pumped through a pair of cells containing potassium iodide solution initiates an electric current proportional to the amount of ozone in the atmosphere. The ozone current is transmitted back to a ground receiver and the partial pressure of ozone is recorded through comparison with the pressure - temperature – humidity readings of an accompanying radiosonde. Designed to measure ozone concentrations from the surface to above the ozone concentration maximum (10-20 hPa), the ozonesonde radiosonde package is flown with a balloon that usually bursts at 4-8 hPa.

4 RESULTS

Figure 1 illustrates a typical end product that is directly accessible at the SHADOZ web site. It shows the profile of ozone/PTU radiosonde from the ground to ca. 4 hPa as obtained on December 31st, 2003. These data have been reprocessed by MeteoSwiss Payerne before being archived on the SHADOZ database. The data are annually sent to the World Ozone and UV Data Centre in Toronto, Canada, for further dissemination to the international community.

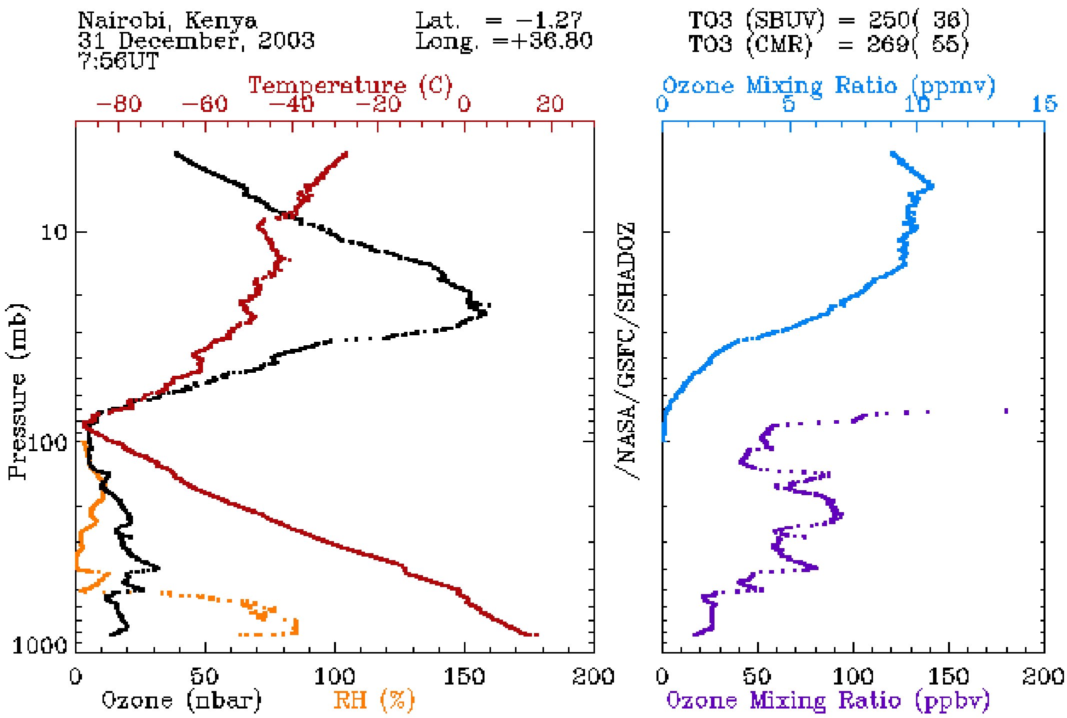

Figure 1: End product on the SHADOZ database of typical O3/PTU profiles from Nairobi. Sounding of December 31 2003, 7 UTC. The colours of the lines as indicated by the axis colouring.

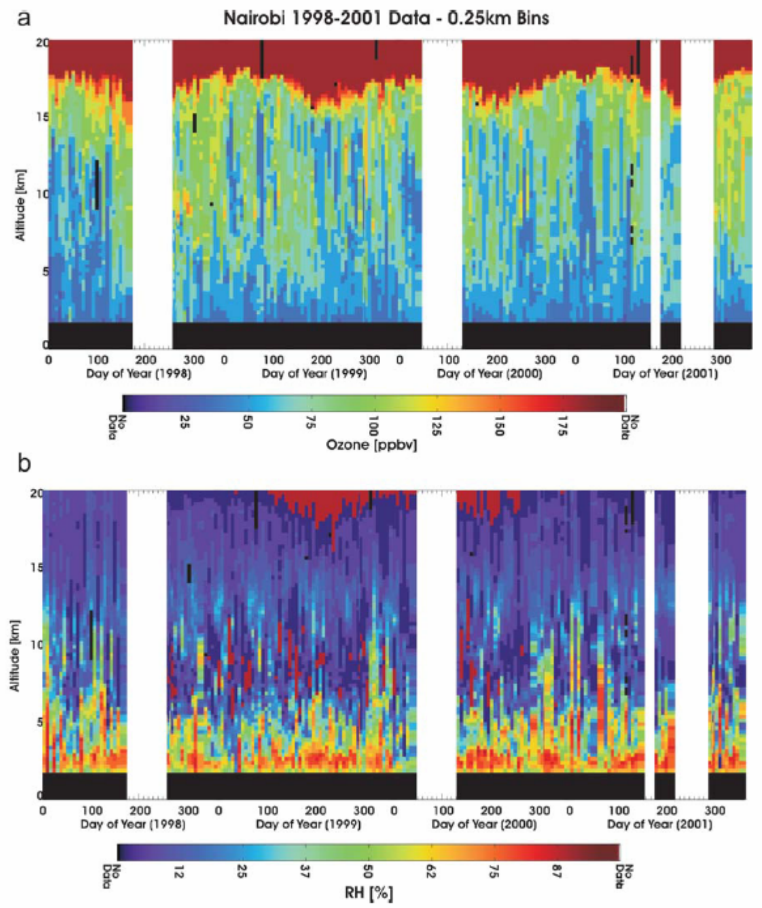

FIG. 9. Week-to-week tropospheric variability at Nairobi, indicated in altitude vs time graphs of the (a) ozone mixing ratio and (b) relative humidity for 1998–2001. Means of 0.25 km are used. Nairobi uses a capacitive-type temperature sensor (temperature profiles also available at SHADOZ Web site) for which corrections are incorporated into the reduction software.

Figure 2: Time series of ozone (upper panel) and relative humidity (lower panel) from Nairobi, from 1998 to 2001. Colour coding: ozone concentration, height in km. From *Thompson et al.* (2004).

Time series of ozone and water vapour profiles are shown in Figure 2, taken from a recent publication in the Bulletin of American Meteorological Society. This is an example of the important contribution that the Nairobi ozone radiosonde site brings to the international atmospheric community.

5 FUTURE PLANS

At the end of 2003, instructions were given to the KMD ozone radiosonde team in order to simultaneously operate a spectrophotometer for ozone total column measurements (Microtops II) together with the ozone radiosonde. Figure 3 illustrates the results obtained in 2004, from comparing the measurements obtained with the spectrophotometer, the value obtained by integrating the vertical ozone profile, and the TOMS satellite data. The two low values around JD 240 are due to balloon bursts at low altitude range. They are indicated in this graph as raw data, but are not validated for the SHADOZ data base.

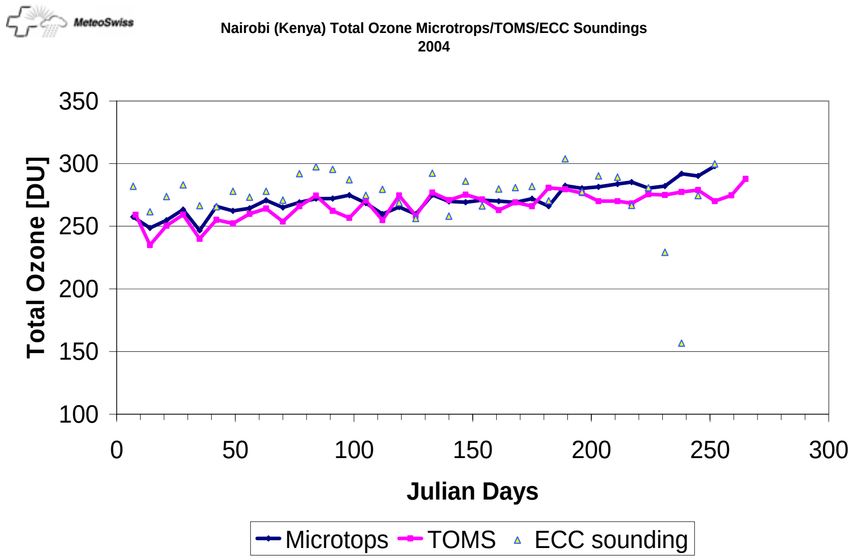

Figure 3: Comparison between Dobson measurements by Microtops II, satellite data by TOMS and integrated ozone profilesfrom ECC soundings over Nairobi. Data from 2004.

- As a major milestone for the project in year 2005, the Dobson 18, one of the WMO reference instrument for total ozone measurements, will be put in operation at the KMD, thus upgrading the Nairobi site with the world reference for the regular observation of integrated ozone over Nairobi.
- Additionally the Nairobi station will be soon proposed as a new member in the global network of NDSC (Network for Detection of stratospheric Change).
- Finally the ozone station Nairobi as part of SHADOZ will be used in satellite data assimilation and represent an "integrating mechanism" in the synergism between satellite and model. Accordingly the Aura NASA Research Announcement considers SHADOZ as one of the important components in the Earth Science Enterprise Research Strategy for addressing issues of variability, forcing, response, consequences, prediction and Aura validation.

6 RESOURCES

At KMD Nairobi: William Ayoma meteorologist, Gertrud Muriuki ingeneer, Martin Oloo logistics, and Joseph Mukola technician.

At MeteoSchweiz: Bertrand Calpini, PI; 0.1 PU/year. Gilbert Levrat, radiosonde expert, 0.2 PU/year.

Table 6.1: Resources of the Nairobi Kenya ozone radiosonde co-operation (per year, averaged over the initiation phase, 1995-2000).

	From GAW-CH Budget		From MeteoSwiss	
	Personnel (person years per year)	Non-salary expenses (kCHF per year)	Personnel (person years per year)	Non-salary expenses (kCHF per year)
Scientists	-		0.10	
PhD students	-		-	
Technicians	-		0.20	
Total	-	83	0.30	-
Total (kCHF/y)	-	83	28	-

Table 6.2: Resources of the Nairobi Kenya ozone radiosonde co-operation (per year, averaged over the consolidation phase, 2001-2004).

	From GAW-CH Budget		From MeteoSwiss	
	Personnel (person years per year)	Non-salary expenses (kCHF per year)	Personnel (person years per year)	Non-salary expenses (kCHF per year)
Scientists	-		0.10	
PhD students	-		-	
Technicians	-		0.20	
Total	-	17	0.30	-
Total (kCHF/y)	-	17	28	-

Table 6.3: Resources of the Nairobi Kenya ozone radiosonde co-operation (per year, averaged over the entire period, 1995-2004).

	From GAW-CH Budget	From MeteoSwiss
Initiation	83	28
Consolidation	17	28
Total (kCHF/y)	57	28

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MONITORING AND RESEARCH ACTIVITIES

THE SWISS GLOBAL ATMOSPHERE WATCH (GAW-CH) PROGRAMME: MONITORING AND RESEARCH ACTIVITIES

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1 INTRODUCTION

The first national conference jointly organised by MeteoSwiss and the Swiss Agency for the Environment, Forest and Landscape in 1993 (*Müller,* 1994) had the aim to review the ongoing activities at that time, to analyse the needs and requirements and to formulate a proposal for a new programme as a contribution to the Global Atmosphere Watch (GAW) programme of the World Meteorological Organisation (WMO). On the basis of the outcome of this conference, it has been decided to start the Swiss GAW Programme GAW-CH. In addition to the services and co-operation activities in the framework of the international programme described in the first part of this report (*Müller and Viatte,* 2005 – this volume), a **national monitoring and research programme** (*Müller,* 1995) has been launched.

2 GOALS

The following goals have been defined for the national monitoring and research programme:

- strengthen the monitoring activities for which Switzerland has already a long tradition and good experience,
- develop monitoring programmes in the fields where a strong need was identified and where Switzerland could contribute with respect to the know-how existing at the national level and the topographical location of the stations,
- establish quality assurance programmes in order to guarantee a high level of integrity and consistency of both the on-going and new measurements,
- initialise development and research activities in order to sustain the measurements and to improve the data use by modellers.

3 APPROACH

3.1 Scientific programmes

Based on the recommendations of the national and international experts at the first conference in 1993 (*Müller,* 1994), it was decided to focus the national activities on three specialized fields: ozone, radiation and aerosols. Three programmes (*Müller,* 1995; *Viatte et al.,* 2002) were set up with the specific sub-programmes or activities described below.

a) Monitoring of Ozone in the stratosphere and troposphere

- Operational ozone measurements
- Improvement of ozone sounding techniques
- Inter-comparison of ozone profiles

- Re-evaluation of long ozone data series
- Climatology of the stratospheric ozone
- Microwave ozone measurements
- Climatology of ozone in the free troposphere.

b) Radiation

- Establishment of broadband and spectral radiation measurements in various spectral bands and at different altitudes in order to ensure a better understanding of the UV-radiation reaching the ground and of the change of the surface radiation budget due to the greenhouse effect.
- Development of a model for the operational UV-forecast.

c) Aerosols

- Build-up of operational aerosol measurements at Jungfraujoch.
- Re-evaluation of measuring and evaluation procedures.
- Contribution to aerosol research.

