Name of research institute or organization:

Empa, Swiss Federal Laboratories for Materials Science and Technology

Title of project:

National Air Pollution Monitoring Network (NABEL)

Project leader and team:

Dr. Martin Steinbacher, Dr. Christoph Hüglin (project leader)

Project description:

The National Air Pollution Monitoring Network (NABEL) is run by Empa in joint collaboration with the Swiss Federal Office for the Environment (BAFU/FOEN). The NABEL network was established in 1978 with initially 8 sites emerging from activities that started already in 1968 as contributions to international observation networks as part of WMO and OECD. In-situ measurements by Empa at Jungfraujoch started in 1973. Early activities mainly focused on sulphur dioxide and particulate matter. In 1990/1991 the NABEL network was extended to 16 monitoring stations that are distributed all over Switzerland. The monitoring stations represent the most important air pollution levels from kerbside to remote free tropospheric background. The NABEL site at Jungfraujoch is a very low polluted site, representing a background station for the lower free troposphere in central Europe.

The current measurement program at Jungfraujoch includes continuous *in-situ* analyses of ozone (O_3), carbon monoxide (CO), nitrogen monoxide (NO), nitrogen dioxide (NO_2), the sum of nitrogen oxides (NO_y), sulphur dioxide (SO_2), methane (CH_4) and carbon dioxide (CO_2). The concentrations of CH_4 are also measured in 24 min intervals along with nitrous oxide (N_2O) and sulphur hexafluoride (SF_6). Molecular hydrogen (H_2) is semi-continuously monitored in 30-min intervals. An extended set of halocarbons and a selection of volatile organic compounds (VOCs) (alkanes, aromatics) are measured with a time resolution of two hours. Daily samples are taken for determination of particulate sulphur. The concentrations of particulate matter < 10 μm (PM10) are continuously observed as well as measured as 24-hour integrated samples.

The NABEL activities have several objectives such as

- the observation of air pollution levels and comparison with air quality standards,
- the long-term measurement of air pollutants for trend determinations and the control of success of air quality reduction mechanisms,
- the contribution to international programmes like the European Monitoring and Evaluation Programme (EMEP) or the Global Atmosphere Watch Programme (GAW) of the World Meteorological Organisation (WMO),
- the provision of information to the public about present air quality, and
- the role of a research platform and user lab.

Highest quality standards have to be applied to meet these goals leading to very demanding requirements for standards, calibrations, traceability, instruments, as well as data handling and standard operational quality control procedures. Special attention has to be paid to time series homogeneity, in particular when looking at atmospheric composition trends. Thus, thorough evaluations and intercomparisons have to be made especially when implementing novel measurement techniques.

A new generation of instrumentation mainly based on spectroscopic techniques has become available for continuous in-situ observations of various trace gases (e.g. CO_2, CH_4, N_2O, CO) in recent years. These instruments do have the potential to complement or replace current techniques as they often provide high precision measurements at high time resolutions. In December 2009, Empa installed a Cavity Ringdown Spectrometer (CRDS) at Jungfraujoch for the continuous observation of methane (CH_4) and carbon dioxide (CO_2) in addition to the existing CH_4 instrument. Up to now, a unique one-year data set of a side-by-side comparison of CH_4 measurements with CRDS and the state-of-the-art Gas Chromatograph coupled with Flame Ionization Detection (GC-FID)) recorded at Jungfraujoch is now available. Figure 1 illustrates a 4-day time series of the CH_4 mixing ratios measured with both techniques. The CRDS records data in 2sec intervals. The high resolution data and 1min and 10min aggregates are shown along with CH_4 results of the discontinuously operating (single injections of 10ml sample volume every 24min) GC-FID. Both instruments report data on the WMO-2004 scale. The overall agreement is very good, no significant bias exists and the overall variability was well captured by both techniques. In terms of precision, the CRDS performs similarly well as the GC-FID at 1min resolution, but achieves superior precision when aggregating 10min averages (i.e. the smallest aggregate that is usually stored within the NABEL network). Moreover, the high resolution data show a considerable atmospheric short-term variability that predominantly appears during daytime that cannot be captured by the GC due to its discontinuous operation. The observed CH_4 elevations of up to 60ppb compared to the general level are usually of very short nature as the elevated data often do not significantly contribute to elevated higher aggregates. However, these data can provide useful information on the steadiness of the ambient conditions. Future analyses are envisaged to use the high-frequency data for the determination of background, i.e. free tropospheric, conditions.

