Swiss National Report for the 8th WMO/UNEP Ozone Research Managers Meeting

Geneva, 02-04 may 2011

1 OBSERVATIONAL ACTIVITIES

1.1 Column measurements of ozone

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

1.2 Profile measurements of ozone

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

1.3 UV measurements

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

1.4 Calibration activities

- At Arosa, regular calibrations and maintenances are organised for the Brewer (every 2 years) and for the Dobson instruments (every 4 years) traceable to the world standards.

- Each ECC ozonesonde is calibrated prior to the flight again a reference UV photometer traceable to the national standard from METAS.
- The CHARM instruments are compared to reference instruments traceable to the world standards.

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

The high Alpine site of Jungfraujoch (3580 m asl) is one of a few stations covering the entire measurement programme of the GAW concerning greenhouse gases and reactive gases. The measurements of ozone depleting substances and halogenated greenhouse gases, such as HFCs, CFCs, HCFCs chlorinated solvents, and bromocarbons are performed continuously at Jungfraujoch since the year 2000 in a joint project of Empa and BAFU (HALCLIM). A thorough description of the project (in German) is available at: http://www.empa.ch/plugin/template/empa/*/101463.

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

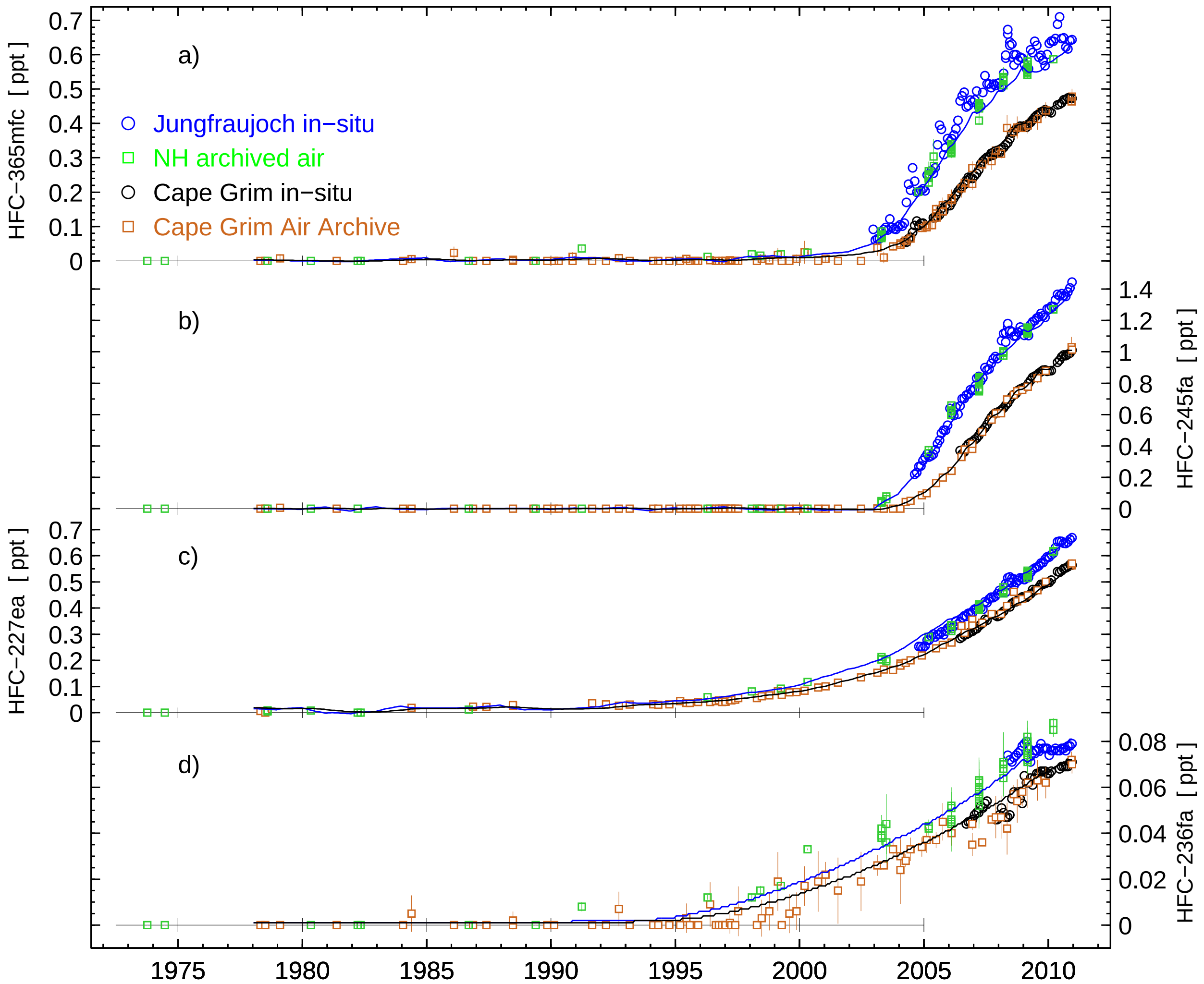