These Programmes respectively sub-programmes or activities are described in more detail in the contributions following this introductory overview.

3.2 Scientific institutions involved in the programme

It has been recognized that an efficient monitoring of long-term atmospheric changes do not need only high quality operational systems, but also related research activities. The following institutions have been efficiently contributing to the programme:

- Institute of Applied Physics University of Bern, Bern,
- Institute of Atmosphere and Climate, Swiss Federal Institute of Technology, Zurich,
- MeteoSwiss, Payerne,
- Paul Scherrer Institute, Villigen,
- Physikalisches Meteorologisches Observatorium, World Radiation Centre, Davos.

3.3 Swiss GAW monitoring network

About 30 stations are part of (or associated to) the Swiss GAW monitoring network (Fig. 1).

The Jungfraujoch observatory, the highest environmental monitoring station in the Alps (3580 m asl), is a global GAW station with many international long term measurements and experiments. Arosa and Payerne are regional GAW stations of stratospheric and tropospheric ozone. The Swiss Radiation Monitoring (CHARM) network covers an extensive radiation measurement programme and includes, besides the stations Jungfraujoch and Payerne, Davos and Locarno as contributing GAW stations.

The Alpine Surface Radiation Budget (ASRB) network features eleven stations for long wave radiation.

Sixteen stations of the National Air Pollution Monitoring Network (NABEL), owned by the Swiss Agency for the Environment, Forests and Landscape (SAEFL), survey the chemical composition of the atmosphere near the surface. Some of them contribute to the data centre of EMEP (European Evaluation and Monitoring Programme) in Norway.

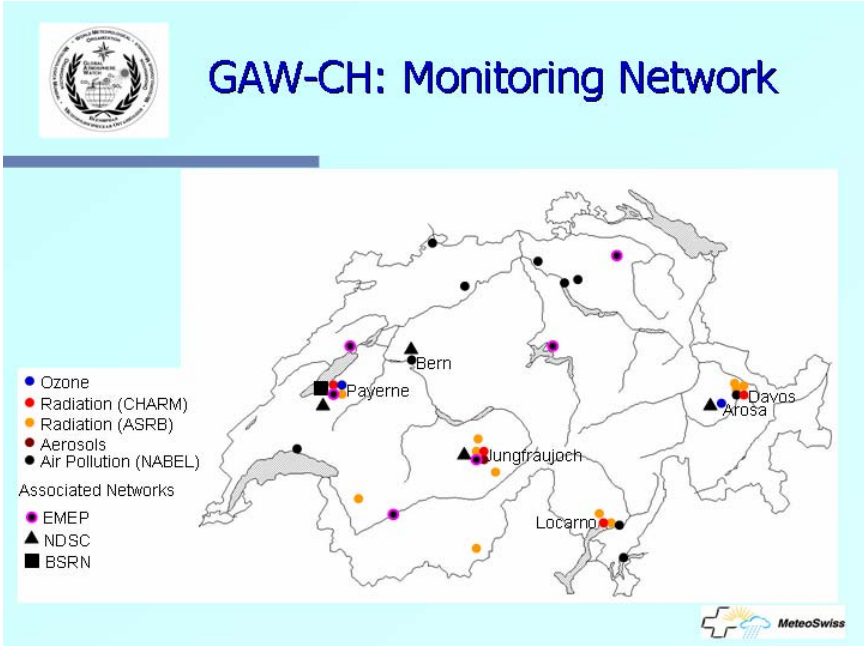

Figure 1: GAW-CH stations for ozone, radiation (BSRN, CHARM), atmospheric gases and aerosol, as well as the ASRB stations and NABEL stations.

4 RESULTS

4.1 Milestones

The following milestones of the last decade are worth mentioning:

1993: first GAW-CH Conference,

1994: allocation of the budget by the Swiss government and start of the programme,

1998: second GAW-CH Conference,

2000: end and final report of the set up phase,

2001: begin of the operational measurements and start of a consolidation phase 2001-04,

2002: third GAW-CH Conference,

2004: prolongation of the consolidation phase for two additional years (up to end of 2006).

4.2 Achievements

As a result of the **set up** phase that ended in 2000, the Swiss GAW Programme was successfully established. The proposals and recommendations of the first national GAW Conference in 1993 have been realized to a very large extent:

- the planed infrastructure has been installed,
- new measuring systems have been developed and put into operation,
- the existing long-term ozone data sets have been homogenized and have been submitted to the world data centre for the ozone trend assessments,
- scientific analyses have been performed and published, which allowed deepening our understanding of atmospheric processes and trends.

In line with the recommendations of the Swiss GAW Conferences in 1998 and 2002 (*Jeannet et al.,* 1999; *Jeannet and Ruffieux,* 2002), an important part of the allocated resources were devoted to process applied research and scientific support to the measurements. Thus, more than eleven Ph.D theses, 33 scientific publications, 33 conference abstracts and 32 reports have been realised during the set up phase.

Since 2001, the operational long-term measurement programmes of a high quality level allow for a long-term monitoring of the atmosphere with respect to ozone, trace gases, radiation and aerosols.

After the set up phase, the projects have been terminated (*Viatte and Jeannet,* 2001) and the monitoring activities were mostly integrated in the operational structure of MeteoSwiss, with the assistance of the partners based on contracts which have been established for the period 2001-04.

The first years of the operational phase have been largely devoted to the **consolidation** of the new measurement programmes and systems, in particular to the

- validation of the new instruments,
- optimisation of the operational procedures,
- improvement of the data fluxes,
- establishment of quality assurance programmes,
- regular delivery of the measurements to the world data centres.

The consolidation phase has been extended to the end of 2006 and the running contracts prolonged by two more years.

4.3 Realization of the objectives

Not all objectives could be realized in the manner it was planed:

In framework of the ozone programme, much more attention than expected had to be focussed on the replacement of the operational Brewer-Mast ozone sonde by the ECC ozone sonde. Therefore, the sub-programme “Climatology of the tropospheric ozone” could not be treated with the priority it would have earned (*Stübi,* 2005 – this volume).

During the realisation of the project, it became clear, that the resources available for the operational phase would not allow to cover eight CHARM stations as foreseen at the beginning of the programme. Therefore, the CHARM network has finally been limited to four stations (*Vuilleumier,* 2005 - this volume).

Concerning the Aerosol Programme, commercial instruments were not available for all the parameters or, if commercial instruments existed, they were not always reliable enough. So, some of the systems could only be installed during the consolidation phase and, subsequently, the corresponding measurement series are rather short. (*Baltensperger,* 2005 – this volume).

4.4 Added value

It has to be emphasized, that the Swiss GAW Programme allowed establishing a strong collaboration between all national institutions and federal offices involved in atmospheric observations and analyses.

The co-operation between institutions in charge of the operational measurements and research oriented laboratories in the framework of this national programme has been particularly fruitful and absolutely crucial for the high quality and for the proper use of the collected data.

5 FUTURE PLANS

The Swiss GAW Programme has now reached its cruising speed with major activities in the coming years in order to

- guarantee the high reliability and quality of the operational measurements,
- integrate the new results and knowledge in the monitoring strategy,
- ensure the extended integration of the collected data in research projects and extend the use of the GAW data by modellers.

The big challenge will be to make a step further, with the aim to

- assure a better link and comparison between different measurement methods, especially ground based in-situ measurements and satellite remote sensing information,
- optimize the financial resources in order to allow the development of new activities.

It will be the purpose of the review meeting to be held at MeteoSwiss in Zurich on April 20-22, 2005, to define with the help of the experts the right balance in ensuring the quality and the use of the measurements (set up respectively consolidated in the last decade) and in taking into account the necessary adaptations or extensions.

6 RESOURCES

The resources for all components of the scientific GAW-CH Programme for the different phases as well as for the whole 10 years period are summarized in the tables 6.1-6.3 below.

Table 6.1: Resources of the scientific GAW-CH programme (per year, averaged over the initiation phase, 1995-2000).

	From GAW-CH Budget		From contributing institutions	
	Personnel (person years per year)	Non-salary expenses (kCHF per year)	Personnel (person years per year)	Non-salary expenses (kCHF per year)
Scientists	1.3		3.7	
PhD students	3.4		1.5	
Technicians	-		3.2	
Total	4.7	312	8.4	100
Total (kCHF/y)	272	312	756	100

Table 6.2: Resources of the GAW-CH scientific programme (per year, averaged over the consolidation phase, 2001-2004).

	From GAW-CH Budget		From contributing institutions	
	Personnel (person years per year)	Non-salary expenses (kCHF per year)	Personnel (person years per year)	Non-salary expenses (kCHF per year)
Scientists	2.9		3.8	
PhD students	1.8		2.5	
Technicians	0.1		1.7	
Total	4.8	187	8.0	75
Total (kCHF/y)	432	187	684	75

Table 6.3: Resources of the scientific GAW-CH programme (per year, averaged over the entire period, 1995-2004).

	From GAW-CH Budget	From contributing institutions
Initiation	584	856
Consolidation	619	759
Total (kCHF/y)	598	817

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THE GAW-CH OZONE PROGRAMME: IMPROVEMENT OF MONITORING ACTIVITIES

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1 INTRODUCTION

MeteoSwiss has the responsibility of the ozone measurements at the Aerological Station Payerne (SAP) since 1968 and at the 'Lichtklimatisches Observatorium' Arosa (LKO) since 1988. In the early nineties, it was recognized that the measurement activity by itself was not sufficient and that a continuous effort of development supported by applied research and scientific studies were required. Consequently, the GAW-CH Ozone programme was initiated to secure the long term ozone monitoring of the atmosphere (responsibility MeteoSwiss) and the collaboration with academic institutions was defined (see contributions of *Staehelin,* 2005 and *Kämpfer,* 2005 – both this volume).

2 GOALS

Four main themes were defined for the MeteoSwiss contribution to the GAW-CH Ozone Programme with the following goals:

i. *Improvement and development of the measurement program*
   - Analysis of the characteristics of the operational Brewer-Mast (BM) at SAP and of the alternative Electrochemical Concentration Cell (ECC) sensors,
   - Review of the LKO observational activities (Dobson and Brewer instruments), adaptation to the future evolution and consolidation the calibration program.

ii. *Re-evaluation of the existing long term series for LKO and SAP:*
   - Review and homogenisation of the SAP ozone sounding dataset (since 1968),
   - Review and homogenisation of the LKO Dobson total ozone (since 1926) and Umkehr (since 1957) datasets. The former is the longest ozone time series in the world. Analysis the more recent Brewer (since 1988) datasets and comparison with Dobson series.

iii. *Scientific studies focussed on the LKO and SAP datasets (see Staehelin 2005, this volume)*
   - Promotion of scientific studies using the Swiss ozone data for PhD theses, scientific publications and improvement of the measurement techniques.

iv. *Development of a new radiometer (see Kämpfer, 2005 – this volume)*
   - Extension of the ozone monitoring up to the middle/upper stratosphere (i.e., above the reach of balloon soundings) with a shorter sampling period then the ozone sounding.

3 APPROACH

SAP ozone sounding. The characteristics of the ozone sensor are difficult to evaluate in flight due to the absence of a reference system. Therefore indirect methods have been used to study the behaviour of the sondes: dual flights, laboratory experiments and participation to international experiments. Four dual flights campaigns between BM and ECC, resp. ECC and ECC were completed between 1996 and 2004 to measure the relative differences of two sonde types. In April 1996, the NASA team from Wallops Island has been invited for a 3-week campaign comparison between ECC (NASA) and BM (SAP) sondes under the same balloon (30 flights). Over the periods 1998/1999 and 2001/2002, 85 respectively 45 duals flights “BM – ECC” were launched at SAP in close connection with the operational service.

In parallel, the laboratory equipment has been developed to measure the sonde response in a controlled environment with a high automation degree. This set-up, which allows a comparison of the sondes to a reference UV photometer, is used for operational sonde preparation and for specific tests. In particular, the response of sondes exposed to ambient (polluted) air compared to pure air, the aging effect after many preparation procedures and the sensitivity to the sensing solution concentration (ECC case) have been studied with this equipment.

MeteoSwiss has also actively participated at the international JOSIE (Jülich Ozone Sonde Intercomparison Experiments) and BESOS (Balloon Experiment on Standards for Ozone Sondes) campaigns. The JOSIE experiments are conducted under the WMO umbrella to test the sondes performances and to help defining standards for the sondes operations. Practically, four ozone sondes are placed in an atmospheric simulator which reproduces various “temperature–ozone” profiles. MeteoSwiss participated in 1996 with BM sondes and in 2000 with ECC sondes (*WMO,* 2004). The BESOS experiment has been organized in 2004 to validate the JOSIE observations in the real atmosphere using a large balloon and a payload of 18 sondes and a reference UV photometer for a single ascent.

Besides of the experimental work, extended data analyses have been performed. First, the influences of the processing algorithm factors have been analysed using the datasets of the dual flight campaigns. Second, the entire series from 1968 have been re-evaluated to detect any jumps, drifts or unusual behaviour with appropriate statistical tools. Corrections have then been applied if the archives have allowed identifying specific actions on the apparatus or changes of the operational procedures. Third, the trend analysis has been updated with the recalculated series and compared to the original one to quantify the effect of the corrections.