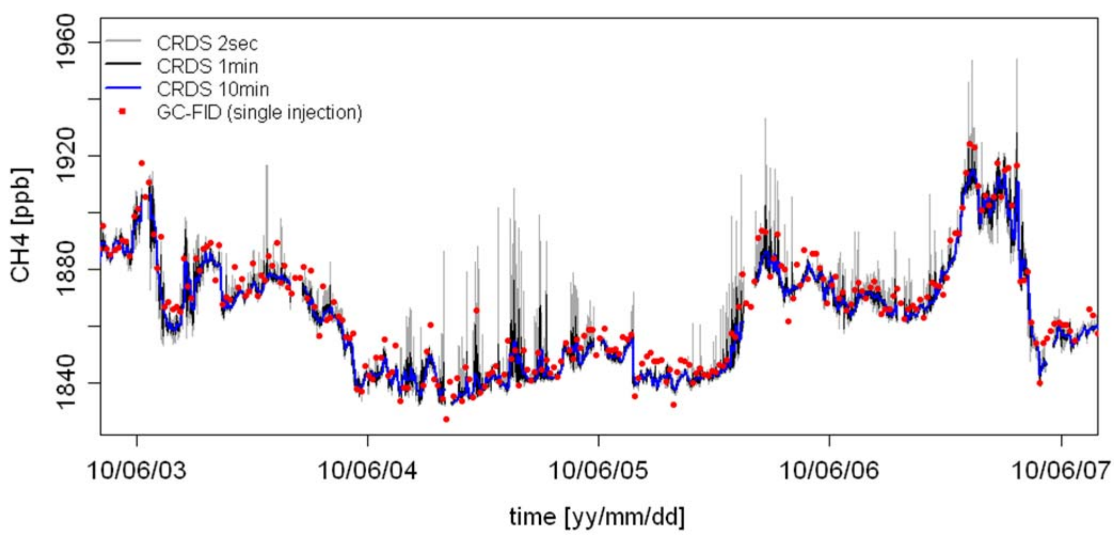

Figure 1: 4-day time series of in-situ CH_4 mixing ratios at Jungfraujoch in June 2010 measured with CRDS and GC-FID. High-resolution data and 1min and 10min aggergates are shown for the CRDS, results of single injections are displayed for the GC-FID.

The excellent agreement of the two techniques can be also seen in Figure 2 that illustrates a scatterplot of hourly averages of the CRDS (i.e. averages of about 1650 readings) and the GC-FID (i.e. mean values of 2 to 3 single injections) for the whole year. When analysing the observed differences (GC-FID – CRDS), only a negligible and insignificant bias (0.3 ± 4.9 ppb) well within the measurement uncertainties was observed.