Figure 1: Comprehensive time series of the new hydrofluorocarbons HFCs--365mfc, -245fa, -227ea and -236fa, measured at several global stations within the AGAGE network (incl. Jungfraujoch) (Vollmer et al., 2011). For HFC-245fa and HFC-365mfc the first measurements world-wide have been performed at Jungfraujoch.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

2 RESULTS FROM OBSERVATIONS AND ANALYSIS

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

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

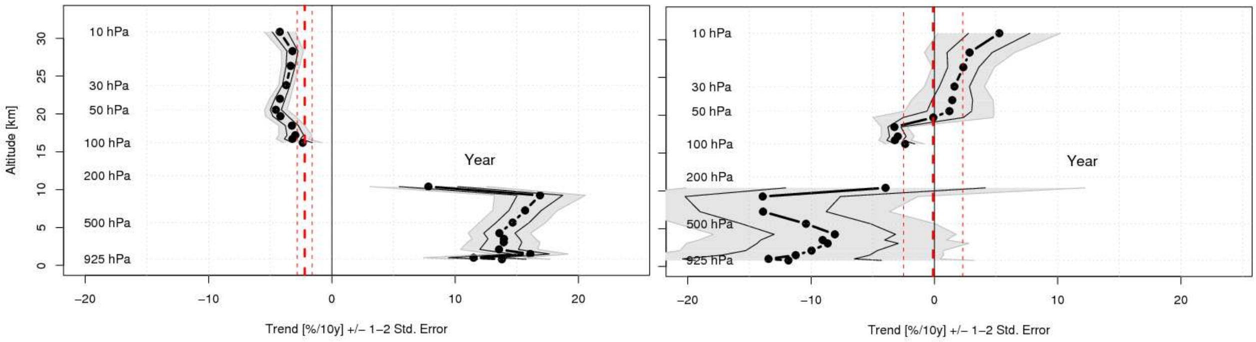

Figure 2: Trend profiles of the Payerne ozone sounding series. Left panel: trends over the periods 1975-1995 on various pressure levels. On the right panel: similar results for the period 1996-2009. The red dashed vertical line corresponds to the trend of the Dobson total ozone series from Arosa.

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

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

Long-term monitoring of the vertical distribution of stratospheric ozone was continued with a 142-GHz microwave radiometer at Bern. Ozone profiles with a time resolution of 2 hours and a vertical resolution of about 10 km were submitted to the Network for the Detection of Atmospheric Composition Change (NDACC). These ozone data were utilized for satellite validation, atmospheric modeling and ozone trend studies by the scientific community. The impact of sudden stratospheric warming on the ozone distribution was analysed.

