

## SWITZERLAND

### OBSERVATIONAL ACTIVITIES

#### Column measurements of ozone

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

#### Profile measurements of ozone

Balloon ozone soundings are measured from the Payerne Aerological Station three times per week since 1968. Until August 2002, Brewer-Mast (BM) ozonesondes were used while since September 2002 ECC (ENSCI – 0.5%) sensors are the operational instruments.

The Umkehr ozone profiles are recorded at sunrise and sunset at Arosa since 1956 in clear sky conditions. Originally the measurements were performed manually but since 1989, the data acquisition of the Dobson Umkehr (D051) is computer-controlled. In 1988, the Brewer (B040) Umkehr series have started and presently the three Brewer are simultaneously measuring the Umkehr profiles.

Since 2001, ozone profiles (20 – 70 km) are retrieved at Payerne from the radiometer SOMORA. This instrument delivers thirty minutes averaged profiles continuously.

#### UV measurements

The **Swiss Atmospheric Radiation Monitoring** programme (CHARM) consisting of 4 stations covering the altitude range of 366 to 3587m was build up between 1995 and 2000. The measurements programme consists of :

**Broadband measurements:** the direct, diffuse and global components of the broad-band erythemal UV-ERY radiation (Solar Light UV-Biometers) are measured.

**Narrowband filter instruments:** spectral direct irradiances are measured with Precision Filter Radiometers (PFR) at 16 wavelengths in the range 305 nm to 1024 nm.

Besides the direct measurements, the UV index, the AOD at various wavelengths as well as the Integrated Water Vapour (IW) are calculated from those data.

Spectral Brewer UV measurements: at Arosa, since 1994 spectral global UVB measurements are recorded with the Brewer instruments 072 on the range 290 nm – 325 nm. Since 1998, the Brewer Mark III 156 is in operation and it measures the range 286.5 - 363 nm.

#### Calibration activities

At Arosa, regular calibrations and maintenances are organised for the Brewer (every year) and for the Dobson instruments (every 4 years) traceable to the world standards.

Each ozonesonde is calibrated prior to the flight again a reference UV photometer.

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

#### Halocarbon measurements at the global GAW station Jungfraujoch

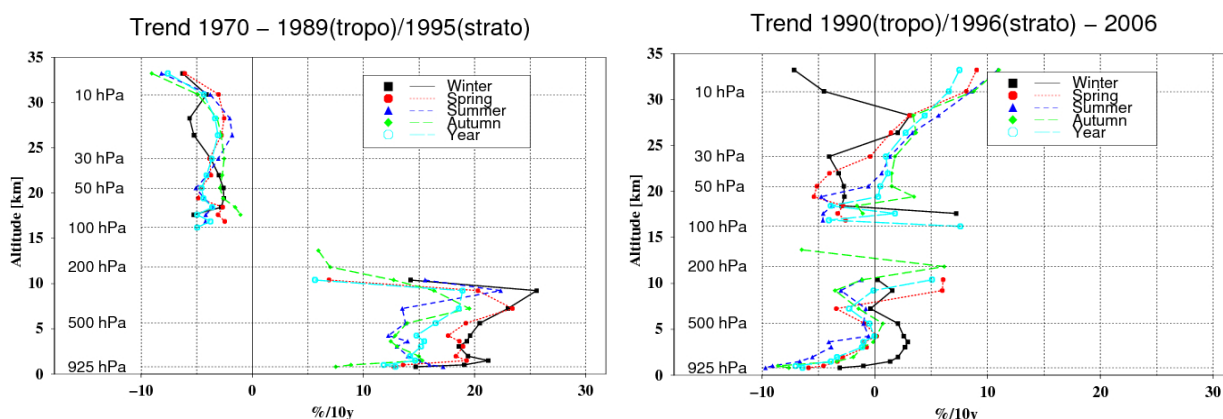
The high Alpine site of Jungfraujoch (3580m) is one of a few stations covering the entire measurement programme of the GAW concerning greenhouse gases and reactive gases. The measurements of chlorocarbons (CFCs, HCFCs) and bromocarbons (halones) are performed continuously at Jungfraujoch since the year 2000. They are part of the SOGE – network (System for Observation of Halogenated Greenhouse Gases in Europe), which is an associate programme to the world-wide AGAGE programme (Advanced Global Atmospheric Gases Experiment). Since

