Name of research institute or organization:

Empa, Swiss Federal Laboratories for Materials Science and Technology

Title of project:

National Air Pollution Monitoring Network (NABEL)

Part of this programme:

EMEP, GAW, ICOS, ACTRIS

Project leader and team:

Dr. Martin Steinbacher, Simon A. Wyss, Dr. Lukas Emmenegger
Dr. Christoph Hüglin (project leader)

Project description:

The National Air Pollution Monitoring Network (NABEL) is run by Empa jointly 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 WMO and OECD observation networks. In-situ measurements by Empa at Jungfraujoch began 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 throughout Switzerland. The locations of these monitoring stations are representative for the most important air pollution levels ranging from the urban 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), carbon dioxide (CO_2) and nitrous oxide (N_2O). These data are stored as 10-min averages. Molecular hydrogen (H_2) is semi-continuously monitored in 30-min intervals. An extended set of halocarbons, sulphur hexafluoride (SF_6) and a selection of volatile organic compounds (VOCs) (alkanes, aromatics) are measured with a time resolution of two hours. The concentrations of particulate matter < 10 μm (PM10) are determined both continuously and in 24-hour integrated samples. Continuous measurements of PM2.5 (particulate matter < 2.5 μm), PM1 (particulate matter < 1 μm) and the particle number concentration between 0.18 and 18μm started in November 2016. Daily samples are taken to quantify particulate sulphur.

Increased attention was paid to the investigation of greenhouse gases in recent years, in particular since the launch of the preparatory phase of the pan-European ICOS (Integrated Carbon Observation System) research infrastructure in 2008 and of the Integrated non-CO_2 Greenhouse Gas Observing System (InGOS) in October 2011. While InGOS terminated as scheduled in late 2015, ICOS steadily progressed, entered to the strategic ESFRI (European Strategy Forum on Research Infrastructures) Roadmap in 2008, was granted with European Research Infrastructure Consortium (ERIC) status by the European Commission in November 2015, and gained ESFRI Landmark status in March 2016. The latter two steps were reached in recognition of the achievements within ICOS and of the important role ICOS will play in particular with respect to Paris Agreement commitments and related future greenhouse gas emission reductions.

ICOS is a research infrastructure for quantifying and understanding the greenhouse gas balance of Europe and its neighboring regions. It provides long-term observations measuring greenhouse gas fluxes from ecosystems and the oceans, and greenhouse gas concentrations in the atmosphere required to understand the present state and to predict future behavior of the

global carbon cycle and greenhouse gas emissions. Taking advantage of maximum synergies, central facilities were established for sensor evaluation, development of processing algorithms, to support and harmonize the observations, for quality control and data analysis as well as to gather all data in a central database and to ease data dissemination. Switzerland is one of the 9 ICOS founding member and observer countries and contributes one ecosystem station, Davos, and one atmospheric station, Jungfraujoch, to the pan-European infrastructure. Partners of the ICOS-Switzerland consortium are ETH Zurich, the Swiss Federal Institute for Forest, Snow and Landscape Research WSL, the University of Bern, Empa, MeteoSwiss and the University of Basel. At Jungfraujoch, Empa is in charge of ICOS-compliant continuous in-situ greenhouse gas observations.

Network-wide reference gases are prepared, referenced to international scales and provided by the ICOS Central Analytical Laboratory in Jena, Germany. Greenhouse gas raw data with 3-second temporal resolution from Jungfraujoch are automatically sent once daily to the Atmospheric Thematic Centre (ATC) in Gif-sur-Yvette, France. There, all ICOS data are automatically processed in a standardized manner (see Hazan et al., 2016), diagnostic plots are routinely generated and operators of ICOS stations can access their data on the ATC server for visual inspection, manual flagging and for final approval (see Figure 1). The automatic processing also includes calibration and water vapor corrections and calculates 1-min and hourly aggregates.