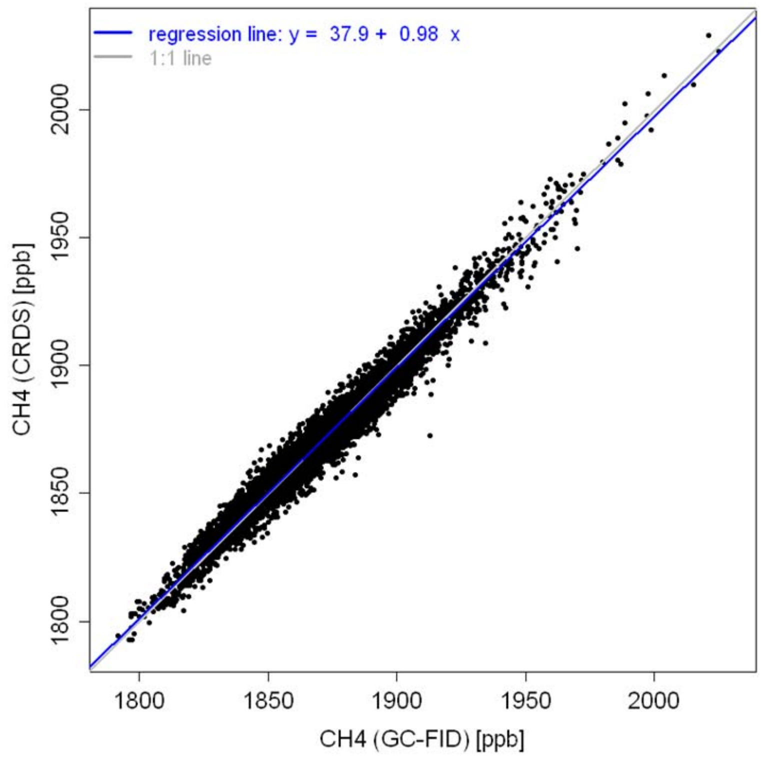

Figure 2: Scatterplot of hourly averages of CH_4 mixing ratios at Jungfraujoch, measured with a Gas Chromatograph – Flame Ionization Detection (GC-FID) and Cavity Ringdown Spectroscopy (CRDS) for 2010. The grey and blue lines illustrate the 1:1 line and the orthogonal regression line, respectively. Number of data: 8152.

The one-year operation of a Cavity Ringdown Spectrometer for the determination of atmospheric CH_4 mixing ratios at Jungfraujoch provides very satisfying results and confirmed the specifications retrieved in the laboratory of highly precise data at high time resolutions. The excellent agreement of the CH_4 data gathered with both techniques will allow monitoring the CH_4 mixing ratios in the future without any inhomogeneity in the overall time series. Thus, the ongoing operation of the spectrometer will enable a more robust trend determination in the future due to its advanced precision. In addition, the instrument might provide useful information on the representativeness of the air masses when making use of the high-frequency data. Nevertheless, the gas chromatograph remains in operation at Jungfraujoch for independent quality control. As gas chromatographs require very little sample volumes, such systems are still well suited for flask analysis and the analysis of reference gases.

Key words:

atmospheric chemistry, air quality, long-term monitoring

Internet data bases:

http://www.empa.ch/nabel
http://www.umwelt-schweiz.ch/buwal/de/fachgebiete/fg_luft/luftbelastung/index.html

Collaborating partners/networks:

Bundesamt für Umwelt (BAFU)/ Federal Office for the Environment (FOEN)
Global Atmosphere Watch (GAW)
Labor für Atmosphärenchemie, Paul Scherrer Institut
MeteoSchweiz
Climate and Environmental Physics, University of Bern

Scientific publications and public outreach 2010:

Refereed journal articles and their internet access

Corazza M., Bergamaschi, P., Vermeulen, A.T., Aalto, T., Haszpra, L., Meinhardt, F., O'Doherty, S., Thompson, R., Moncrieff, J., Popa, E., Steinbacher, M., Jordan, A., Dlugokencky, E.J., Brühl, C., Krol, M., Dentener, F., Inverse modelling of European N_2O emissions: assimilating observations from different networks, Atmospheric Chemistry and Physics Discussions, **10**, 26319-26359, 2010.
http://www.atmos-chem-phys-discuss.net/10/26319/2010/acpd-10-26319-2010.html

Gilge S., Plass-Duelmer, C., Fricke, W., Kaiser, A., Ries, L., Buchmann, B., Steinbacher, M., Ozone, Carbon monoxide and Nitrogen oxides time series at four Alpine GAW mountain stations in Central Europe, Atmospheric Chemistry and Physics, **10**, 12295-12316, 2010.
http://www.atmos-chem-phys.net/10/12295/2010/acp-10-12295-2010.html

Liu, D., Flynn, M., Gysel, M., Targino, A., Crawford, I., Bower, K., Choularton, T., Juranyi, Z., Steinbacher, M., Hueglin, C., Curtius, J., Kampus, M., Petzold, A., Weingartner, E., Baltensperger, U., Coe, H., Single particle characterization of black carbon aerosols at a tropospheric alpine site in Switzerland. Atmospheric Chemistry and Physics, **10**, 7389-7407, 2010.
http://www.atmos-chem-phys.net/10/7389/2010/acp-10-7389-2010.html