LKO ozone measurements. The uniqueness of the LKO ozone record is maintained today with the simultaneous operation of three Dobson and three Brewer instruments primarily dedicated to total ozone, Umkehr and spectral UV measurements. The last double-grating Brewer instrument was acquired in 1998 within the GAW-CH programme to complete a triad. To assure the calibration of all these instruments, Dobson inter-comparisons have been organized in 1995, 1999 (*WMO,* 2000) and 2003. Similarly, annual services for the Brewer have been organised since 1998 for maintenance and calibration aligned to the Toronto Brewer triad. Therefore, since the beginning of the eighties, the calibration history of the six LKO instruments is traceable to the world standards of each type.

Similarly to the sondes records, the data analyses represent an important task to improve the quality control, to re-evaluate the LKO very long series and for more fundamental studies like the analysis of the differences observed between Dobson and Brewer total ozone data. The Dobson total ozone (since 1926) and Umkehr series (since 1957) have been revised. In particular, the changes of instruments and/or operating procedures have received a special attention and the inhomogeneities have been corrected when necessary.

4 RESULTS

SAP ozone sounding. The characteristics of the operational BM ozone sonde have been carefully analyzed in the light of a potential move to another system. Finally, it was decided that a change from BM to ECC was the optimal solution. The three BM-ECC dual flights campaigns have allowed to determining a transfer function between BM and ECC (*Stübi et al.,* 1999; 2000; 2004a; *Stübi,* 2002). This function will be helpful to homogenize this change. At the same time, the comprehensive algorithms analysis was the occasion to test various options proposed in the literature and to quantify the confidence domain of the sondes data (*Stübi,* 2002). The operational ECC configuration has been chosen based on the analyses of the different laboratory studies, the dual ECC-ECC flights and the JOSIE results. The analysis of BESOS experiments have further corroborated the performances of ECC sondes as measured in the SAP operational service and in the specific SAP experiments.

To participate to the elaboration of the Standard Operating Procedures (SOPs) for ECC, sensitivity studies in the laboratory and in flight have been done at SAP. On a six months period, ECC sondes characteristics have been measured periodically to study any change of the sensor's response with time and at various sensing solution concentrations. At the end, these sondes were successfully launched in dual and their response in real environment analysed (*Stübi et al.,* 2004a).

To re-evaluate the SAP series, a systematic comparison of ozone time series on different pressure levels has been done with the coincident ones from Hohenpeissenberg (D) and Uccle (Be). This exercise has revealed in-homogeneities in the SAP series (e.g change of launch time, change of meteorological sonde in 1990, etc) which have been corrected. A revised dataset for the Payerne ozone soundings has been produced and the trend analysis updated (*Favaro et al.,* 2002).

LKO ozone measurements. The main result for LKO is certainly the constitution of a unique platform with two types of independently well calibrated spectrophotometers. The parallel Brewer and Dobson measurements facilitate the data control but also produce a higher complexity to the re-evaluation process. As an illustration, the observed differences in total ozone records between Dobson and Brewer can be ideally studied with the LKO datasets (*Stübi et al.,* 2004b) (see also *Staehelin,* 2005 – this volume). Some of the approximations made in the data processing have to be revisited to explain the observations and possibly correct them. LKO has also been selected as a future calibration site of the European Brewer network.

Similarly to the re-processing of the SAP dataset, the Umkehr series (since 1957) have been treated and the transition, in 1988, from the former Dobson 015 to the present Dobson 051 has been adjusted based on parallel measurements. The revised dataset has been calculated and used for a revised trend analysis (*Maillard et al.,* 2004).

The participation to the validation of different instruments aboard satellites belongs to the activities of MeteoSwiss either as data provider within a team (*Meijer et al.,* 2004) or to specifically analyse coincident data (*Fricke et al.,* 2004). In other projects like MATCH, SAP data are provided in quasi-real time and are used for process studies (*Rex et al,.* 2002). Yet another study in collaboration with IAP to merge information from soundings and radiometer has been carried out (*Calisesi et al.,* 2000; 2003).

5 FUTURE PLANS

Various publications are in preparation on the following topics: the multiple dual flights experiments of BM-ECC and the algorithmic sensitivity study, the dual flight with two ECCs and the laboratory experiments, the description of the homogenized SAP sounding series and the trend analysis, the description of the revised LKO Umkehr datasets and the trend analysis.

New methodologies (*Kerr,* 2002) have been recently developed that extend the measurements of Brewer to the aerosol optical depth (AOD) and the ozone layer effective temperature. These methods will be developed in collaboration with other observatories and introduced at LKO. The AOD can also be derived by Langley plot method and the calculation of the LKO AOD time series is already progressing in collaboration with Belgian colleagues.

The merge of soundings-SOMORA ozone profiles will be used more efficiently to benefit from the short sampling period of the SOMORA and the high spatial resolution of the sondes. A close look at the atmospheric dynamic as revealed by the ozone profile is now possible.

Some of the recent questions raised by the JOSIE and BESOS experiments will be tackled in the SAP ozone laboratory. As well, new series of dual flights are already programmed to test the ECC recycling procedures and also to measure the differences between ECC sondes providers.

International collaboration will be further developed in different fields like the update of the Umkehr retrieval algorithm (*Petropavloskikh et al.,* 2004) or the improvement of the AOD calculation (*Cheymol and De Backer,* 2003). Our instruments can contribute to the algorithms input definition as well as to their validation.

The GAW-CH ozone programme has allowed developing a balanced distribution of the resources among instrumental and scientific work. This should continue for maintaining the Swiss monitoring capacities intact to document the ozone layer recovery stage.

6 RESOURCES

Table 6.1: Resources of the MeteoSwiss ozone sub-programme (per year, averaged over the initiation phase, 1995-2000).

	From GAW-CH Budget		From MeteoSwiss	
	Personnel (person years per year)	Non-salary expenses (kCHF per year)	Personnel (person years per year)	Non-salary expenses (kCHF per year)
Scientists	0.33		1.60	
Students	0.67		-	
Technicians	-		0.70	
Total	1.00	47	2.30	20
Total (kCHF/y)	66	47	248	20

Table 6.2: Resources of the MeteoSwiss ozone sub-programme (per year, averaged over the consolidation phase, 2001-2004).

	From GAW-CH Budget		From MeteoSwiss	
	Personnel (person years per year)	Non-salary expenses (kCHF per year)	Personnel (person years per year)	Non-salary expenses (kCHF per year)
Scientists	0.50		0.80	
PhD students	-		-	
Technicians	-		0.40	
Total	0.50	40	1.20	20
Total (kCHF/y)	60	40	128	20

Table 6.3: Resources of the MeteoSwiss ozone sub-programme (per year, averaged over the entire period, 1995-2004).

	From GAW-CH Budget	From MeteoSwiss
Initiation	113	268
Consolidation	100	148
Total (kCHF/y)	108	220

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THE GAW-CH OZONE PROGRAMME: QUALITY ASSESSEMENT AND SCIENTIFIC ANALYSES

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1 INTRODUCTION

Until 1988 the Light Climatic Observatory at Arosa was part of the former Institute for Atmospheric Physics of ETHZ and H.U. Dütsch (1917-2003), a world known pioneer in ozone research, was in charge of both, operational measurements at Arosa and scientific interpretation (*Staehelin and Weiss,* 2001). Since 1988 MeteoSwiss is responsible for the execution and scientific follow up of the operational measurements, which were extended by simultaneous measurements with Brewer instruments. IACETH is involved in (i) the data quality assessment of the measurements and in (ii) the scientific analysis of these Swiss long-term ozone measurements that are unique in the world. This work of IACETH in GAW-CH includes several aspects providing an interface between the data producer (i.e., MeteoSwiss, which is mainly involved in the production of high quality measurements) and data users (science community), and IACETH attempts to help to fulfil the demands of both communities. Also the commitment of the IAC project leader to volunteer as a member of the Scientific Advisory Group for Ozone of WMO is part of this engagement.

2 GOALS

- *Data quality assessment* (comparison of simultaneous total ozone measurements presently performed at Arosa by Dobson and Brewer instruments; *homogenization of Swiss ozone measurements* (e.g., homogenization of the world's longest total ozone series and advice for the homogenization of the Umkehr series).
- *Scientific analysis* of the long-term ozone series, including total ozone and profile measurements.

3 APPROACH

Data Quality Assessment/Data Quality Control: Comparison of simultaneous total ozone measurements which are presently performed at Arosa by 2 Dobson spectrophotometers and 3 Brewer instruments based on extended data analysis. The resulting transfer functions can also be used for early detection of data quality problems of the instruments operated at Arosa. Data quality of historical total ozone measurements were studied in collaboration with Stefan Broennimann (during the start of the collaboration S. Br. was postdoc at the Lunar and Planetary Laboratory, University of Tuscon, Arizona, USA, presently he works as assistant professor at IAC) (*Broennimann et al.,* 2003a; 2003b). Single ascents of ozone sonde profiles were inspected for data quality control as long as Brewer Mast sensors were used.

Homogenization of the world longest total ozone series: Extended statistical analysis and study of all available historical documents. The close inspection of the Dobson instrument D15 in 1992 (the main instrument of the measurements between 1949-1990) revealed that this instrument was operated in optical misalignment, most probably during all the time since its first use in 1949; this enabled us to introduce a statistical correction using simultaneous measurements of 2 Dobson spectrometers of the period 1986-1990. In addition advice was provided for the homogenization of Arosa's Umkehr series.

In the *scientific analysis of the long-term Swiss ozone measurements* different methods are used including multiple regression analysis (*Staehelin et al.,* 2001) and trajectory analysis.

4 RESULTS

The Arosa total ozone series was successfully homogenized (*Staehelin et al.,* 1998a, see Fig. 1). Data analysis showed characteristic differences in the seasonal variation of total ozone measurements of Brewer and Dobson instruments (*Staehelin et al.,* 1998a) as documented from other sites as well (see *Staehelin et al.,* 2003).

Multiple regression models were used to analyse long-term trends of the homogenized total ozone series of Arosa (*Staehelin et al.,* 1998b). When the North Atlantic Oscillation (NAO) was introduced as an explanatory variable part of the long-term winter total ozone trends of Arosa could be attributed to long-term variations in NAO and not only to changes in stratospheric concentrations of ozone depleting substances (*Appenzeller et al.,* 2000). It appears, that northern hemispheric stratospheric ozone trends were substantially increased by NAO (or the Arctic Oscillation (AO)) which is strongly correlated with NAO) until around 1995, when NAO index became gradually more negative. However, when considering the period from 1970 to 2004 the influence of dynamically caused stratospheric ozone trends is small because NAO changed after 1995 to more positive values again. Ozone profile trends were analysed (*Harris et al.,* 1997; *Logan et al.,* 1999). Changes in NAO significantly

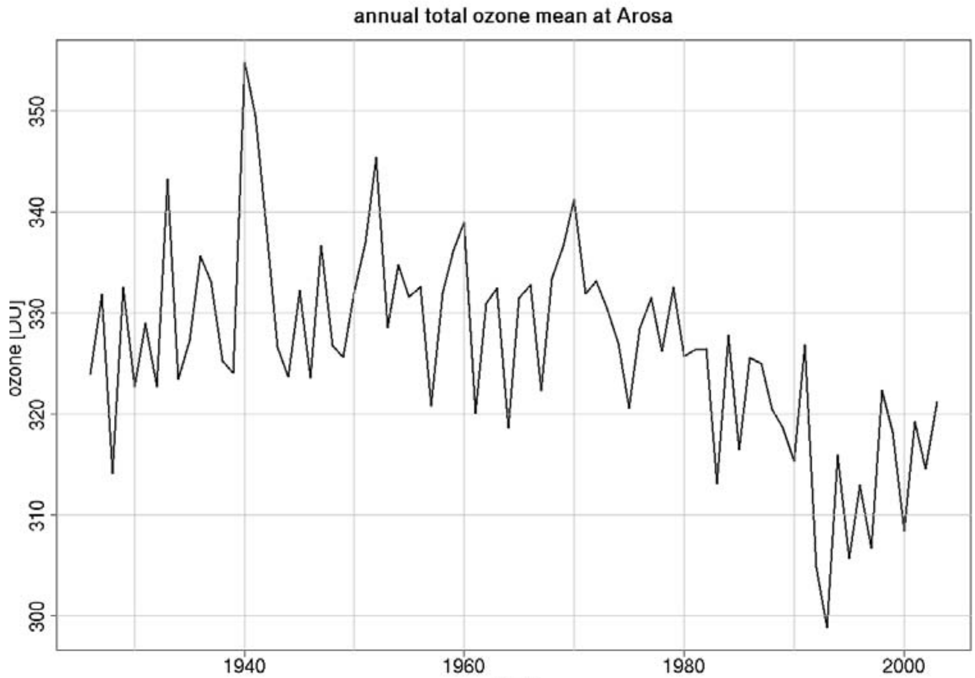

Figure 1: Homogenized time series of annual mean total ozone column (in [DU]) at Arosa, updated from *Staehelin et al.* (1998).