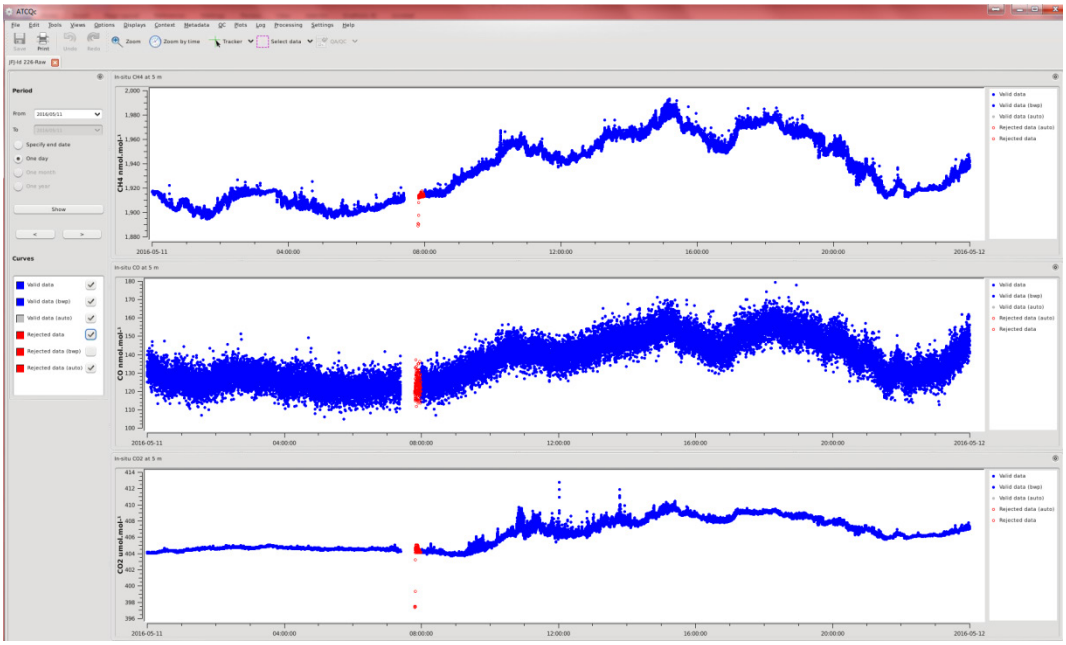

Figure 1. Screenshot of the quality control front-end at ATC (ATCQc). High-resolution (3-second) CO, CH_4 and CO_2 data are shown for May 11, 2016. A reference gas was measured between 7AM and 8AM. These data are automatically removed from the in-situ data set and are kept separately for quality assurance and quality control. First data after the reference gas measurement are flagged automatically (see red data) to account for signal stabilization after switching the sample source.

Final data are forwarded to the ICOS Carbon Portal for easy dissemination, usage tracking and elaborated data analysis. See Figure 2 for a schematic of the ICOS data flow.

ICOS implemented a stringent two-step evaluation process to assess the suitability of the station for the network as well as the instrumentation, performance and operation to ensure best possible quality and standardization throughout the infrastructure. Jungfraujoch was among the first three stations that passed step 1 in April 2016; the second step of the evaluation is currently in process. Assignment of the ICOS label is expected in spring 2017.

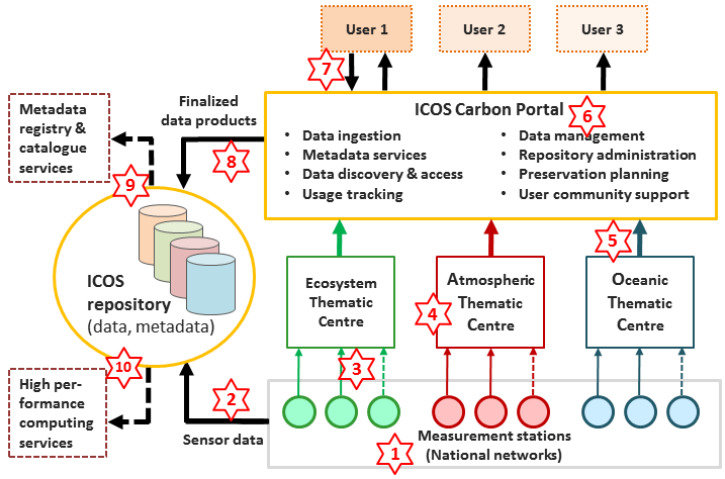

Figure 2. Schematic of the data flow within ICOS, Figure is courtesy of ICOS Carbon Portal, https://www.icos-cp.eu/.