February 2008 the identical preconcentration unit (“MEDUSA”) as used within the AGAGE network has been installed at Jungfraujoch for the continuous measurements.

## RESULTS FROM OBSERVATIONS AND ANALYSIS

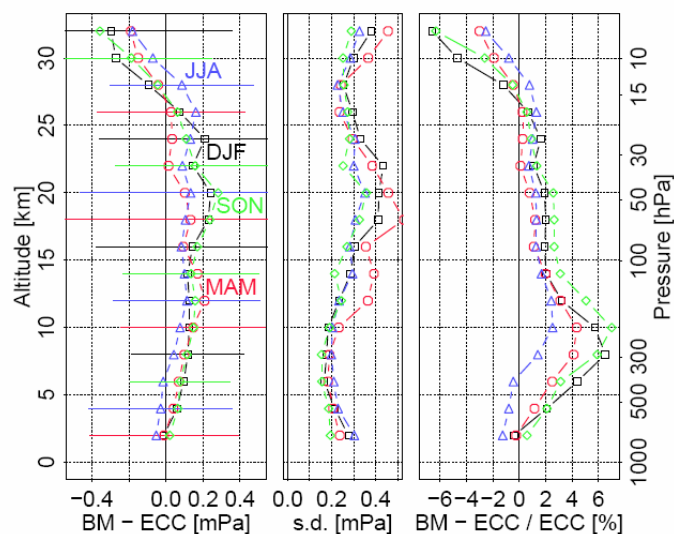
### Ozone at MeteoSwiss / Payerne (Dr. R. Stübi, P. Jeannet)

A detailed analysis of the 35 years long series of BM ozone sounding at Payerne has been published in 2007 (Jeannet et al. 2007). An updated trend analysis is included in this paper and the seasonal trends are reproduced in the figures below (see the reference for further details).



**Figure 1:** Trend profiles of the homogenized Payerne ozone sounding series. On the left panel, the trends over the periods 1970-1989 (1970-1995) for the troposphere (stratosphere) are given. On the right panel, the similar results for the period 1990-2006 (1996-2006) for the troposphere (stratosphere) are reported.

As mentioned earlier, the ozonesonde type for Payerne station has been changed in 2002. Prior to this change, a systematic analysis of the difference between BM and ECC ozonesondes has been done over a long period of time. The final results are published in Stübi et al, 2008. In figure 2, the seasonal difference profiles between BM and ECC based on more than 100 dual flights are given. For further details on this analysis, see Stübi et al., 2007. Other similar studies related to the difference between ozonesondes have been realised in international projects. The Payerne team has participated to the JOSIE (Smit et al. 2007) and BESOS (Deshler et al. , 2008) campaigns.