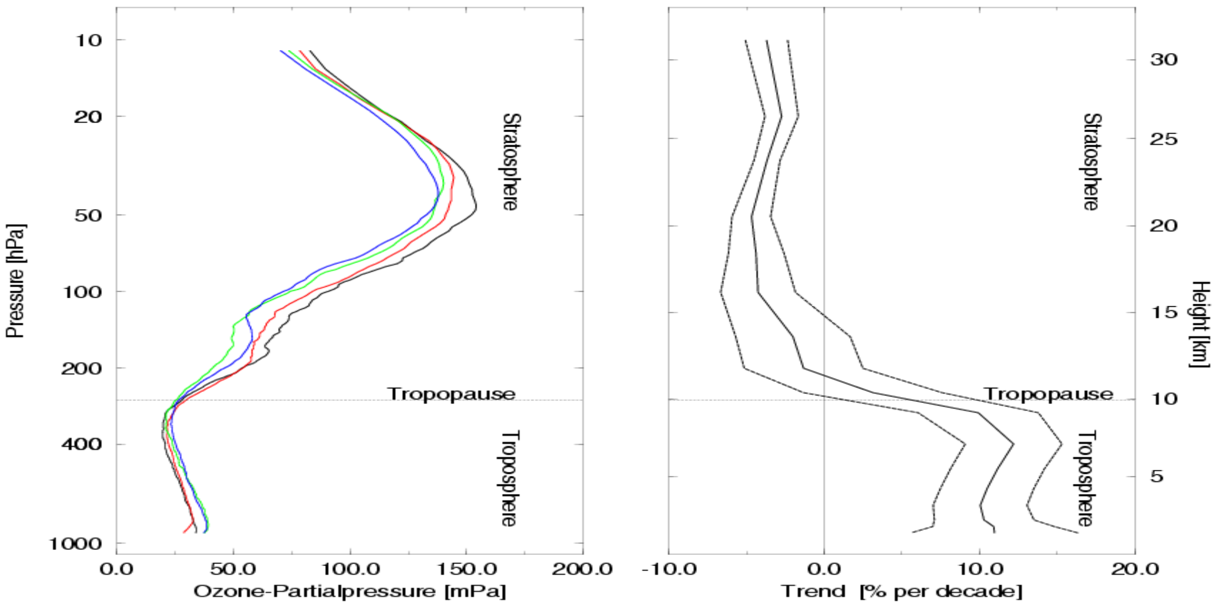

Figure 2: *Ozone profile trends above Payerne*. Left side: Profiles for selected years: black: 1970; red: 1980; green: 1990; blue: 2000; right side: Long-term ozone trends (linear regression vs. time and confidence intervals (95% error probability) (dotted lines)) (from *Staehelin*, 2003).

contributed to lower stratospheric ozone trends (*Weiss et al.,* 2001; *Staehelin et al.,* 2002), when analysing the period up to 1995. Trajectory analysis showed that changes in ozone profile trends (particularly concerning the lowermost stratosphere) have to be attributed to changes in the origin of air masses (*Koch et al.,* 2002). In collaboration with Stefan Broennimann the record high total ozone values in the early 1940 were analyzed in detail (*Broennimann et al.*, 2004a; 2004b) which also revealed a strong coupling between El Nino and the Northern hemispheric circulation strongly affecting stratospheric ozone.

5 FUTURE PLANS

In the next future the Dobson and Brewer total ozone series will be further analyzed and the developed transfer functions will be made available for use in the operational measurements at Arosa. For the period 1990-1995 inconsistencies between the Dobson and the Brewer total ozone series at Arosa were documented (*Staehelin et al.,* 1998a), which will be analyzed in more detail. The re-evaluated and readjusted Dobson and Brewer measurements will be sent to the WOUDC (World Ozone and Ultraviolet Data Centre) and the performed adjustments will be described in a publication.

In our research activities the documentation of the effect of the Montreal Protocol on the development of stratospheric ozone will be further analysed (note that the increase in total ozone since 1991 (see Fig. 1) is caused by several factors including (i) the eruption of Mt. Pinatubo in 1991 leading to record low values in the early 1990s, (ii) long-term climatic variability (NAO leading to a decrease in total ozone until the early 1990s but an increase thereafter), (iii) cold Artic winters causing strong polar ozone loss and (iv) changes in chemical ozone depletion by manmade chemicals, which peaked in the late 1990s.

It is attempted to analyse the long-term tropospheric ozone series of the balloon measurements at the aerological station of MeteoSwiss in Payerne (see Fig. 2) and other sites using trajectory analysis. The import of ozone from the stratosphere and its possible changes will be particularly studied.

6 RESOURCES

Table 6.1: Resources of the IACETH ozone sub-programme (per year, averaged over the initiation phase, 1995-2000). [1)] Includes a PhD thesis supported by an ETHZ research grant and 10% of time of the PI.

	From GAW-CH Budget		From IACETH [1)]	
	Personnel (person years per year)	Non-salary expenses (kCHF per year)	Personnel (person years per year)	Non-salary expenses (kCHF per year)
Scientists	-		0.10	
PhD students	0.67		0.13	
Technicians	-		-	
Total	0.67	-	0.23	-
Total (kCHF/y)	27	-	17	-

Table 6.2: Resources of the IACETH ozone sub-programme (per year, averaged over the consolidation phase, 2001-2004. [2)] Includes a PhD thesis supported by a research grant of ETHZ, our contribution to the EU-project CANDIDOZ and 10% of time of the PI.

	From GAW-CH Budget		From IACETH [2)]	
	Personnel (person years per year)	Non-salary expenses (kCHF per year)	Personnel (person years per year)	Non-salary expenses (kCHF per year)
Scientists	-		1.10	
PhD students	0.75		0.52	
Technicians	-		-	
Total	0.75	-	1.62	-
Total (kCHF/y)	30	-	153	-

Table 6.3: Resources of the IACETH ozone sub-programme (per year, averaged over the entire period, 1995-2004).

	From GAW-CH Budget	From IACETH
Initiation	27	17
Consolidation	30	153
Total (kCHF/y)	28	71

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THE GAW-CH OZONE PROGRAMME: MICROWAVE REMOTE SENSING OF STRATOSPHERIC OZONE PROFILES

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1 INTRODUCTION

In order to understand the chemical, physical, and radiative processes in the atmosphere it is essential to characterise the vertical distribution of ozone both in the troposphere and the stratosphere. Ozone not only in the troposphere but also in the stratosphere plays an important role in climate variability and change. The observed stratospheric ozone losses over the last two decades have caused a negative radiative forcing of the surface-troposphere system. The sign and the magnitude of this forcing are governed by the vertical profile of the ozone loss throughout the lower to the upper stratosphere. Because of these roles, it is imperative that the vertical profile of ozone is monitored and that particularly the GAW ozone sonde measurement program be continued and extended to provide data of sufficiently high quality to characterise the global vertical distribution of ozone from the ground to the middle stratosphere (*WMO*, 2001).

Profile information has been obtained since many years from the conventional ozone sondes that are carried aboard of weather balloons operated by MeteoSwiss. However the information about the ozone distribution is limited to the burst altitude of the balloon at approx. 30km. It would be favourable to complement the information above that level by a different technique. Microwave radiometry offers this possibility.

1.1 Microwave radiometry

Microwave radiometry offers the possibility to measure the vertical distribution of ozone in the range of approx. 17km up to the mesopause (*Kämpfer*, 1995). It is possible to retrieve an ozone profile during day and night with a time resolution of one hour. The method is based on the measurement of pressure broadened emission lines that allow to retrieve the altitude information with an appropriate inversion algorithm. Such an instrument (called GROMOS) has been operated on a regular basis at the University of Bern since 1994. This instrument is part of the Network for the Detection of Stratospheric Change (NDSC) and is providing data to the NDSC-data archive (http://www.ndsc.ws/).

2 GOALS

According to the recommendations by *WMO* (1993; 1996) to put special efforts on expanding microwave measurements, MeteoSwiss commissioned an improved version of the GROMOS instrument from the Institute of Applied Physics, University of Bern, for operational use in Payerne. The goals for the new instrument, called SOMORA (Stratospheric Ozone MOnitoring RAdiometer) were

- To monitor the ozone distribution in the middle atmosphere from 20 – 60km with a time resolution of 30 min on an operational basis in the frame of the NDSC;

- To use the data from the ozone radiometer to optimize balloon profiles above the burst altitude;
- To perform scientific studies, e.g. investigations on the temporal variability of the ozone distribution; climatological studies or relation to other trace gases.

3 APPROACH

In a first phase (1997 – 1999) a completely new radiometer has been designed, built and tested at the IAP, University of Bern (*Rindlisbacher*, 1999). Appropriate optics and subsystems such as the acousto optical spectrometers were commissioned from industry according the IAP design studies. System integration and test was done in house with first successful measurements in 1999. In parallel, algorithms were developed in order to retrieve the ozone profile from the measured spectra (*Calisesi*, 2000). In order to assess the suitability of the microwave profiles for complementation of ozone soundings detailed studies were performed (*Calisesi*, 1997; *Calisesi,* 1998; *Calisesi et al.,* 1998; *Calisesi et al.,* 2000). A first operational test phase of the radiometer SOMORA was performed in 2000 when the instrument and the data analysis was optimized (*Calisesi*, 2000).

During a consolidation phase from 2001 – 2004 the SOMORA instrument monitored middle atmospheric ozone on an operational basis. In a first step the instrument was operated from Bern at the same location as the NDSC instrument GROMOS in order to properly validate the new instrument. After this successful phase the instrument was transferred in 2002 to Payerne where it since then operates on a routine basis. Based on data from a longer period obtained by SOMORA the instrument was thoroughly validated against other instruments (*Calisesi et al.,* 2002, *Blumenstock et al.,* 2002, *Lambert et al.,* 2002), a prerequisite for integration in NDSC. The consolidation phase ended with a successful application (*Calisesi*, 2003) to operate the system in the frame of NDSC. In parallel scientific studies were performed based on the long data set from the GROMOS instrument to deepen the understanding of complementing Brewer-Mast soundings with microwave radiometry data (*Calisesi et al.,* 2003). Further studies were devoted to the analysis of the temporal evolution of the ozone distribution over Bern (*Calisesi et al.,* 2001; *Calisesi et al.,* 2004a; 2004b; *Dumitru et al.,* 2004).

4 RESULTS

As stated in section 3 above the main task in the first phase of the Swiss GAW project was the realization of a new ground based microwave radiometer for the detection of the rotational ozone line at 142 GHz. An impression of the instrument is given in Figure 1.

A series of 5-year balloon-borne ozone soundings using Brewer-Mast ozone sondes has been compared with concurrent measurements by GROMOS (*Calisesi et al.,* 2003). The Payerne BM soundings had previously been corrected and normalized to total ozone according to the standard operation procedure. The comparison showed that the Payerne BM soundings systematically underestimate ozone above 20 hPa with respect to the other methods, by about 10 % at 10 hPa and 17 % at 6 hPa. These results confirm the findings of other studies, according to which the standard correction applied for decreasing BM sonde pump efficiency with decreasing atmospheric pressure is too low.

Figure 1: SOMORA instrument with ozone spectrum on screen.

The long term data set of the GROMOS instrument was used to investigate large episodic perturbations of the mid stratospheric ozone volume mixing ratio values observed during the winters 1994-1995 through 1998-1999 (*Calisesi et al.,* 2001). Backward trajectory calculations showed that the observed episodes are coincident with periods of enhanced meridional transport. Representations of the isentropic potential vorticity field indicated that this transport went along with significant deformations and southward excursions of the polar vortex in association with strong planetary wave activity. Along the eastern edge of the distorted vortex, northward advection of subtropical air led to anomalously high ozone volume mixing ratio (VMR) values in the midlatitudes middle stratosphere, whereas the passage of polar vortex air over Bern led to midstratospheric ozone minima. For another episode the influence of photochemical processes was investigated, and it was found that photochemistry acts to damp (rather than to enhance) the effects of planetary wave-driven meridional transport. It is concluded that the extreme ozone episodes observed over Bern during winter are primarily a dynamical feature, their amplitude being determined by the meridional ozone VMR gradient rather than by photochemical processes.

5 FUTURE PLANS

In the frame of the "Network for the Detection of Stratospheric Change" (NDSC) the IAP together with MeteoSwiss operates microwave radiometers at Bern and at Payerne for the detection of ozone. The unique dataset of ozone profiles over the last ten years with a high time resolution will allow for

- investigation of temporal structures in the long term data set of ozone at Bern complemented with data from Payerne with special emphasis on phenomena such as solar cycle, QBO (Quasi Biannual Oscillation), planetary waves etc.;
- comparison of the ozone data with satellite data such as from ENVISAT or AURA;
- investigation on how balloon sonde data with the new ECC sonde can be complemented by microwave data;
- analysis of links between water vapour and ozone.

6 RESOURCES

Table 6.1: Resources of the ozone microwave sub-programme (per year, averaged over the initiation phase, 1995-2000).

	From GAW-CH Budget		From IAP	
	Personnel (person years per year)	Non-salary expenses (kCHF per year)	Personnel (person years per year)	Non-salary expenses (kCHF per year)
Scientists	0.20		0.10	
PhD students	0.30		0.30	
Technicians	-		-	
Total	0.50	62	0.40	30
Total (kCHF/y)	31	62	23	30

Table 6.2: Resources of the ozone microwave sub-programme (per year, averaged over the consolidation phase, 2001-2004).