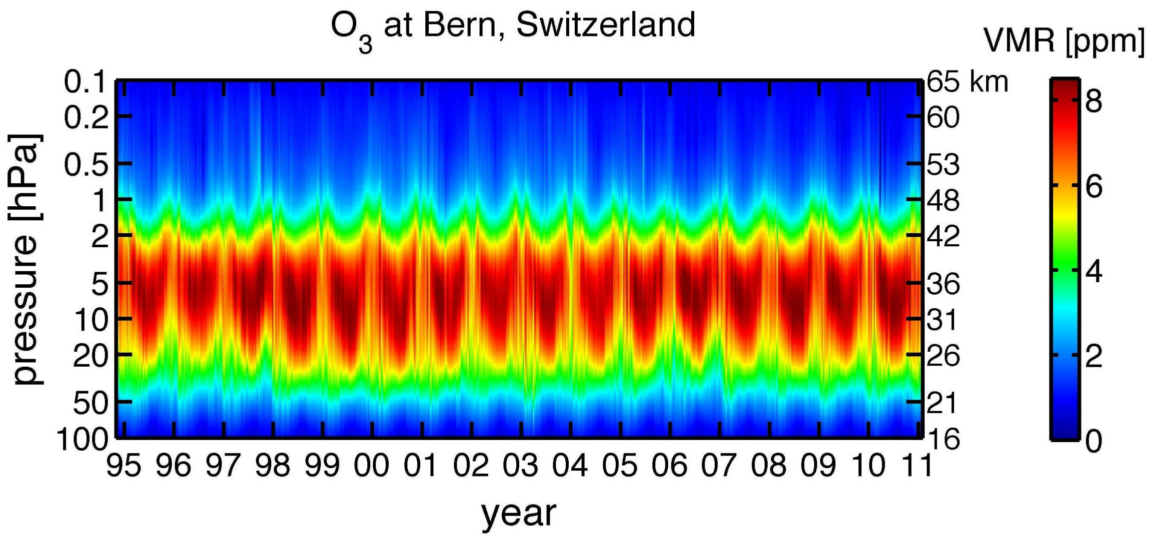

Figure 3: Ozone volume mixing ratio as function of time and pressure level above Bern. Observations were obtained by a 142-GHz microwave radiometer (IAP, Bern). Tick marks are on January 1.

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

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

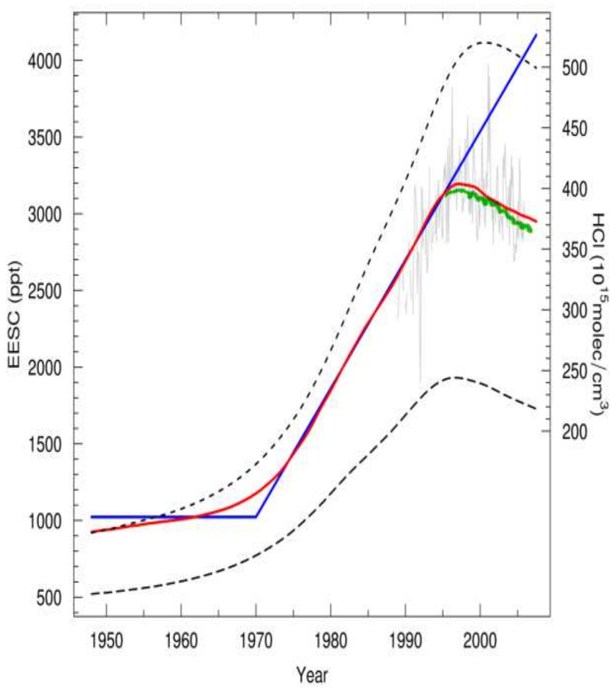

Figure 4: Time series of EESC (in red, Equivalent Effective Stratospheric Chlorine, describing the integral effect of chemical ozone depletion by ozone depleting substances on stratospheric ozone for midlatitude) compared with a linear trend (blue). Grey: Measurements of column HCl measured at Jungfraujoch (Switzerland).

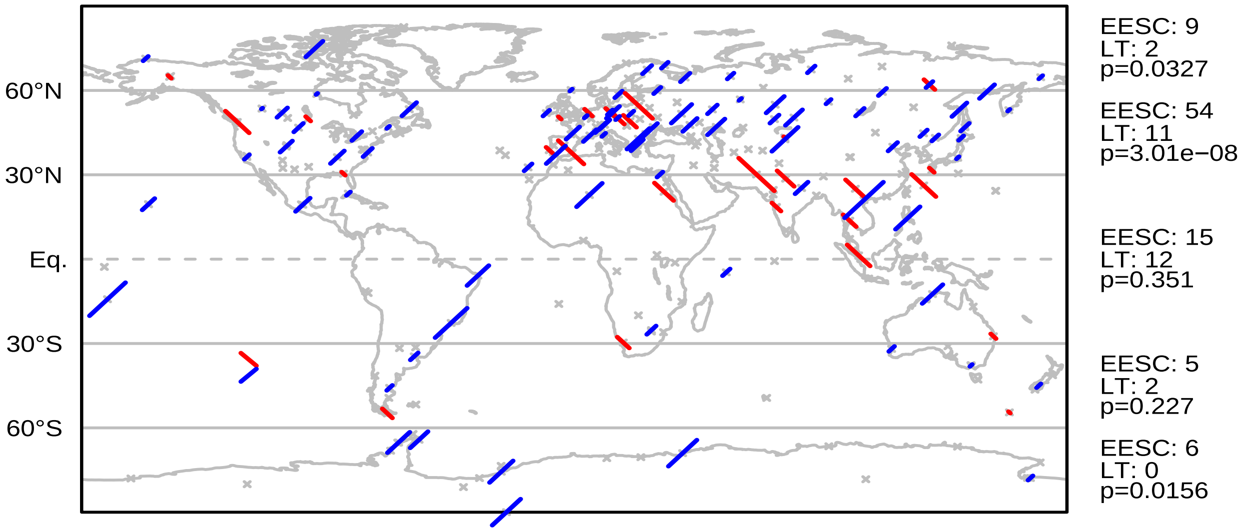

Figure 5: Preference of individual long-term ground based total ozone series for a time evolution following EESC (blue) or a linear (downward) trend (red). On the right side: Results of statistics for individual latitudinal bands (from Mäder et al., 2010).