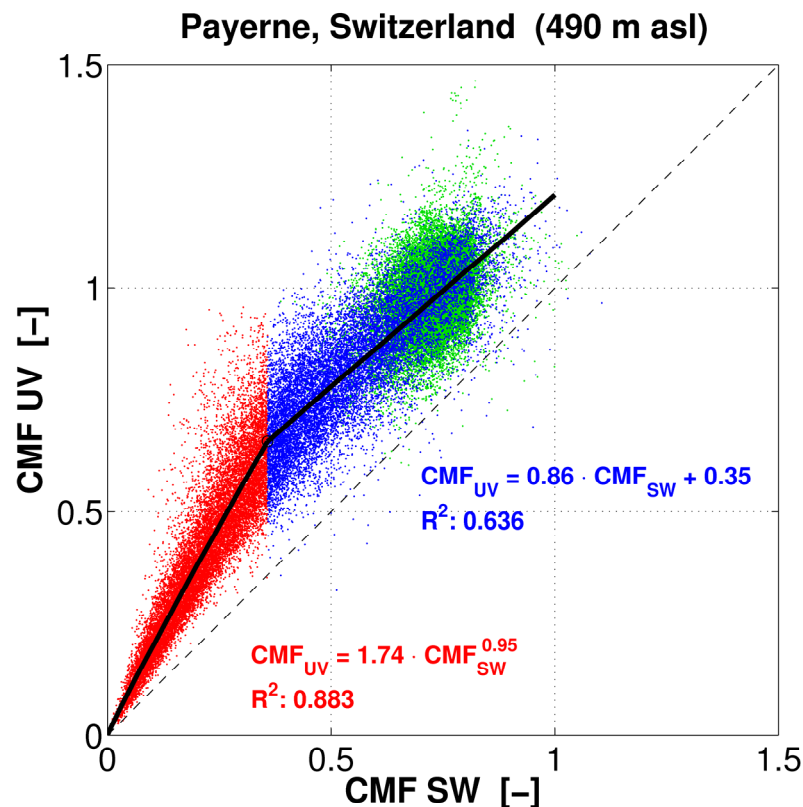


**Figure 2:** Seasonal difference profiles between Brewer-Mast and ECC ozonesondes from dual flights campaigns. Left panel: the direct difference [mPa]; middle panel: standard deviation [mPa]; right panel: relative difference [%].

### UV at MeteoSwiss / Payerne (Dr. L Vuilleumier, D. Walker)

The European COST action 726 deals with the long term changes and climatology of ultraviolet (UV) radiation over Europe. The main objective is to advance the understanding of UV distribution under various meteorological conditions. In the framework of this study, MeteoSwiss focus on the interaction of erythemal UV radiation with clouds and the complex alpine topography including varying snow coverage. Measured time series of erythemal UV radiation are often too short and spatially sparse to draw climatological conclusions as requested by the users' community. Therefore, different approaches for UV reconstruction (inference of UV radiation ground flux based on proxy data and modeling) are assessed.

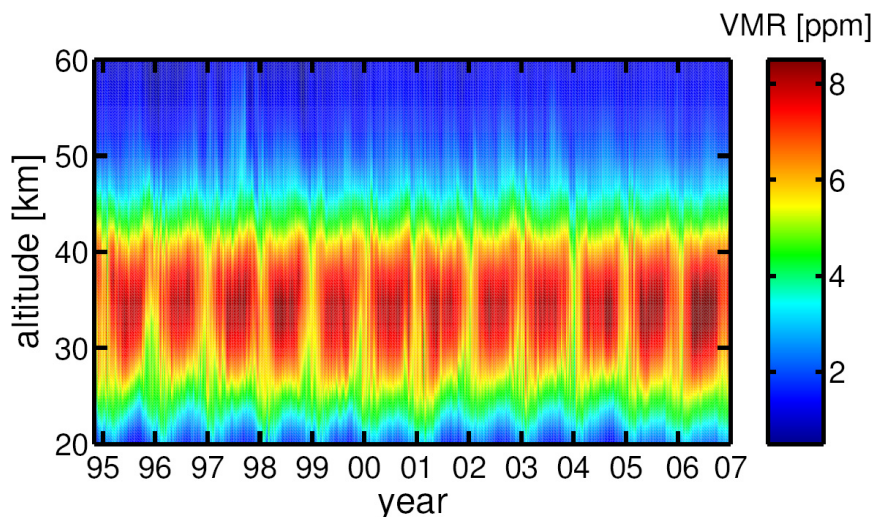
In the course of this study the short-term variability of UV radiation due to clouds and turbidity of the atmosphere is analyzed. The introduction of clouds in radiative transfer models (RTMs) requires detailed information about cloud properties and for the simulation of the most frequent scattered cloud situations even 3D modeling techniques are necessary. Therefore, we restrict the application of the RTM to clear sky conditions and investigate the cloud influence using shortwave global radiation (SW) as a proxy. Shortwave global radiation not only holds information about the transmittance of the atmosphere but is also a very common parameter measured within meteorological networks that usually offers superior spatial coverage and longer reliable time series than UV radiation.