Ruckstuhl A.F., Henne, S., Reimann, S., Steinbacher, M., Buchmann, B., Hueglin, C., Robust extraction of baseline signal of atmospheric trace species using local regression, Atmospheric Measurement Techniques Discussions, **3**, 5589-5612, 2010.
http://www.atmos-meas-tech-discuss.net/3/5589/2010/amtd-3-5589-2010.html

Tuzson B., Mohn, J., Emmenegger, L., Henne, S., Brunner, D., Steinbacher, M., Buchmann, B., Continuous isotopic composition measurements of tropospheric CO_2 at Jungfraujoch (3580 m asl), Switzerland: real-time observation of regional pollution events, Atmospheric Chemistry and Physics Discussions, **10**, 24563-24593, 2010.
http://www.atmos-chem-phys-discuss.net/10/24563/2010/acpd-10-24563-2010.html

Yver, C., Pison, I., Fortems-Cheiney, A., Schmidt, M., Bousquet, P., Ramonet, M., Jordan, A., Søvde, A., Engel, A., Fisher, R., Lowry, D., Nisbet, E., Levin, I., Hammer, S., Necki, J., Bartyzel, J., Reimann, S., Vollmer, M.K., Steinbacher, M., Aalto, T., Maione, M., Arduini, I., O'Doherty, S., Grant, A., Sturges, W., Lunder, C.R., Privalov, V., Paramonova, N., A new estimation of the recent tropo-

spheric molecular hydrogen budget using atmospheric observations and variational inversion, Atmos. Chem. Phys. Discuss., **10**, 28963-29005, 2010.
http://www.atmos-chem-phys-discuss.net/10/28963/2010/acpd-10-28963-2010.pdf

Conference papers

Balzani Lööv, J.M., S. Henne, G. Legreid, J. Staehelin, S. Reimann, A.S.H. Prevot, M. Steinbacher, and M.K. Vollmer, Estimation of background concentrations of trace gases at the Swiss Alpine site Jungfraujoch (3580 m asl, Symposium on Atmospheric Chemistry and Physics at Mountain Sites, Interlaken, CH, 8 – 10 June 2010.

Bergamaschi, P., M. Corazza, A. Vermeulen, A. Manning, M. Athanassiadou, P. Bousquet, R. Thompson, M. Heimann, K. Trusilova, E. Popa, L. Haszpra, J. Mocrieff, R. Neubert, E. Nisbet, T. Alto, F. Meinhardt, L. Ries, M. Steinbacher, F. Artuso, and E. Dlugokencky, Inverse modeling of European CH_4 and N_2O emissions, Nitrogen and the European Greenhouse Gas Balance, Solothurn, CH, 3 – 4 February 2010.

Brunner, D., S. Henne, J. Klausen, and B. Buchmann, A Global Lagrangian Model to Study Trace Gas Variability and Long Range Transport, Symposium on Atmospheric Chemistry and Physics at Mountain Sites, Interlaken, CH, 8 – 10 June 2010.

Buchmann, B., Reactive Gases and Greenhouse Gases at the GAW site Jungfraujoch, Earth Observation Programme Board, Jungfraujoch, CH, 28 May 2010.

Buchmann, B., Integrated Carbon Observation System, Status Switzerland, ICOS Stakeholder Meeting, Helsinki, FIN, 31 May – 2 June 2010.

Collaud Coen, M., E. Weingartner, S. Nyeki, M. Steinbacher, and U. Baltensperger, Impact of synoptic weather types on the planetary boundary layer influence at the Jungfraujoch, Symposium on Atmospheric Chemistry and Physics at Mountain Sites, Interlaken, CH, 8 – 10 June 2010.

Emmenegger, L., B. Tuzson, J. Mohn, N. Heeb, D. Brunner, M. Steinbacher, and B. Buchmann, Regional pollution events observed by continuous measurements of $\delta^{13}C\text{-}CO_2$ and $\delta^{18}O\text{-}CO_2$ at Jungfraujoch using quantum cascade laser spectroscopy, Symposium on Atmospheric Chemistry and Physics at Mountain Sites, Interlaken, CH, 8 – 10 June 2010.