	From GAW-CH Budget		From IAP	
	Personnel (person years per year)	Non-salary expenses (kCHF per year)	Personnel (person years per year)	Non-salary expenses (kCHF per year)
Scientists	0.70		0.30	
PhD students	-		1.00	
Technicians	0.10		-	
Total	0.80	3.6	1.30	30
Total (kCHF/y)	70	4	71	30

Table 6.3: Resources of the ozone microwave sub-programme (per year, averaged over the entire period, 1995-2004).

	From GAW-CH Budget	From own institution
Initiation	93	53
Consolidation	74	101
Total (kCHF/y)	85	72

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THE GAW-CH ATMOSPHERIC RADIATION MONITORING PROGRAMME

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1 INTRODUCTION

Long-term monitoring of surface radiation fluxes is a prominent component of climate change monitoring, because radiation is the driving force in energy exchanges between the atmosphere, the oceans and the ground. Furthermore, the long-wave downward irradiance at the ground has been singled out as a candidate for the early detection of the greenhouse signal (*Wild et al.*, 1997; *Wild and Ohmura*, 2004). In addition, long-term surface radiation time series fulfilling pre-defined accuracy and stability standards is an important validation tool for satellite-based monitoring of radiation fluxes.

Because of the well developed infrastructure and strong elevation gradients in Switzerland, radiation monitoring can be performed there at elevation ranging from about 300 m to over 3500 m a.s.l. This allows probing effects of many factors that affect radiation and present large variations within the first few thousand meters of the atmosphere (e.g., water vapor, aerosols or clouds). However, care should be taken that such monitoring is not conducted solitarily in Switzerland, but is integrated in an international network for global significance.

Prior to the early 1990's, most radiation measurements were performed in Switzerland as campaigns or experiments with a limited time frame. When first attempts of continuous monitoring were conducted, it was recognized that internationally standardized operational procedures were necessary. In response, the Baseline Surface Radiation Network (BSRN) was established in the early 1990's within the World Climate Research Programme (*Ohmura et al.*, 1998). BSRN requires its stations to commit to long-term radiation monitoring using a consistent methodology for guaranteeing the accuracy necessary for analysis of radiation transfer processes, long-term climate change monitoring and satellite validation.

As one of the BSRN founders, MeteoSwiss built a station at Payerne. In addition, the Swiss Atmospheric Radiation Monitoring program (CHARM) was established by complementing the Payerne BSRN station with three other stations located at elevations between 370 and 3580 m a.s.l., which are all operated following a BSRN-like methodology.

2 GOALS

Since the CHARM program was conceived in response to BSRN requirements, its aims are similar to those of BSRN. It is designed for a) long-term monitoring of climate-relevant radiation parameters measured at the ground, b) providing data for the study of atmospheric radiative processes, and c) allowing validation of satellite-based radiation flux measurements.

Atmospheric radiation parameters that were considered to be climate relevant include:

- the components of the surface radiation budget (short- and long-wave irradiance), since they are necessary for understanding the energy partition in the atmosphere,
- the UV irradiance, because of its importance for public health and because of concerns regarding a potential increase of its level due to ozone depletion, and

- integrated water vapor (IWV) and aerosol optical depth (AOD), since water vapor is the source of one of the most important positive feedbacks to CO_2 forcing, while aerosols are considered as one of the main sources of uncertainty in global climate model prediction.

3 APPROACH

The CHARM network consist of 4 stations including 2 alpine stations, at Davos (1590 m a.s.l.) and Jungfraujoch (3580 m a.s.l.), and 2 stations at lower elevation, one north of the Alps at Payerne (491 m a.s.l.) and the other on the south side at Locarno-Monti (366 m a.s.l.). The BSRN-required set of monitored parameters including short-wave (SW) global, diffuse and direct irradiance as well as downward long-wave (LW) irradiance are measured at all stations, except at Jungfraujoch where harsh conditions preclude monitoring of SW diffuse irradiance. In addition, UV erythemal irradiance and spectral direct irradiance (the latter allowing determination of AOD and IWV) are measured at all stations. Finally, the reflected SW and upward LW irradiance are also monitored at Payerne. CHARM uses fully automated data acquisition systems with a time step of 1 or 2 minutes (depending on the station).

Using instruments and techniques largely developed in response to BSRN requirements allows reaching the necessary accuracy. The required stability is guaranteed by applying a rigorous maintenance and calibration program. At the Payerne station, this program is derived from the BSRN standard operating procedures. Maintenance is less frequent at other stations, but is performed at least four times a year. Instruments are regularly calibrated, with traceability to standards maintained by BSRN-agreed calibration centres.

CHARM puts a strong emphasis on national and international collaboration, for operation and scientific projects. As mentioned above, CHARM operational procedures are derived from those of BSRN. Technical and scientific developments are usually conducted within national or international partnerships, which ensures comparability of CHARM results with those of other national and international networks. BSRN is the primary umbrella organization for such partnerships, but integration in more focalized efforts, such as relevant European COST actions, is also sought for addressing specific problems. Finally, collaboration with academic research institutes is systematically sought when initiating research projects.

4 RESULTS

4.1 Long-term surface radiation flux observation

CHARM's most important goal is building continuous long-term radiation time series. The first measurements were started in 1991 at Davos, and end of 1992 at Payerne. Later, stations were established at Jungfraujoch (1996) and at Locarno (2001). While trend detection is not yet possible, climatologic studies were conducted in collaboration with the ETHZ Institute for Atmospheric and Climate Science (IACETH). The climatology of surface radiation flux at Payerne (*Goeldi et al.*, 2000) was studied in a Ph.D. thesis being concluded now, while a recently started Ph.D. thesis focuses on the influence of cloud on surface radiation fluxes.

The Alpine Surface Radiation Budget (ASRB) network was set up in a joint project of the Word Radiation Centre at Davos (WRC), the IACETH and CHARM. All CHARM stations are part of ASRB, and seven additional ASRB stations have been established by WRC. Data from this network were used to study the greenhouse effect in the Alps (*Philipona et al.,* 1997; *Marty,* 2000; *Philipona et al.,* 2004; *Philipona and Dürr,* 2004). These studies showed a significant increase in LW radiation outweighing corresponding changes in SW radiation, and constituting evidence of greenhouse gas forcing.

4.2 Analysis of atmospheric radiative processes, model validation and satellite validation

Data from the Payerne BSRN station were used in studies aimed at improving the description of atmospheric radiative processes in climate models. *Chevallier and Morcrette* (2000) used BSRN data (including Payerne) together with satellite data for assessing the quality of LW and SW fluxes computed by the ECMWF operational forecast system, while *Morcrette* (2002) studied the improvement potential linked to different parameterizations affecting the modeling of radiation transfer in the ECMWF model. *Wild et al.* (2001) used the BSRN LW downward radiation data for validating the radiation schemes of four global climate models and found these models to predict a too strong latitudinal gradient for LW surface radiation.

BSRN being recognized as the primary ground-based radiation measurement reference, the Payerne data were used in several recent validation studies of satellite radiation flux data. *Manninen et al.* (2004) used data from Payerne and two other stations for validating AVHRR-derived surface albedo, which allowed testing a new algorithm to deduce clear-sky albedo from all-sky data. As an example, Figure 1 shows a comparison between the AVHRR-based cloudy albedo distribution for Payerne and a simulated cloudy albedo distribution based on Payerne BSRN ground albedo data and an appropriate cloud probability distribution function. The AVHRR surface albedo needs to be shifted by 3% toward higher values for the best match between peaks. *Roesch et al.* (2004) validated MODIS albedo products with data from Payerne and 8 other BSRN stations, and demonstrated a good agreement with deviations less than 0.05 at most sites during snow-free periods. *Zhang et al.* (2004) used latitudinal averages of BSRN data for validating surface radiation fluxes inferred from ISCCP data, and estimated the uncertainty on these fluxes to be on the order 20-25 W/m^2. Finally, *Meetschen et al.* (2004) developed a new scheme for inferring cloud fields from Meteosat data and computed corresponding SW and LW surface radiation fluxes with a NWP radiative transfer model. These fluxes were validated using data from a Dutch network and the BSRN stations of Payerne and Lindenberg.

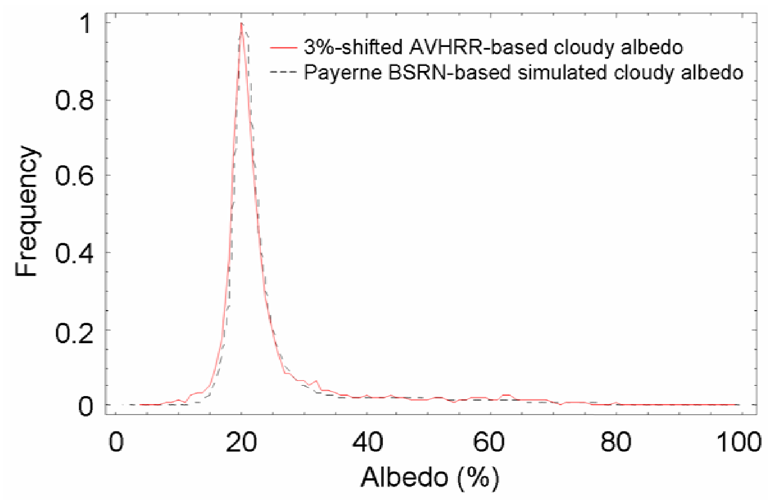

Figure 1: AVHRR-based cloudy albedo distribution and Payerne BSRN-based simulated cloudy albedo distribution (from *Manninen et al.*, 2004).

4.3 UV radiation

The CHARM UV radiation monitoring activities contribute to answering public health questions. Particularly, the MeteoSwiss CHARM program participated in the development of forecasting capabilities for UV radiation exposure at the ground, and studied the influence on UV radiation of changes in environmental parameters such as the ozone content of the atmosphere. The MeteoSwiss UV forecasting capabilities were developed in a Ph.D. thesis conducted in partnership between IACETH and MeteoSwiss (*Lehmann,* 2001; *Lehmann et al.,* 2000). This work also studied the influence on UV doses of environmental parameters, as did a study by *Philipona, et al.* (2001) using Davos CHARM data. A more recent study conducted by MeteoSwiss and the Finnish Meteorological Institute used such dependencies and historical data records of proxies for the desired environmental parameters (total ozone column, sunshine duration for cloudiness and snow cover for surface albedo) in order to estimate the evolution of past UV doses at Davos since 1926 (*Lindfors and Vuilleumier,* 2005). Figure 2 shows the deviation of the yearly mean values of the estimated daily UV doses from their 1940–1969 mean level. In order to assess to what extent each input parameter contributes to the changes seen in the estimated UV level, three additional time series of estimated UV were produced letting only one factor at a time vary as observed, while keeping the other ones at their climatological values, i.e., they were allowed to vary according to their climatological cycle within each year, but no year to year variation was allowed. As seen from the lower part of Figure 2, most of this variability is explained by the changes that have occurred in the total ozone column and in the relative sunshine duration (cloudiness). The influence of cloudiness is dominant until the 80's, while the influence of ozone is dominant since then.

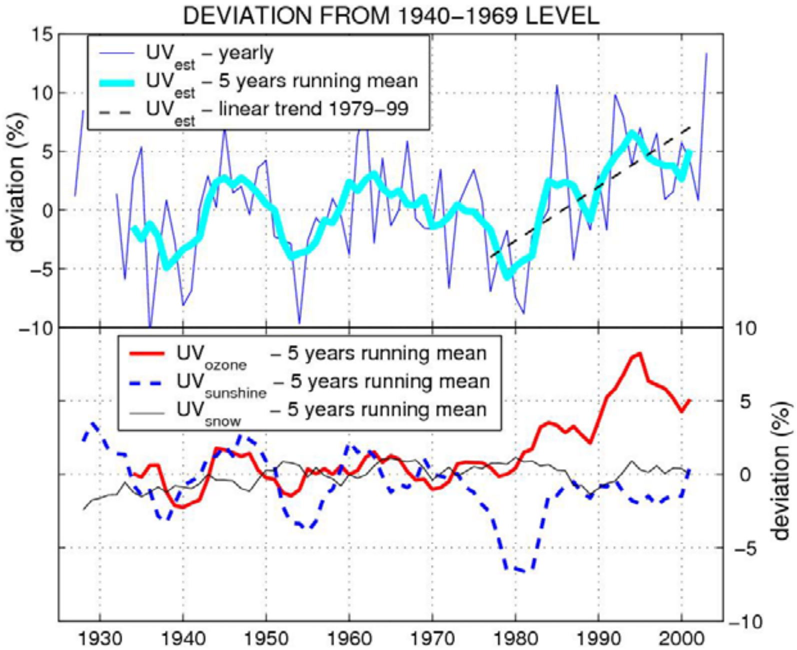

Figure 2: Evolution of UV erythemal daily doses at Davos from 1926 to present, shown as deviation from the 1940–1969 mean level (from *Lindfors and Vuilleumier*, 2005).

4.4 Aerosols, water vapor and ozone column

AOD and IWV can be inferred from sunphotometer measurements. The CHARM program set up such measurements in partnership with the World Optical Depth Research and Calibration Centre at Davos and the Institute for Applied Physics at the Bern University (IAP). The collaboration with IAP allowed developing the analysis tools needed for deducing AOD and IWV from the spectral irradiance (*Ingold*, 2000). *Ingold et al.* (2001) studied the AOD climatology in Switzerland, while *Schmid et al.* (1997) used the AOD wavelength dependence to infer the aerosol size distribution. CHARM also participated in an IAP-lead project within the *National Centre of Competence in Research (NCCR) – Climate* for building a database of water vapor measurements in Switzerland. This project allowed establishing sunphotometer-derived IWV time series starting in 1995 at Davos, 1999 at Jungfraujoch and 1998 at Bern.