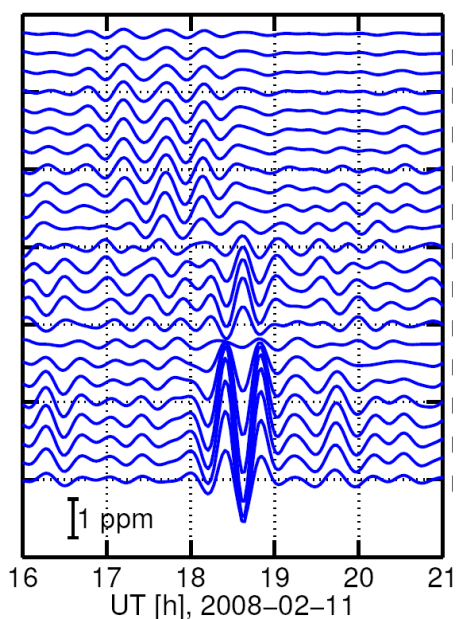
**Figure 3:** The relationship between the cloud modification factors (CMFs) in the shortwave and UV range at the BSRN station Payerne (CH) is shown. The CMFs represent the ratios between observed irradiances and their respective values in case of clear sky conditions. They describe the effect of clouds and turbidity on radiation with respect to clear-sky conditions. The relationship can be separated into three clusters representing different meteorological situations: a circular shaped data cluster (green) close to a  $CMF_{UV}$  of one describes situations close to clear sky conditions. On the other hand, the data shown in red or blue represent cloud situations with more or less intense cloud coverage, respectively. This separation of the data is found at all stations in Switzerland that measure UV, independently of the climate regime of the meteorological station.

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

Two ozone microwave radiometers (GROMOS and SOMORA) are continuously operated by IAP at University of Bern and by MeteoSwiss at Payerne. Both microwave radiometers provide ozone profiles with a vertical resolution of about 8-10 km and a time resolution of about 30 min to various data centres such as NDACC and the Aura Validation Data Centre (Hocke et al., 2007). Currently a homogenization of the data sets of GROMOS and SOMORA is in work in order to generate a long term series for detection of ozone trends (GROMOS: 1994-2000; SOMORA since 2000; Figure 4).



**Figure 4:** Homogenized time series from the GROMOS (1994 – 2000) and SOMORA (since 2000) radiometers.



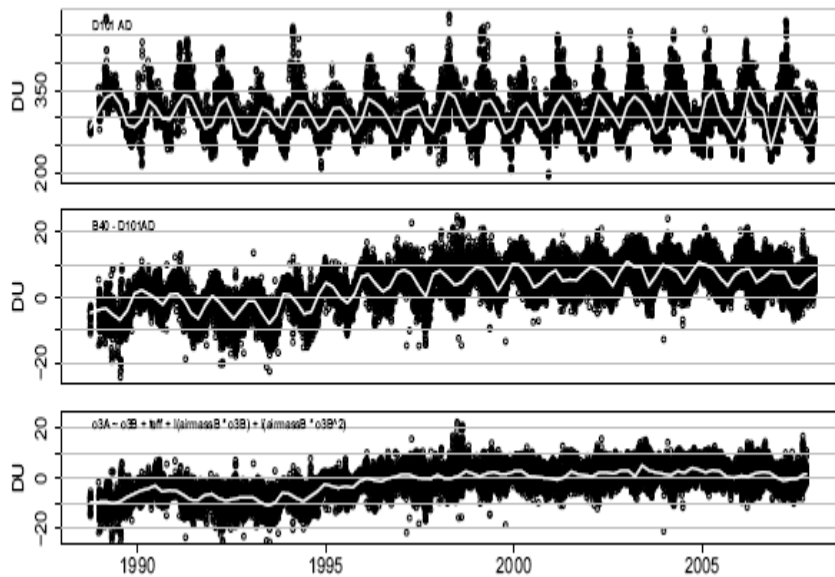
The sampling time of the ozone profiles can be shortened from 30 min to 2 min so that the ozone measurements can be utilized for monitoring of tides and gravity waves in the middle atmosphere. Figure 5 shows such an analysis of the GROMOS data from February, 2<sup>nd</sup> 2008.