In northern midlatitude the results are most convincing, whereas in southern midlatitude only few long-term measurements are available probably making the result statistically insignificant. For tropical stations the results are not conclusive probably attributable to the fact that the long-term total ozone trends are much smaller in the tropics than in the extra tropics. The results of Antarctica need to be taken with care since at the South pole ozone chemical ozone depletion is presently saturated by ODS. For more details see Mäder et al., 2010.

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

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

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

3 DISSEMINATION OF RESULTS

3.1 Data reporting

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

3.2 Information to the public

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

3.3 Relevant scientific papers

J. A. Mäder, J. Staehelin, T. Peter, D. Brunner, H. E. Rieder, and W. A. Stahel: Evidence for the effectiveness of the Montreal Protocol to protect the ozone layer, Atmos. Chem. Phys., Atmos. Chem., 10, 12161-12171, (2010).

H. E. Rieder, J. Staehelin, J. A. Maeder, T. Peter, M. Ribatet, A. C. Davison, R. Stübi, P. Weihs, and F. Holawe: Extreme events in total ozone over Arosa – Part 1: Application of extreme value theory, Atmos. Chem. Phys., 10, 10021-10031 (2010).

H. E. Rieder, J. Staehelin, J. A. Maeder, T. Peter, M. Ribatet, A. C. Davison, R. Stübi, P. Weihs, and F. Holawe: Extreme events in total ozone over Arosa – Part 2: Fingerprints of atmospheric dynamics and chemistry and effects on mean values and long-term changes, Atmos. Chem. Phys., 10, 10033-10045 (2010).

H. E. Rieder, L. M. Jancso, S. Di Rocco, J. Staehelin, J. A. Maeder, T. Peter, M. Ribatet, A. C. Davison : Extreme events in total ozone over the Northern mid-latitudes: An analysis based on long-term data sets from five European ground-based stations.

Rigby, M., J. Mühle, B. Miller, R. Prinn, P. Fraser, P. Krummel, P. Steele, N.Derek, R. Weiss, P. Salameh, C. Harth, S. O'Doherty, P. Simmonds, M.K Vollmer, S. Reimann, J. Kim, R. Wang, E. Dlugokencky, and G. Dutton, History of atmospheric SF6 from 1973 to 2008, ACP, 10, 2010.

C. Schnadt Poberaj, J. Staehelin, D. Brunner, V. Thouret, H. De Backer, and R. Stübi: Long-term changes in UT/LS ozone between the late 1970s and the 1990s deduced from the GASP and MOZAIC aircraft programs and from ozonesondes, Atm. Chem. Phys., 9, 5343-5369 (2009).

C. Schnadt Poberaj, J. Staehelin and D. Brunner: Missing stratospheric ozone depletion at Southern Hemisphere middle latitudes after Mt. Pinatubo, subm. to J. Atmos. Sci.(2011), in revision.

Vollmer, M.K., B.R. Miller, M. Rigby, S. Reimann, J. Mühle, P. B. Krummel, S. O'Doherty, J. Kim, T.S. Rhee, R.F. Weiss, P.J. Fraser, P.G. Simmonds, P.K. Salameh, C.M. Harth, R.H.J. Wang, L.P. Steele, D. Young, C.R. Lunder, O. Hermansen, D. Ivy, T. Arnold, N. Schmidbauer, K-R. Kim, B.R. Greally, M. Hill, M. Leist, A. Wenger, R.G. Prinn, Atmospheric histories and global emissions of the anthropogenic hydrofluorocarbons (HFCs) HFC-365mfc, HFC-245fa, HFC-227ea, and HFC-236fa, in press at J. Geophys. Res., 2011.

Xiao, X., R.G. Prinn, P.J. Fraser, P.G. Simmonds, R.F. Weiss, S. O'Doherty, B.R. Miller, P. Salameh, C. Harth, P.B. Krummel, L.W. Porter, J.Mühle, B.R. Greally, D.Cunnold, R.Wang, S.A. Montzka, J.W. Elkins, G.S. Dutton, T.M. Thompson, J.H. Butler, B.D. Hall, S. Reimann, M.K. Vollmer, F. Stordal, C. Lunder, M. Maione, J. Arduini, Y. Yokouchi, Optimal Estimation of the Surface Fluxes of Methyl Chloride using a 3-D Global Chemical Transport Model,. Atmos. Chem. Phys., 10, 5515-5533, 2010.

4 PROJECTS AND COLLABORATION

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

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

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

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