Figure 3 shows the time series of carbon dioxide, methane, nitrous oxide, and carbon monoxide at Jungfraujoch since summer 2013 when ICOS-CH – the Swiss contribution to this European effort – was launched after it was included in the Swiss Infrastructure Roadmap and entered in the Federal Council Dispatch on Education, Research and Innovation (ERI).

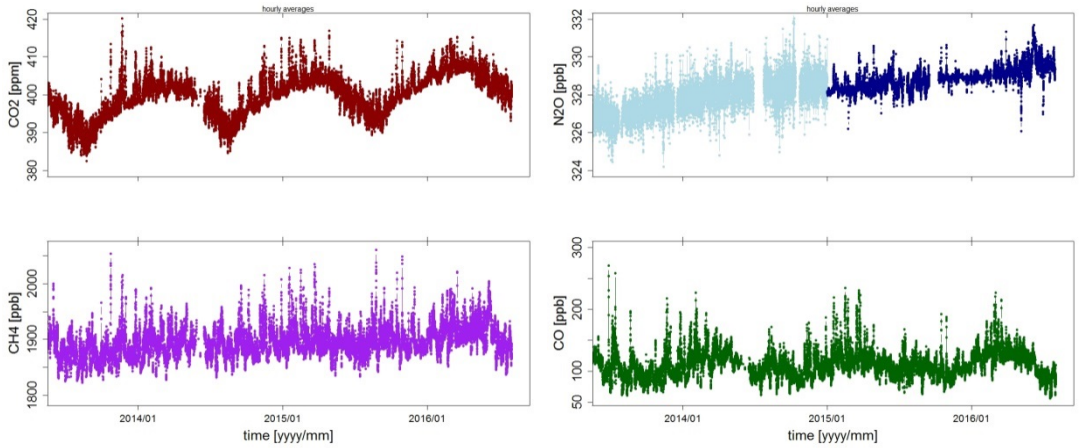

Figure 3. Time series of hourly averages of carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4), and carbon monoxide (CO) mole fractions at Jungfraujoch from July 2013 to August 2016. Different colors in the N_2O panel refer to different instruments.

Within this period, a Quantum Cascade Laser (QCL) infra-red spectrometer measuring nitrous oxide was purchased which replaced the gas chromatograph as master instrument in January 2015. An optimized calibration strategy and associated quality assurance/quality control procedures were designed which resulted in robust and reproducible results in addition to the superior precision of the spectrometer compared to previous state-of-the-art gas chromatography (GC) technique. For quality control purpose and to ensure a smooth transition and homogeneity of the full time series, the GC ran in parallel to the QCL for 18 months. The new instrumentation now also allows detecting short-term events such as stratospheric intrusions which could not be identified by the N_2O signal before (see May 2016). The CO_2 and CO time series show the characteristic seasonal patterns which are mostly driven by biospheric CO_2 uptake and CO removal through reaction with the hydroxyl

radical in summer. The CH_4 mole fractions continue to rise as it is the case for approximately the last 10 years following a period of stable CH_4 levels during the first half of the last decade.

Further consolidation and elaboration of the ICOS related activities are foreseen under the European Commission Horizon 2020 project RINGO (Readiness of ICOS for Necessities of integrated Global Observations). A prolongation of funding of the ICOS-CH activities is currently under negotiation with ICOS-CH being also on the Swiss Roadmap for Research Infrastructures in view of the ERI Dispatch 2017-2020.

References

Hazan, L., J. Tarniewicz, M. Ramonet, O. Laurent, A. Abbaris, Automatic processing of atmospheric CO_2 and CH_4 mole fractions at the ICOS Atmosphere Thematic Centre, Atmospheric Measurement Techniques, 9, 4719–4736, 2016.