Fiore, A., D. Jaffe, E. Fischer, J. Staehelin, S. Pandey, M. Steinbacher, and C. Zellweger, Measured and modelled PAN mixing ratios in the free troposphere, Symposium on Atmospheric Chemistry and Physics at Mountain Sites, Interlaken, CH, 8 – 10 June 2010.

Henne, S., C. Hüglin, D. Brunner, M. Steinbacher, and B. Buchmann, Robust estimation of baseline signal considering latitudinal concentration gradients, Symposium on Atmospheric Chemistry and Physics at Mountain Sites, Interlaken, CH, 8 – 10 June 2010.

Henne, S., D. Brunner, J. Klausen, and B. Buchmann, Inter-Annual Variability of CO and CH_4 Observations Interpreted by a Global Lagrangian Transport Model, European Geophysical Union, Vienna, AUT, 3 – 7 May 2010.

Henne, S., D. Brunner, J. Klausen, and B. Buchmann, Inter-Annual Variability of CO and CH_4 Observations Interpreted by a Global Lagrangian Transport Model, NOAA ESRL Global Monitoring Annual Meeting, Boulder, Colorado, USA, 18 – 19 May 2010.

Hueglin, C., Recent technologies for air pollution monitoring, Workshop and Conference on Current and Future Air Quality Monitoring, Royal Society of Chemistry/AirMonTech, London, GB, 14 – 15 December 2010.

Hueglin, C., Performance of laserspectroscopic technologies for determination of regulated compounds, Workshop and Conference on Current and Future Air Quality Monitoring, Royal Society of Chemistry/AirMonTech, London, GB, 14 – 15 December 2010.

Kaiser, A., H. Scheifinger, M. Steinbacher, S. Gilge, L. Ries, C. Uglietti, and M. Leuenberger, Meteorological interpretation of the high Alpine carbon dioxide and ozone concentrations, Symposium on Atmospheric Chemistry and Physics at Mountain Sites, Interlaken, CH, 8 – 10 June 2010.

Pandey, S., J. Staehelin, D. Brunner, M. Steinbacher, U. Weers, C. Zellweger, E. Weingartner, and M. Collaud Coen, M., NO_y speciation and relationship with PAN in the troposphere from measurements at Jungfraujoch, Symposium on Atmospheric Chemistry and Physics at Mountain Sites, Interlaken, CH, 8 – 10 June 2010.

Pandey, S., S. Henne, J. Staehelin, U. Weers, L. Ries, M. Steinbacher, and T.Peter, PAN transport at Alpine sites from European planetary boundary layer, American Geophysical Union Fall Meeting, San Francisco, USA; 13 – 17 Decmber 2010.

Ruckstuhl, A.F., S. Henne, S. Reimann, M. Steinbacher, B. Buchmann, and C. Hueglin, Estimation of background concentrations of atmospheric trace gases using robust local regression, Symposium on Atmospheric Chemistry and Physics at Mountain Sites, Interlaken, CH, 8 – 10 June 2010.

Scheeren, B., and M. Steinbacher, Comparing in-situ greenhouse gas observations from Jungfraujoch and Ispra: on the role of advection of Po Valley air pollution, Symposium on Atmospheric Chemistry and Physics at Mountain Sites, Interlaken, CH, 8 – 10 June 2010.

Staehelin, J., J. Cui, S. Pandey, M. Sprenger, M. Steinbacher, S. Henne, and M. Collaud Coen, Ozone and ozone precursors at Jungfraujoch (Switzerland): Data analysis and long-term changes, Symposium on Atmospheric Chemistry and Physics at Mountain Sites, Interlaken, CH, 8 – 10 June 2010.

Steinbacher, M., D. Brunner, S. Henne, M. K. Vollmer, and S. Reimann, In-situ Methane Observations at Jungfraujoch: European Source Allocations and Emission estimates, Symposium on Atmospheric Chemistry and Physics at Mountain Sites, Interlaken, CH, 8 – 10 June 2010.

Steinbacher, M., B. Schwarzenbach, B. Buchmann, and C. Hueglin, Continuous in-situ Air Quality Measurements at Jungfraujoch as Part of the Swiss National Air Pollution Monitoring Network (NABEL), Symposium on Atmospheric Chemistry and Physics at Mountain Sites, Interlaken, CH, 8 – 10 June 2010.