**Figure 5:** Ozone mixing ratio deviations from the mean on specific pressure levels (top: 0.1 hPa; bottom: 53.9 hPa). This corresponds to an altitude range from ~19 km to ~62 km. The data are filtered with a band pass between 20 and 40 minutes

#### ETH Zurich / IAC (Prof J. Staehelin, Dr. B. Scarnato)

Comparisons of spectrophotometric total ozone measurements of Arosa: The extended data set of Arosa mentioned in § 1.1 allows for detailed comparisons of total ozone measurements of Dobson and Brewer spectrophotometers. Part of the differences of the column ozone of the two types of standard instruments (see Fig. 6) can be attributed to the different wavelengths and the temperature dependences of the ozone cross sections used in the two instruments. Note, that the retrieval algorithms of the two spectrophotometers ignore atmospheric temperature variability. The data analysis (Scarnato et al., 2008a) also indicated, that the accuracy of well calibrated and maintained sun spectrophotometers are presently limited by the information of the ozone cross sections and their dependence on temperature in the wavelength band of 300-340 nm, where ozone cross section considerably depend on temperature. Using an empirical approach a transfer

function could be deduced allowing for conversion of Dobson in Brewer measurements and vice versa (Scarnato et al., 2008b).



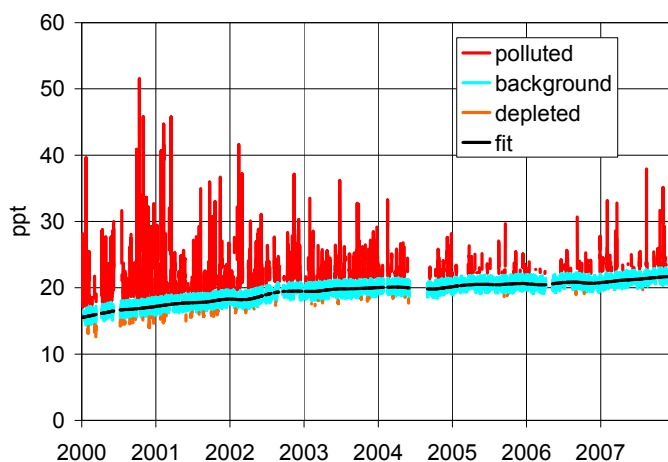
**Figure 6:** Time series of measurements of column ozone of a Dobson (first panel) operated at Arosa. The second panel shows the difference of the coincident data from a Brewer and a Dobson. The bottom panel, the Dobson measurements are converted to the Brewer scale applying an empirical transfer function (Scarnato et al., 2008b)

The readings of the historical total ozone series of Oxford (UK) was digitized and homogenized (Vogler et al., 2007).