Key words:

Atmospheric chemistry, air quality, trace gases, long-term monitoring

Internet data bases:

http://empa.ch/web/s503/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)
Belgian Institute for Space Aeronomy, Brussels
Institut d'Astrophysique et de Géophysique, Université de Liège
Labor für Atmosphärenchemie, Paul Scherrer Institut
MeteoSchweiz
Climate and Environmental Physics, University of Bern
GAW – Global Atmosphere Watch
EMEP – European Monitoring and Evaluation Programme
ICOS – Integrated Carbon Obervation System
InGOS – Integrated non-CO_2 Greenhouse gas Observation System
ACTRIS – Aerosol, Clouds, and Trace Gases Research Network

Scientific publications and public outreach 2016:

Refereed journal articles and their internet access

Boose, Y., Z.A. Kanji, M. Kohn, B. Sierau, A. Zipori, I. Crawford, G. Lloyd, N. Bukowiecki, E. Herrmann, P. Kupiszewski, M. Steinbacher, U. Lohmann, Ice Nucleating Particle Measurements at 241 K during Winter Months at 3580 m MSL in the Swiss Alps, Journal of Atmospheric Sciences, **73**, 5, 2203-2228, doi: 10.1175/jas-d-15-0236.1, 2016. http://dx.doi.org/10.1175/JAS-D-15-0236.1

Bukowiecki, N., E. Weingartner, M. Collaud Coen, P. Zieger, E. Herrmann, M. Gysel, M. Steinbacher, H.W. Gäggeler, U. Baltensperger, The essence from more than 20 years of aerosol observation at the high altitude research station Jungfraujoch, Switzerland (3580 m asl) – a review, Aerosol and Air Quality Research, **16**, 764-788, doi: 10.4209/aaqr.2015.05.0305, 2016. http://dx.doi.org/10.4209/aaqr.2015.05.0305

Chambers, S.D., A.G. Williams, F. Conen, A.D. Griffiths, S. Reimann, M. Steinbacher, P.B. Krummel, L.P. Steele, M.V. van der Schoot, I.E. Galbally, S.B. Molloy, J.E. Barnes, Towards a universal "baseline" characterisation of air masses for high- and low-altitude observing stations using Radon-222, Aerosol and Air Quality Research, **16**, 3, 885-899, doi: 10.4209/aaqr.2015.06.0391, 2016.
http://aaqr.org/VOL16_No3_March2016/33_AAQR-15-06-SIMtS-0391_885-899.pdf

Henne, S., D. Brunner, B. Oney, M. Leuenberger, W. Eugster, I. Bamberger, F. Meinhardt, M. Steinbacher, L. Emmenegger, Validation of the Swiss methane emission inventory by atmospheric observations and inverse modelling, Atmospheric Chemistry and Physics, **16**, 3683-3710, doi:10.5194/acp-16-3683-2016, 2016. http://www.atmos-chem-phys.net/16/3683/2016/

Hoyle, C.R., C.S. Webster, H.E. Rieder, E. Hammer, M. Gysel, N. Bukowiecki, E. Weingartner, M. Steinbacher, U. Baltensperger, Chemical and physical influences on aerosol activation in liquid clouds: a study based on observations from the Jungfraujoch, Switzerland, Atmospheric Chemistry and Physics, **16**, 4043-4061, doi:10.5194/acp-16-4043-2016, 2016. http://dx.doi.org/10.5194/acp-16-4043-2016

Stopelli, E., F. Conen, C.E. Morris, E. Herrmann, S. Henne, M. Steinbacher, C. Alewell, Predicting abundance and variability of ice nucleating particles in precipitation at the high-altitude observatory Jungfraujoch, Atmospheric Chemistry and Physics, **16**, 8341-8351, doi: 10.5194/acp-16-8341-2016, 2016. http://dx.doi.org/10.5194/acp-16-8341-2016

Book sections

Buchmann B., C. Hueglin, S. Reimann, M.K. Vollmer, M. Steinbacher, and L. Emmenegger, Reactive gases, ozone depleting substances and greenhouse gases, in Willemse, S., and M. Furger (eds.), *From weather observations to atmospheric and climate sciences in Switzerland*, vdf Hochschulverlag AG, 361-374, 2016.