5 FUTURE PLANS

Improvements must be planned so that CHARM central commitment of ensuring a continuous long-term radiation monitoring is not put at risk, and care should be taken that resources are planned for guaranteeing the continuation of current operation in parallel with new developments. Therefore, the primary objective is to sustain current operation in the long term. In addition, two developments would enhance the CHARM contribution to climate research: The first is developing the capability of measuring the solar irradiance in spectral bands. Distinct parts of the radiation spectrum are affected differently by climate change. For instance, solar radiation at wavelengths shorter than 700 nm is more affected by vegetation changes than radiation at longer wavelengths. Satellites have been equipped with capabilities to measure separately a number of spectral bands, and demands on similar capabilities at surface stations are growing. The second is creating a synergy between CHARM radiation measurements and future cloud detection capabilities at MeteoSwiss. The effect on the radiation energy partition of climate change related variations in cloud type or amount is a question currently challenging climatologists, and instruments automatically measuring cloud characteristics are improving. In case such instruments are installed at MeteoSwiss, it would be of prime interest to co-locate such systems with CHARM stations, particularly at Payerne.

6 RESOURCES

Table 6.1: Resources of CHARM (per year, averaged over initiation phase, 1995-2000).

	From GAW-CH Budget		From MeteoSwiss / IAC	
	Personnel (person years per year)	Non-salary expenses (kCHF per year)	Personnel (person years per year)	Non-salary expenses (kCHF per year)
Scientists	-		0.95	
PhD students	1.33		0.67	
Technicians	-		2.33	
Total	1.33	169*	3.95	25
Total (kCHF/y)	56	169*	328	25

* Includes 15 kCHF space rental cost at the JFJ.

Table 6.2: Resources of CHARM (per year, averaged over consolidation phase, 2001-2004).

	From GAW-CH Budget		From MeteoSwiss / IAC	
	Personnel (person years per year)	Non-salary expenses (kCHF per year)	Personnel (person years per year)	Non-salary expenses (kCHF per year)
Scientists	0.55		0.45	
PhD students	0.50		0.50	
Technicians	-		1.00	
Total	1.05	105*	1.95	-
Total (kCHF/y)	90	105*	154	-

* Includes 15 kCHF space rental cost at the JFJ.

Table 6.3: Resources of CHARM (per year, averaged over entire period, 1995-2004).

	From GAW-CH Budget	From MeteoSwiss / IAC
Initiation	225	353
Consolidation	195	154
Total (kCHF/y)	213	273

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THE GAW-CH AEROSOL PROGRAMME AT THE JUNGFRAUJOCH

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1 INTRODUCTION

It is the goal of the Global Atmosphere Watch (GAW) programme to ensure long-term measurements in order to detect trends in global distributions of chemical constituents in air and the reasons for them. With respect to aerosols, the objective of GAW is to determine the spatio-temporal distribution of aerosol properties related to climate forcing and air quality on multi-decadal time scales and on regional, hemispheric and global spatial scales.

Aerosols influence the atmospheric energy budget through direct and indirect radiative effects. Direct effects include the scattering and absorption of radiation and the subsequent influence on planetary albedo and the climate system. Indirect effects involve the influence of the anthropogenic aerosol on the number of available cloud condensation nuclei (CCN). An increase in aerosol number concentration tends to increase the CCN concentration, which in turn leads to an increased cloud albedo and to changes in the Earth’s radiation budget. Cloud lifetimes and precipitation frequencies can also be affected. This alters the hydrological cycle and water supply. Scientific evidence indicates that in regions with high anthropogenic aerosol concentrations, aerosol forcing is of the same magnitude, but opposite in sign to the combined effect of all greenhouse gases. However, uncertainties are much higher than for the greenhouse gases. To contribute to a reduction of these uncertainties and in line with the overall GAW objectives the Swiss GAW Aerosol Programme was initiated on the Jungfraujoch (JFJ). Today, it belongs to the most comprehensive aerosol programmes at GAW stations worldwide.

2 GOALS

- Continuous long-term determination of a number of aerosol parameters relevant to climate
- Delivery of quality assured data to the GAW world data centre in Ispra (via EMEP)
- Performance of a full physical, chemical, and optical characterization of the background aerosol present at the Jungfraujoch to better quantify the direct aerosol effect (by dedicated field campaigns)
- Investigation of the interaction of aerosol with clouds, for a better quantification of the indirect effect (by dedicated field campaigns)

3 APPROACH

The Jungfraujoch aerosol programme builds on the recommendations given by the GAW Scientific Advisory Group (SAG) for Aerosol (chaired by Urs Baltensperger). The aerosol measurements recommended by the SAG are given in Table 3.1.

Table 3.1: List of comprehensive aerosol measurements that are recommended by the GAW Scientific Advisory Group on Aerosols for long-term measurements in the global network. Measurements performed at the Jungfraujoch are identified in bold. Institutes in parentheses denote groups other than PSI performing or contributing to the measurement.

Continuous Measurements
Multiwavelength optical depth (MeteoSwiss)
Mass in two size fractions (PSI+EMPA)
Major chemical components in two size fractions
Light absorption coefficient
Light scattering coefficient at various wavelengths
Hemispheric backscattering coefficient at various wavelengths
Aerosol number concentration
Cloud condensation nuclei at 0.5% supersaturation
Intermittent Measurements
Aerosol size distribution
Detailed size fractionated chemical composition
Dependence on relative humidity
CCN spectra (various supersaturations)
Vertical distribution of aerosol properties (EPFL)

The Jungfraujoch is 40% of the time in clouds (*Baltensperger et al.,* 1998), where most of the aerosol mass is activated to cloud droplets. To eliminate a negative bias during these time periods, an inlet system was built which samples cloud droplets up to 40 µm at wind speeds up to 20 m/s. This inlet is heated to 20°C resulting in evaporation of the hydrometeors, which allows for a determination of the full aerosol loading also during cloud events (*Weingartner et al.,* 1999). Since all continuous measurements are performed in the laboratory at room temperature, the relative humidity is low (<10%). A specified low relative humidity is also recommended by the SAG in order to avoid a variable and non-quantified contribution to the aerosol mass by water.

The regular GAW measurements at the JFJ started in 1995 and were since then continuously enlarged. Wherever commercial instruments along with accepted calibration procedures were available, the best-suited instrument was purchased and operated at the JFJ. This applied e.g. for the nephelometer to measure the scattering coefficient or the condensation particle counter to determine the number concentration. In other cases, commercial instruments were available, however, there were known artefacts associated with these instruments and no agreed calibration procedures were available. This applied to instruments to determine the absorption coefficient such as the aethalometer. Here, we applied the strategy to run several different instrument types side by side in order to quantify the differences between the instruments. In addition, several extensive laboratory experiments were performed at the AIDA chamber in Karlsruhe with the goal to come up with a general calibration procedure. Results of the first campaign were published (*Weingartner et al.,* 2003), while the subsequent campaigns are still being evaluated. For other parameters where no commercial instruments were available, we built our own instrument. One example is the hygroscopicity tandem differential mobility analyzer, HTDMA (*Weingartner et al.,* 2002; *Gysel et al.,* 2002), with which the hygroscopic growth of aerosol particles can be measured. This instrument has the unique feature that the hygroscopic growth can be measured at the temperature relevant for the Jungfraujoch, i.e. at -10°C. Due to its innovation the instrument was awarded WMO's prestigious Vaisala award in 2003. In addition, a cloud condensation nuclei (CCN) instrument was built in collaboration with the University of Applied Sciences Aargau in Windisch and tested for the first time in 2004 at the JFJ. Data analysis is still ongoing; if successful, the instrument might also be used at other GAW sites for continuous CCN measurements.

4 RESULTS

Data from 1995 to 2004 have been delivered to the EMEP data centre and are available from the EMEP site http://www.nilu.no/projects/ccc/create/database.htm as well as from the GAW world data centre http://rea.ei.jrc.it/netshare/wilson/WDCA/. According to an agreement between GAW and EMEP, data have been delivered to EMEP in 'NASA Ames 1001' data format since 2003, from where they are mirrored to the GAW data centre in the NARSTO data exchange standard format. In addition, a website was created which provides information for the general public about aerosol research (in German) and an on-line presentation of all continuously measured aerosol parameters (see http://aerosolforschung.web.psi.ch/, "Online-Messungen").

A first climatology of the JFJ atmosphere was performed with epiphaniometer and radon data which were started by PSI at the JFJ in 1988. The seasonal variation (with summer values being an order of magnitude higher than in winter) could be attributed to the seasonality of thermal convection, resulting in efficient injection of planetary boundary layer air into the free troposphere (*Baltensperger et al.,* 1997; *Lugauer et al.,* 1998; 2000; *Chevillard et al.,* 2002). In accordance with this, the diurnal variations showed a peak in the late afternoon during summer. While at that time these observations were in contrast to the common knowledge based on analysis of ozone data, they are widely accepted nowadays. The diurnal variation during summer was confirmed with airborne lidar measurements during flights over the Alps (*Nyeki et al.,* 2000; 2002; *De Wekker et al.,* 2004).

The chemical composition was first investigated in exploratory field campaigns both concerning the inorganic composition (*Zellweger et al.,* 2000; *Hinz et al.,* 2005) and the carbonaceous aerosol (*Lavanchy et al.,* 1999; *Krivacsy et al.,* 2001a; 2001b). A detailed size fractionated investigation was used to identify a cut of 1 µm as the best discrimination point between the coarse mode mainly consisting of mineral dust and the accumulation mode mainly consisting of anthropogenic components (*Streit et al.,* 2000). This size cut was then applied in the design of the sampling tree for the inorganic chemical composition that has been used in the long-term GAW programme since 1999 (*Henning et al.,* 2003).

Due to their climate relevance, optical parameters have a high priority in the GAW programme. Measurements of the light scattering coefficient and the light absorption coefficient showed the same seasonal behavior as the epiphaniometer data (Nyeki et al., 1998a). The two measurements are used to calculate the single scattering albedo (SSA) which is defined as the scattering coefficient divided by the extinction coefficient (Fig. 1). High temporal resolution measurements of the single scattering albedo can be used for a highly sensitive detection of Saharan dust events, since the wavelength dependence of the SSA is inversed during Saharan dust events (*Collaud Coen et al.,* 2004). In this way, about 30 individual Saharan dust events were identified per year.

While the dry measurements are important for comparison between individual stations, they do not represent the ambient conditions, due the water loss of the particles as mentioned above. Therefore, hygroscopic growth factors were measured for different seasons (*Weingartner et al.,* 2002; *Sjögren et al.,* in preparation). Using these data, extensive model calculations were successfully applied to correct the measured (dry) optical parameters (such as particle size as well as the light absorption and scattering coefficients) to the ambient conditions (*Nessler et al.,* 2003; 2005a; 2005b). This framework can now be used to determine 'true' wavelength dependent single scattering albedos, which are highly important for climate research. Since both the scattering and the absorption coefficient are measured at multiple wavelengths we will be able to report the SSA at multiple wavelengths.

Due to the regular presence of clouds at the Jungfraujoch, the interaction of aerosol particles with clouds can be investigated as well. For warm clouds, the microphysics of the Twomey effect (predicting smaller cloud droplets for higher concentrations of aerosol particles) was experimentally verified (*Henning et al.,* 2002). In cold clouds (during winter), the Bergeron-Findeisen process becomes important: on the formation of ice crystals water vapor is transported from the supercooled cloud droplets to the ice crystals, due to the different saturation vapor pressures over ice and water. This results in evaporation of the cloud droplets and accordingly to a much lower activated fraction of aerosol particles (*Henning et al.,* 2004). This phenomenon is highly important for the aerosol indirect effect on climate (since in these cold clouds the number of CCN is not important for the radiative balance of a cloud, in contrast to warm clouds). The involved processes are currently being investigated in a large international collaboration (CLACE-3 and CLACE-4 experiments, performed in March 2004 and February/March 2005, under the lead of PSI, Fig. 2).

5 FUTURE PLANS

We plan to continue the long-term measurement programme, which after 10 years is just at the edge of the ability to detect trends. 'True' single scattering albedos at multiple wavelengths will be determined, based on the developed framework to correct the dry measurements for water uptake at ambient relative humidity.

Furthermore, we plan to perform a more detailed chemical characterization of the JFJ aerosol during dedicated campaigns. This includes the semi-continuous determination of organic and elemental carbon, as well as the determination of the ^{14}C content both on the organic and elemental carbon. The latter provides a unique opportunity to provide a distinction between fossil fuel usage and other sources of carbonaceous aerosol (wood combustion, secondary organic aerosol formation from biogenic gaseous precursors), thus contributing to the goal of assessing the relative importance of anthropogenic versus natural sources of the JFJ aerosol.