A global three dimensional ozone data series in the framework of theta/equivalent latitude coordinates was produced by data assimilation from a satellite total ozone series (Brunner et al., 2006a). The data series can be used for trend analysis using multiple regression analysis (Brunner et al., 2006b)

#### **EMPA Dübendorf / Zürich (Dr. S. Reimann)**

The continuous in-situ measurements at Jungfraujoch are used to detect trends of ozone-depleting halocarbons (CFCs, HCFCs, halones) in the free troposphere over Europe [Reimann et al., 2008]. As an example measurements of HCFC 141b at Jungfraujoch are shown in Fig. 7. After usage was forbidden in the non-Article 5 countries in 2003, pollution events declined and the trend levelled out [Derwent et al., 2007].



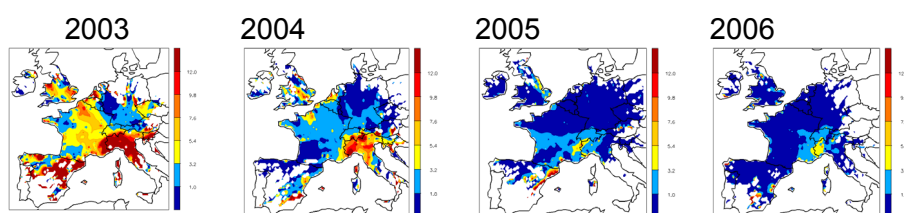
**Figure 7:** Concentrations of HCFC 141b measured at Jungfraujoch. Pollution events are distinguished from background and depletion.



Furthermore, measurements have been used to calculate the positive trade-offs of the Montreal Protocol to climate change by the curbing of the greenhouse active CFCs and HCFCs [Steinbacher et al., 2008].

Continuous in-situ measurements at Jungfraujoch could be used to justify Europe's phasing-out of methyl chloroform [Reimann et al., 2005], previously challenged by data from a short-term airplane campaign [Krol et al., Nature, 2003].

Pollution events from the European boundary layer can be used for the localisation of potential European source regions of ozone-depleting halocarbons. For this purpose concentrations during pollution events are linked with the respective trajectories from MeteoSwiss (COSMO). Results of the temporal development of the emissions for HCFC 141b are shown in Fig. 8.



**Figure 8:** Source regions from trajectory statistics of HCFC 141b between 2003-2006 at Jungfraujoch. Units indicate averaged relative increase over the baseline, linked to trajectories that passed over the respective grid cell.

## DISSEMINATION OF RESULTS

### Data reporting

The ozone data from Arosa, respectively Payerne are regularly deposited at the WODC and at the NDACC data centres. They are also deposited at NILU data centre for validation projects and measurements campaigns (Satellites, ECMWF, MATCH).

The SOMORA radiometer data are deposited at NDSC and NILU data centres.

The radiation data from the CHARM Payerne station are deposited at the WRM-BSRN data centre.

### Information to the public

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

### Relevant scientific papers

- Brunner, D., J. Staehelin, J. Maeder, H.-R. Kuensch, and G.E. Bodeker (2006a), A Kalman filter reconstruction of the vertical ozone distribution in an equivalent latitude – potential temperature framework from TOMS/GOME/SBUV total ozone observations, *J. Geophys. Res.*, 111, D12308, doi:10.1029/2005JD006279.
- Brunner, D., J. Staehelin, J.A. Maeder, I. Wohltmann, and G.E. Bodecker (2006b), Variability and trends in total and vertically resolved stratospheric ozone based on the CATO ozone data set, *Atmos. Chem. Phys.*, 6, 4985-5008.
- Derwent, R.G., Simmonds, P.G., Grealley, B.R., O'Doherty, S., McCulloch, A., Manning, A., Reimann, S., D. Folini, Vollmer, M.K. (2007) The phase-in and phase-out of European emissions of HCFC-141b and HCFC-142b under the Montreal Protocol: Evidence from observations at Mace Head, Ireland and Jungfraujoch, Switzerland from 1994 to 2004, *Atmos. Environ.*, 41, 757–767.
- Deshler, T., et al. (2008), Atmospheric comparison of electrochemical cell ozonesondes from different manufacturers, and with different cathode solution strengths: The Balloon Experiment on Standards for Ozonesondes, *J. Geophys. Res.*, 113, D04307, doi:10.1029/2007JD008975.