Conference papers

Berhanu, T., E. Satar, S. Szidat, D. Brunner, M. Steinbacher, M. Leuenberger, Quantification of fossil fuel associated CO_2 emissions based on radiocarbon measurements at the Beromünster tall tower, Switzerland, ICOS Science Conference, Helsinki, Finland, September 27-29, 2016.

Burri, S., M. Steinbacher, L. Merbold, L. Hörtnagl, N. Buchmann and the ICOS-CH Consortium, ICOS-CH: The Swiss Contribution to a Pan-European Environmental Research Infrastructure, ICOS Science Conference, Helsinki, Finland, September 27-29, 2016.

Henne, S., B. Oney, M. Leuenberger, W. Eugster, F. Meinhardt, M. Steinbacher, I. Bamberger, L. Emmenegger, D. Brunner, Constraining Swiss Methane Emissions from a Dense Network of Atmospheric Observations, ICOS Science Conference, Helsinki, Finland, September 27-29, 2016.

Leuenberger, M.C., M.F. Schibig, S. Henne, B. Lejeune, E. Mahieu, Intercomparison of in-situ NDIR and column FTIR measurements of CO_2 at Jungfraujoch, ICOS Science Conference, Helsinki, Finland, September 27-29, 2016.

Poltera, Y., G. Martucci, M. Hervo, A. Haefele, L. Emmenegger, D. Brunner, S. Henne, M. Haeffelin, Automatic remote sensing detection of the convective boundary layer structure over flat and complex terrain using the novel PathfinderTURB algorithm, ICOS Science Conference, Helsinki, Finland, September 27-29, 2016.

Steinbacher, M., Updates from RI Committee, Atmospheric Monitoring Station Assembly, Atmospheric Thematic Centre & Central Analytical Laboratories, ICOS-CH National Meeting, Dübendorf, Switzerland, September 1, 2016.

Steinbacher, M., Atmospheric observations in support of IG3IS in Switzerland (and abroad), Planning of IG3IS National Consultations, WMO Headquarters, Geneva, Switzerland, December 5-7, 2016.

Steinbacher, M., B. Schwarzenbach, M. Hundt, B. Tuzson, L. Emmenegger, New direct NO_2 measurement technologies, GAW Expert meeting on Nitrogen Oxides, York, United Kingdom, April 12-13, 2016.

Steinbacher, M., S.A. Wyss, E. Harris, C. Zellweger, J. Mohn, L. Emmenegger, Continuous Nitrous Oxide Observations with Mid-Infrared Laser Spectroscopy at Jungfraujoch, Switzerland, ICOS Science Conference, Helsinki, Finland, September 27-29, 2016.

Steinbacher, M., S.A. Wyss, B. Tuzson, F. Conen, G. Martucci, T.A. Berhanu, M. Leuenberger, L. Emmenegger, The Swiss Contribution to Atmospheric Observations in ICOS RI The Class 1 Candidate Station Jungfraujoch, ICOS Atmospheric Monitoring Station Assembly, Helsinki, Finland, September 26-27, 2016.

Data books and reports

BAFU, NABEL – Luftbelastung 2015, Messresultate des Nationalen Beobachtungsnetzes für Luftfremdstoffe (NABEL), Bundesamt für Umwelt, Bern, Umwelt-Zustand Nr. 1624, pp. 132, 2016. http://www.bafu.admin.ch/publikationen/publikation/01869/index.html?lang=de

Address:

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

Contacts:

Dr. Martin Steinbacher
Tel.: +41 58 765 4048
Fax: +41 58 765 1122
e-mail: martin.steinbacher@empa.ch
URL: http://empa.ch/web/s503/nabel