Further experiments are planned to study the aerosol cloud interaction in cold clouds, taking advantage of the unique location of the JFJ: close enough to anthropogenic sources to see their impact, far enough away from local sources to be representative of a full region, high enough to allow for the presence of mixed phase and cold clouds, and easily accessible throughout the year. These experiments, which ultimately aim at a better characterization of ice nuclei in the atmosphere will be performed in collaboration with the newly formed German 'Sonderforschungsbereich' (special research activity) TROPEIS, the Tropospheric Ice Phase.

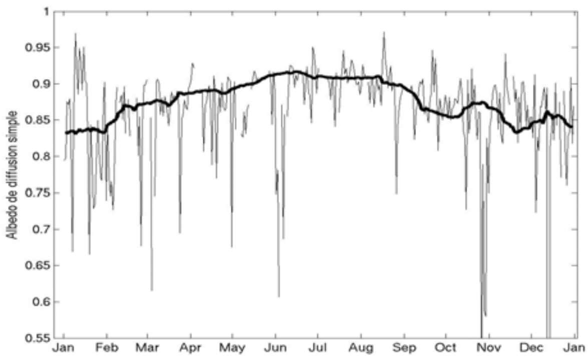

Figure 1: SSA 2004 daily data at 470 nm for dry conditions and monthly running mean of the period 3.2001-12.2004.

Figure 2: Ernest Weingartner and Stefan Mertes (IfT Leipzig) installing the new sampling device for ice crystals.

6 RESOURCES

Table 6.1: Resources of the aerosol programme (per year, averaged over the initiation phase, 1995-2000).

	From GAW-CH Budget		From PSI	
	Personnel (person years per year)	Non-salary expenses (kCHF per year)	Personnel (person years per year)	Non-salary expenses (kCHF per year)
Scientists	0.75		0.90	
PhD students	0.40		0.40	
Technicians	-		0.20	
Total	1.15	34*	1.50	25
Total (kCHF/y)	92	34*	140	25

* includes 15 kCHF space rental cost at the JFJ since 1998

Table 6.2: Resources of the aerosol programme (per year, averaged over the consolidation phase, 2001-2004).

	From GAW-CH Budget		From PSI	
	Personnel (person years per year)	Non-salary expenses (kCHF per year)	Personnel (person years per year)	Non-salary expenses (kCHF per year)
Scientists**	1.15		1.15	
PhD students	0.50		0.50	
Technicians	-		0.25	
Total**	1.65	38*	1.90	25
Total (kCHF/y)	182	38*	178	25

* includes 15 kCHF space rental cost at the JFJ
** includes 0.5 person years per year at MeteoSwiss

Table 6.3: Resources of the aerosol programme (per year, averaged over the entire period, 1995-2004).

	From GAW-CH Budget	From PSI
Initiation	126	165
Consolidation	220	203
Total (kCHF/y)	164	180

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THE GAW-CH GREENHOUSE AND REACTIVE GASES PROGRAMME AT THE JUNGFRAUJOCH

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1 INTRODUCTION

Our atmosphere is affected by the continuous increase of human activities. Long-term observations improve the understanding of the present state and the future behavior of the atmosphere with respect to natural and anthropogenic changes and allow estimations of anthropogenic sources. The influence on the atmosphere differs depending on the property of the emitted compounds. Relatively long-lived halocarbons like CFCs, HCFCs and HFCs are greenhouse gases and were therefore included into the Kyoto Protocol. Halocarbons in total are responsible for about 14% of the radiative forcing by anthropogenic greenhouse gases Other important greenhouse gases are nitrous oxide (N_2O) and methane (CH_4), which also have considerable anthropogenic sources.

The reactive gases (like NO_x and VOCs), on the other hand, do not affect the global climate directly but they can be regarded as indirect climate gases as they are precursors of tropospheric ozone and aerosols. The oxidizing potential of the atmosphere is governed by reactive gases and the effect of ozone and particles on human health is an important issue.

Due to its unique place, year-round accessibility and excellent infrastructure, the Jungfraujoch research station is well suited for long-term ground-based monitoring of background-free troposphere conditions and trend analyses. In addition, its location in central Europe and the proximity to potential source regions offers an appropriate study site for European regional source allocations during pollution events. Jungfraujoch is a relevant site in many networks and programmes, such as the Network for the Detection of Stratospheric Change (NDSC), the Global Atmosphere Watch Programme, the European monitoring and evaluation programme (EMEP) under the Convention of Long-Range Transboundary Air Pollution Transport (*Ballaman et al.,* 2004) and the Swiss National Air Pollution Monitoring Network (NABEL).

2 GOAL

2.1 Providing reliable, traceable, long-term observations of the atmospheric composition on a global and a regional scale in order to asses its contribution to climate change and environmental issues, which is also an objective of the GAW – programme.

2.2 Analysis and understanding of the variation of the central Europe background concentration of primary and secondary anthropogenic pollutants and understanding of meteorological and chemical processes in the alpine atmosphere.

2.3 Verification of European non-CO_2 greenhouse gas emissions by combining accurate continuous measurements at the Jungfraujoch site in the centre of Europe with appropriate meteorological information (trajectory models, LPDM). These figures could play a key role for an independent assessment of the bottom-up inventories from individual European countries.

3 APPROACH

3.1 Measurement

At the high Alpine site of Jungfraujoch (3580 m asl) **greenhouse gases** and **reactive gases** are continuously measured using state-of-the art analytical methods.

Jungfraujoch is one of a few stations covering the entire measurement programme of the GAW concerning greenhouse gases and reactive gase:

		recommended for GAW	**Jungfraujoch**	funding
Greenhouse gases	CH_4	✔	✔	NABEL (BUWAL, Empa)
	N_2O	✔	✔	NABEL (BUWAL, Empa)
	CFC	✔	✔	SOGE (Empa, BUWAL)
	HCFC, HFC		✔, ✔	SOGE (Empa, BUWAL)
	SF_6		✔	NABEL (BUWAL, Empa)
	CO_2	✔	✔	University of Berne
Reactive gases	O_3	✔	✔	NABEL (BUWAL, Empa)
	CO	✔	✔	NABEL (BUWAL, Empa)
	SO_2	✔	✔	NABEL (BUWAL, Empa)
	NO, NO_2, NO_y	✔, ✔, ✔	✔, ✔, ✔	NABEL (BUWAL, Empa)
	PAN, HNO_3	✔, ✔	**campains**	Empa
	VOC, OVOC		✔, **campains**	NABEL (BUWAL, Empa)
	H_2		✔	Empa

Based on this program Jungfraujoch has recently (February 2005) been added to the list of *GAW Global stations*.

The halogenated greenhouse gases are analysed continuously by gas chromatography-mass spectrometry (GCMS, Agilent, 5793N). Every 4 hours 23 individual halocarbons and selected VOCs are automatically analysed by pre-concentrating 2 litres of air on a carbon micro trap with subsequent release to the analytical instrument. The measurements of halocarbons at the Jungfraujoch are a part of the SOGE – project (System for Observation of Halogenated Greenhouse Gases in Europe) which is related in terms of standard and quality assurance to the world-wide AGAGE program (Advanced Global Atmospheric Gases Experiment). The recently started measurements of CH_4 and N_2O are performed with a GC-FID/ECD with a loop injection and are also linked to AGAGE. The observations of all the other measurement parameters at the Jungfraujoch are conducted within the scope of the Swiss National Air Pollution Monitoring Network (*NABEL,* 2004; *Buchmann,* 2004).

3.2 Trend analysis

The trends of specific halocarbons provide important information about the global emission of these chemicals. In combination with other background sites in the Northern and Southern hemisphere the determination of the inter-hemispheric gradient for specific substances can be attained. Filter functions are applied to calculate background concentrations (see DACH contribution and *Forrer et al.,* 2000; *Reimann et al.,* 2004 and 2005; *Brönnimann et al.,* 2000; *Zanis et al.,* 1999).

A statistical trajectory model is used to identify the location of those regions in central Western Europe, which contribute to the observed elevated concentrations at the Jungfraujoch. Thereby, measurement data at the Jungfraujoch is combined with respective back trajectories using the Swiss Alpine Model (*Reimann et al.,* 2004).

3.3 Emission estimation

Emissions of halogenated greenhouse gases are estimated by a tracer-ratio method using carbon monoxide (CO) as *a priori* information. Thereby, CO values above the baseline concentrations are taken as a measure for pollution events at Jungfraujoch. Then the ratio of concurrent elevated halocarbon concentrations vs. these CO concentrations is calculated. Finally, European and Swiss halocarbon emissions are estimated by combining this ratio during pollution events with European resp. Swiss CO emissions invetaries (*Buchmann et al.,* 2003, *Reimann et al.,* 2004). Although sources of CO and halocarbons are not necessarily co-located, we assume that the relative abundances of CO and halocarbons averaged over all pollution events are representative for the polluted boundary layer.

4 RESULTS

4.1 Greenhouse gases

The pattern of the halocarbons within SOGE (System for Observation of Halogenated Greenhouse Gases in Europe) is different for each site. As an example, HFC 134a (used as a cooling agent in air conditioners and fridges) is shown in Figure 1. Jungfraujoch and Monte Cimone (Italy) are influenced in a remarkable manner by regional sources (e.g. from the Po-valley in Northern Italy), while data from the stations in Mace Head (Ireland) and especially in Ny-Alesund (Spitzbergen) are more representative for the hemispheric background, showing rarely effects from pollution events. Nevertheless, all sites simultaneously show an increase of the background level, indicating a considerable global emission of long-lived compounds.

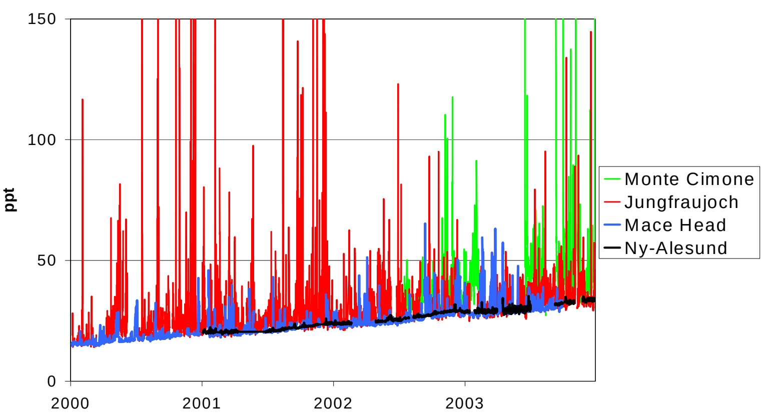
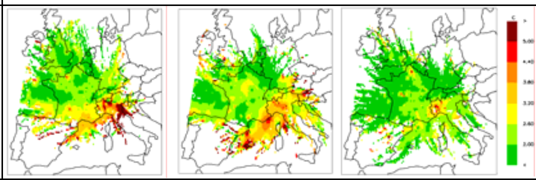
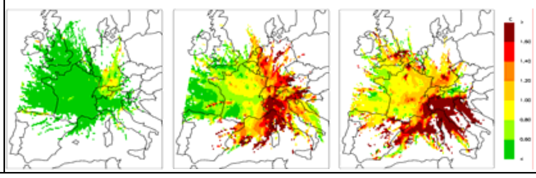


Figure 1:
Time series of HFC 134a at the Jungfraujoch (Switzerland), Mace Head (Ireland), Ny-Alesund (Norway) and Monte Cimone (Italy).

European emissions of hydrofluorocarbons (HFCs), derived from our measurements, are compared to data submitted by European countries to the UNFCCC, with the result that for some of the gases substantial differences were found. An example, showing the advantage of continuous measurements at Jungfraujoch is our estimate of European methyl chloroform (1,1,1,-trichloroethane, CH_3CCl_3) emissions (*Reimann et al.,* 2005). This substance was widely used as a solvent before it was phased-out under the Montreal Protocol. Subsequently, its atmospheric concentration has steadily declined. Recent European CH_3CCl_3 consumption and emissions were estimated to be less than 0.1 Gg yr^{-1}. However, data from a short-term tropospheric measurement campaign (EXPORT) indicated that European CH_3CCl_3 emissions would be as high than 20 Gg in 2000. Our analysis of long-term data at Jungfraujoch and Mace Head (Ireland) could put this result from a short campaign ito perspective; it showed that European methyl chloroform emissions declined from about 60 Gg yr^{-1} in the mid-1990s to only 0.3-3.4 Gg yr^{-1} in 2000-03.

For the localisation of potential European halocarbon source regions a trajectory model was used based on the Swiss Alpine Model, aLMo. Results of the temporal development of the emissions for HCFC 141b and HFC 152a, seen with the trajectory statistics, are shown in Figure 2. In 2001, air from Italy used to be polluted with the now forbidden HCFC 141b – but emissions have declined dramatically. On the other hand, emissions of HFC 152a (not restricted in the Montreal-Protocol), predominately used in foam blowing, have increased substantially.

	2001 2002 2003	:
HCFC 141b		*Figure 2* Source regions resulting from trajectory statistics of the HCFC 141b and the HFC 152a between 2001-2003 seen at Jungfraujoch.
HFC 152a		Units indicate averaged concentrations above the baseline [ppt], linked to trajectories that passed over the respective grid cell.

4.2 Reactive gases:

The regional background levels of ozone have been studied in detail (*Zanis et al.,* 1999; *Brönimann et al.,* 2000; *Brönimann et al.,* 2002). An analysis of hydrocarbon concentrations in combination with backward trajectories revealed that events with strongly aged air arriving at the Jungfraujoch are usually accompanied by warm conveyer belt transport phenomena while thermal lifting can sometimes transport fresh emissions from the adjacent valleys to the research station (*Li et al.,* 2005).