- Hocke K., N. Kämpfer, D. Ruffieux, L. Froidevaux, A. Parrish, I. Boyd, T. von Clarmann, T. Steck, Y.M. Timofeyev, A.V. Polyakov, and E. Kyrölä, *Comparison and synergy of stratospheric ozone measurements by satellite limb sounders and the ground-based microwave radiometer SOMORA*, *Atmos. Chem. Phys.*, 7, 4117-4131, 2007
- Jeannot, P., R. Stübi, G. Levrat, P. Viatte, and J. Staehelin (2007), *Ozone balloon soundings at Payerne (Switzerland): Reevaluation of the time series 1967–2002 and trend analysis*, *J. Geophys. Res.*, 112, D11302, doi:10.1029/2005JD006862.
- Reimann, S., Vollmer, M.K., Folini, D., Steinbacher, M., Hill, M., Buchmann, B., Zander, R., Mahieu, E (2008) *Observations of Long-Lived Anthropogenic Halocarbons at the High-Alpine site of Jungfraujoch (Switzerland) for Assessment of Trends and European Sources*, *Sci. Tot. Environ.*, 391, 224–231.
- Reimann, S., Manning, A.J., Simmonds, P.G., Cunnold, D.M., Wang, R.H.J., Li, J., McCulloch, A., Prinn, R.G., Huang, J., Weiss, R.F., Fraser, P.F., O'Doherty, S., Grevilly, B.R., Stemmler, K., Hill, M. and Folini, D (2005) *Low European methyl chloroform emissions inferred from long-term atmospheric measurements*, *Nature*, 433, 506-508.
- Smit, H. G. J., et al. (2007), *Assessment of the performance of ECC-ozonesondes under quasi-flight conditions in the environmental simulation chamber: Insights from the Juelich Ozone Sonde Intercomparison Experiment (JOSIE)*, *J. Geophys. Res.*, 112, D19306, doi:10.1029/2006JD007308.
- Scarnato, B., J. Staehelin, R. Stübi, H. Schill and J. Groebner (2008a), *Total ozone observations at Arosa (Switzerland) by Dobson and Brewer spectrophotometers: Temperature and ozone slant path effects*, in prep.
- Scarnato, B., J. Staehelin, R. Stübi, and H. Schill (2008b), *Long term total ozone observations at Arosa (Switzerland) by Dobson and Brewer instruments (1988-2007)*, in prep.
- Steinbacher, M., Vollmer, M.K., Buchmann, B., Reimann, S. (2008) *An evaluation of the current radiative forcing benefit of the Montreal Protocol at the high-Alpine site Jungfraujoch*, *Sci. Tot. Environ.*, 391, 217–223.
- Stübi et al. (2008), *In flight comparison of Brewer-Mast and Electrochemical Concentration Cells Ozonesondes*, *J. Geophys. Res.*, in press, doi:10.1029/2007jd009091
- Vogler, C., S. Brönnimann, J. Staehelin, and R.E.M. Griffin (2007), *Dobson total ozone series of Oxford: Re-evaluation and applications*, *J. Geophys. Res.*, 112, D20116, doi:10.1029/2007JD008894.

## PROJECTS AND COLLABORATION

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

- Support to the ozone sounding **station Nairobi** of the Kenyan Meteorological Institute,
- **World Optical Depth Research Centre (WORCC)** at Physikalisch-Meteorologisches Observatorium / World Radiation Centre (PMOD /WRC) in Davos
- **World Calibration Centre (WCC) and Quality Assurance /Science Activity Centre (QA/SAC)** for Surface Ozone, carbon monoxide and methane at the Swiss Federal Laboratories for Materials Testing and Research (EMPA) in Dübendorf.
- Support to the **Jungfraujoch site** which recently reached to the status of global GAW station

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

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

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