Steinbacher, M., Experiences from the Swiss National Air Pollution Monitoring Network, International Workshop on GAW, Jakarta, IDN, 06 – 07 October 2010.

Steinbacher, M., S. Reimann, M. K. Vollmer, M. Hill, and C. Hueglin, VOC Observations Within the Swiss National Air Pollution Monitoring Network, 3rd WMO/GAW expert meeting on global observations of VOCs, Helsinki, FIN, 29 – 30 June 2010.

Steinbacher M., C. Zellweger, and C. Hueglin, Continuous in-situ CH_4 and CO_2 Observations at Jungfraujoch using Cavity Ring Down Spectroscopy, Swiss Global Change Day, Bern, CH, 20 April 2010.

Tuzson, B., J. Mohn, M. Steinbacher, S. Henne, D. Brunner, and L. Emmenegger, Long-term and in situ spectroscopic measurements of $\delta^{13}C$ and $\delta^{18}O$ of CO_2 at Jungfraujoch (3580 masl) reveal regional pollution events. ISI 2010, The Fifth International Symposium on Isotopomers. Amsterdam, NED, 21 – 25 June 2010.

Theses

Bond, S. W. Sources and Sinks of Hydrogen in the Atmosphere during Transition to Hydrogen-based Transportation. PhD Thesis, ETH Zurich, 2010.

Data books and reports

BAFU, NABEL Luftbelastung 2009. Umwelt Zustand Nr. 1016, pp. 142. Bundesamt für Umwelt, Bern, 2010.

Empa and BAFU, Technischer Bericht 2010 zum Nationalen Beobachtungsnetz für Luftfremdstoffe (NABEL), pp. 206, Dübendorf, 2010. Available online: http://www.empa.ch/plugin/template/empa/*/99311

Magazine and Newspapers articles

"Nuages de cendres", 24 heures, April 20, 2010.

"Asche hat die Jungfrau erreicht", Berner Zeitung, April 20, 2010.

"Vulcano: aumentano le polveri fini", Corriere del Ticino, April 20, 2010.

"Hausse des particules fines liées au volcan en Suisse", tsrinfo.ch, rsr.ch, April 20, 2010.

"La situazione", Le Regione Ticino, April 21, 2010.

"Aschewolke laut WHO unbedenklich", Walliser Bote, April 21, 2010.

"Bisher keine gesundheitlichen Folgen des Vulkanausbruchs", Tagesanzeiger, April 21, 2010.

"Empa bestimmt erstmals Vulkanaschekonzentrationen auf dem Jungfraujoch", Chemie.de NEWS-Center, http://www.chemie.de/news/d/116681, April 22, 2010.

"Empa bestimmt erstmals Vulkanaschekonznetrationen auf dem Jungfraujoch", analytica-world, http://www. analytica-world.com/news/d/116681, April 22, 2010.

"Vulcano: le ceneri sono in Svizzera", ticinonews.ch, April 23, 2010.

"Vulkanasche ist im Schweizer Flachland gelandet", Basler Zeitung, April 23, 2010.

"Vulkanaschekonzentrationen auf dem Jungfraujoch", Der PVB – Ihre Zeitung, May 06, 2010.

"Lähmendes Halbwissen", Nachrichten aus der Chemie, #58, July – August 2010, 2010.

"Unabhängige Überwachung der Emissionen", NZZ am Sonntag, December 06, 2010.

"Unschätzbare Informationen durch langfristige Messungen", SCNAT info, 2/2010, 2010.

"Gebirgsobservationen liefern weitreichende Resultate aus grosser Höhe / Les observatoires de montagne fournissent des données de haut vol", Geosciences ACTUEL, 03/2010, pp. 23 – 26, 2010.

Address:

Empa
Laboratory for Air Pollution/Environmental Technology
Ueberlandstrasse 129
CH-8600 Dübendorf

Contacts:

Martin Steinbacher
Tel.: +41 44 823 4654
Fax: +41 44 821 6244
e-mail: martin.steinbacher@empa.ch
URL: http://www.empa.ch/nabel