The interpretation of long-term CO and NOx time series and their variabilities with respect to meteorological conditions also showed that thermally induced transport can influence the sampling site on a local range. On a regional and synoptic scale, Foehn events and frontal passages can also result in rapidly changing trace gas concentrations at the Jungfraujoch (*Forrer et al.,* 2000). Similar analysis for reactive nitrogen species showed that the NOy mixing ratio and partitioning strongly depends on meteorological conditions and the variability driven by meteorology often dominates the seasonal variability (*Zellweger et al.,* 2003).

5 FUTURE PLANS

To strive for ***emission estimation of the entire set of greenhouse gases*** on a regional and a European scale. This becomes feasible since the recently started continuous measurements of the most important greenhouse gases N_2O, CH_4 and CO_2 makes these data sets available.

Furthermore, participation in European initiatives for the ***co-ordination of the quality assurance*** of the measurements of these gases (e.g. MethMonitEUr) is planned.

To aim at a ***better coverage of the regional*** level by expanding the already existing analyses of the data from Jungfraujoch by merging with data of other stations in the SOGE network. In the beginning the existing trajectory model will be used, it is planed to replace this by inverse modelling.

Special attention will be given to the ***uncertainty treatment*** of emission estimations. Thus emission estimations by means of long-term observations become an even more powerful tool supporting the Kyoto Protocol. The big advantage of this method is the ***independent verification*** of greenhouse gas emissions declared by European countries.

6 RESOURCES

Reactive gases: an inherent part of the Swiss national network for air pollution (NABEL): funded by the Swiss Agency for Environment, Forests and Landscape (SAEFL) and Empa

Greengouse gases: contribution within the 'System for Observation of Halogenated Greenhouse Gases in Europe (SOGE)' and NABEL funded by the Swiss Agency for Environment, Forests and Landscape (SAEFL) and Empa, which includes funding of EU – project SOGE.

Carbon Dioxide: responsible Physics Institute of University of Berne (PD Dr. Markus Leuenberger) funded through FR6 CarboEurope IP.

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RESOURCES OF THE GAW-CH PROGRAMME FOR THE PERIOD 1995 - 2004

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The following Tables 1-3 provide an overview on the resources of the whole GAW-CH Programme.

Table 1: Resources of the GAW-CH Programme (per year, averaged over the initiation phase, 1995-2000).

	From GAW-CH Budget		From contributing institutions	
	Personnel (person years per year)	Non-salary expenses (kCHF per year)	Personnel (person years per year)	Non-salary expenses (kCHF per year)
Scientists	3.6		4.2	
PhD students	3.4		1.5	
Technicians	0.2		3.7	
Total	7.2	499	9.4	154
Total (kCHF/y)	525	499	851	154

Table 2: Resources of the GAW-CH Programme (per year, averaged over the consolidation phase, 2001-2004).

	From GAW-CH Budget		From contributing institutions	
	Personnel (person years per year)	Non-salary expenses (kCHF per year)	Personnel (person years per year)	Non-salary expenses (kCHF per year)
Scientists	5.8		4.3	
PhD students	1.8		2.5	
Technicians	0.3		2.0	
Total	7.9	329	8.8	96
Total (kCHF/y)	804	329	760	96

Table 3: Resources of the GAW-CH Programme (per year, averaged over the entire period, 1995-2004).

	From GAW-CH Budget	From contributing institutions
Initiation	1023	1005
Consolidation	1133	856
Total (kCHF/y)	1067	945

The following remarks apply to the resources in Tables 1-3:

- The values cover salaries as well as investments and consumables averaged over the entire period of the Swiss GAW Programme, but no overhead and infrastructure costs are included.
- The costs for the operational ozone measurements in Payerne and Arosa, which were running before the Swiss GAW Programme started, are not taken into account. The GAW-CH ozone programme concentrated on the improvement of the quality assurance of the existing measurements, the re-evaluation of the long series and the development of the microwave radiometer.

Concerning the resources over the whole 10 years period 1995-2004, the following conclusions can be drawn from Tables 1-3:

- The overall costs for the Swiss GAW Programme (services and scientific programmes) were 20.1 Mio CHF, 10.7 Mio CHF (53%) coming from the GAW-CH budget and 9.5 Mio CHF (47%) being brought in by the contributing institutions.
- The part coming from the contributing institutions has been slightly reduced from 50% to 43% in the consolidation phase. This is due to the fact that the partner institutions have produced their main effort during the set-up phase.
- Globally, the costs related to the personnel represent 72%, with 67% in the initiation phase and 78% in the consolidation phase. The partners have largely (85%) contributed with man-power.
- With respect to the 10.7 Mio CHF of the GAW-CH Budget, 6.4 Mio CHF, representing 60%, have been spent for salaries, the remaining part for instruments and running costs. In line with the fact that most equipment has been purchased in the set-up phase, the non-salary expenses represent 49% during the set-up phase and 30% during consolidation.
- Roughly 166 person years have been at the disposal of the GAW-CH Programme during the decade 1995-2004, 44% paid by the GAW-CH budget and 56% in charge of the contributing institutions.
- From the persons involved in the GAW activities, 82% were scientists or PhD students. Concerning the GAW-CH Budget, more than 95% of the salary costs have been spent to finance scientist and PhD positions. This shows the prominent role R&D activities played in the GAW-CH Programme.

LIST OF ABBREVIATIONS

ACVE	Atlantic Climate Variability Experiment
AERONET	AErosol RObotic NETwork
AIDA	Aerosol-Interkalibrationen und Dynamik in der Atmosphäre
AIROS	Atmospheric Integrated Regional Observing System
ANETZ	Automatisches messNETZ
AO	Arctic Oscillation
AOD	Aerosol Optical Depth
ASRB	Alpine Surface Radiation Budget
ASRC	Atmospheric Sciences Research Center
AURA	earth observing satellite for trace gases
AVHRR	Advanced Very High Resolution Radiometer
BAMS	Bulletin of the American Meteorological Society
BAPMoN	Background Air Pollution Monitoring Network
BESOS	Balloon Experiment on Standards for Ozone Sondes
BM	Brewer-Mast (ozone sonde)
BSRN	Baseline Surface Radiation Network
BUWAL	Bundesamt für Umwelt, Wald und Landschaft
CANDIDOZ	Chemical ANd Dynamical Influences on Decadal OZone Change
CAS	Commission for Atmospheric Sciences
CCC	Chemical Coordinating Centre
CCL	Central Calibration Laboratory
CCN	Cloud Condensation Nuclei
CHARM	CH Atmospheric Radiation Monitoring Programme
CIMO	Commission for Instruments and Methods of Observation
CLACE	Cloud and Aerosol Characterization Experiment
CMDL	Climate Monitoring and Diagnostics Laboratory
CN	Condensation Nuclei
COST	european COoperation in the field of Scientific and Technical research
CSCS	Swiss national Supercomputing Centre
DACH	joint Co-Operation between German (D), Austrian (A), Swiss (CH) meteorological agencies
DWD	Deutscher Wetterdienst, Germany
ECC	Electrochemical Concentration Cell (ozone sonde)

ECMWF	European Centre for Medium-Range Weather Forecasts
ECV	Essential Climate Variable
EMEP	European Evaluation and Monitoring Programme
EML	Environmental Measurements Laboratory
EMPA	Swiss Federal Laboratories for Materials Testing Research and Research Testing
ENVISAT	ENVIronmental Monitoring SATellite (ESA)
EPFL	Ecole Polytechnique Fédérale de Lausanne, Switzerland
ESA	European Space Agency
ESRIN	European Space Research INstitute
ETHZ	Eidgenössische Technische Hochschule Zürich (Swiss Federal Institute of Technology Zurich, Switzerland)
EU	Europäische Union
EUCOS	EUMETNET Composite Observing System
EU-FP	EUropean Framework Programme for research, technology and demonstration of the EU
FWIS	Future WMO Information System
FZ	Forschungs-Zentrum
GAW	Global Atmosphere Watch
GAW-CH	GAW Swiss Contribution
GAWSIS	GAW Station Information System
GAWTEC	GAW Training and Education Centre
GCOS	Global Climate Observing System
GCM	Global Climate Model
GEF	Global Environment Facility
GEWEX	Global Energy and Water cycle EXperiment
GEMS	Global Environmental Monitoring System
GMES	Global Monitoring for Environment and Security
GOMOS	Global Ozone Monitoring by Occultation of Stars (instrument of the ENVISAT satellite)
GROMOS	GROund-based Millimeter-wave Ozone Spectrometer
GURME	GAW Urban Research Meteorology and Environment
HALCLIM	measurements of HALogenated greenhouse gases at the Jungfraujoch
HTDMA	Hygroscopic Tandem Differential Mobility Analyzer
IAC	Institute for Atmospheric and Climate Science
IACETHZ	IAC of the Swiss Federal Institute of Technology Zurich, Switzerland

IAP	Institute of Applied Physics, University Bern, Switzerland
IEEE	Institute of Electrical and Electronics Engineers
IfT	Institute for Tropospheric research, Leipzig, Germany
IGAC	International Global Atmospheric Chemistry
IGACO	Integrated Global Atmospheric Chemistry Observations
IGOS	Integrated Global Observing Strategy
IGY	International Geophysical Year
IMK-IFU	Institut für Meteorologie und Klimaforschung - Bereich Atmosphärische Umweltforschung, Karlsruhe, Germany
IRS	International Radiation Symposium
ISCCP	International Satellite Cloud Climatology Project
Ispra	European joint research center
ISWS	Illinois State Water Survey
IWV	Integrated Water Vapor
JFJ	Jungfraujoch
JMA	Japan Meteorological Agency
JOSIE	Jülich Ozone Sonde Intercomparison Experiments
JRC	environment institute, Ispra, Italy
KMD	Kenyan Meteorological Department
LIDAR	LIght Detection And Ranging
LKO	Licht Klimatisches Observatorium
LPDM	Lagrange Particle Dispersion Model
LW	Long-Wave
MAP	Mesoscale Alpine Programme
MGO	A.I. Voeikov Main Geophysical Observatory, Russia
MATCH	measurement campaigns within the european arctic stratosphere ozone experiment
MIPAS	Michelson Interferometer for Passive Atmospheric Sounding
MISCHTRA	DACH project related to pollutant transport in the boundary layer
MSC	Meteorological Service of Canada
NABEL	National Air Pollution Monitoring Network
NAO	North Atlantic Oscillation
NARSTO	North American Research Strategy for Tropospheric Ozone
NASA	National Aeronautic and Space Administration
NCCR	National Center of Competence in Research
NCDC	National Climate Data Center

NDSC	Network for Detection of Stratospheric Change
NIST	National Institute for Standards and Testing, Gaithersburg, MD, USA
NMHS	National Meteorological and Hydrological Service
NOAA	US National Oceanic and Atmospheric Administration
NRA	NASA Research Announcement for the upper atmosphere research satellite
NWP	Numeric Weather Prediction
NZ	New Zealand
OA	On-site Analyses
PARAGON	computer for parallel computing
PFR	Precision Filter Radiometer
PhD	Philosophy Doctorate
PMOD/WRC	Physikalisch-Meteorologisches Observatorium, Davos/ World Radiation Center, Davos, Switzerland
PSI	Paul Scherrer Institut, Villigen, Switzerland
PTB	Physikalisch-Technische Bundesanstalt, Berlin, Germany
PTU	Pressure-Temperature-hUmidity
QA	Quality Assurance
QA/SAC	Quality Assurance / Science Activity Centre
QBO	Quasi Biannual Oscillation
QC	Quality Control
QOS	Quadrennial Ozone Symposium
REMO	Regional Model
SAEFL	Swiss Agency for the Environment, Forests and Landscape
SAG	Scientific Advisory Group
SAP	Station Aérologique de Payerne, Switzerland
SHADOZ	Southern Hemisphere ADditional OZone sondes
SMI	Swiss Meteorological Institute (old name for MeteoSwiss)
SOGE	System for Observation of halogenated Greenhouse gases
SOMORA	Stratospheric Ozone Monitoring Radiometer
SONDEX / OZEX	campaigns of parallel B-M/ECC sondes at Payerne
SOP	Standard Operating Procedure
SPIE	international society for optical engineering
SRP	Standard Reference Photometer
SRRB	Surface Radiation Research Branch (NOAA)
SSA	Single Scattering Albedo
SUNY	State University of New York, USA

SW	Short-Wave
TOMS	Total Ozone Mapping Spectrometer
TROPEIS	TROPspheric Ice Phase
TS	Traveling Standard
TXRF	Total reflection X-Ray Fluorescence
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
UBA	Umweltbundesamt (German environmental protection agency, Berlin, Germany)
UV	Ultra Violet radiation
VMR	Volume Mixing Ratio
WCC	World Calibration Centre
WDCA	World Data Center for Aerosols
WG-EPAC	Working Group on Environmental Pollution and Atmospheric Chemistry
WMO	World Meteorological Organization
WMO RA VI	WMO Region VI (Europe)
WOUDC	World Ozone and UV Data Centre
WORCC	World Optical Depth Research and Calibration Centre
WRC	World Radiation Center
WRMC	World Radiation Monitoring Center
ZAMG	Zentralanstalt für Meteorologie und Geodynamik, Austria

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