Trace gas observations at Jungfraujoch as part of European Research Infrastructures

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1. Project description

Atmospheric in-situ trace gas observations at Jungfraujoch have a long tradition and are nowadays an integral part of the National Air Pollution Monitoring Network (NABEL) which is run by Empa jointly with the Swiss Federal Office for the Environment (FOEN). The NABEL network was established in 1978 with 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 monitoring stations represent the most important air pollution levels ranging from the urban kerbside to the 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. An extended set of halocarbons (e.g. CFCs, HFCs), sulphur hexafluoride (SF_6) and a selection of volatile organic compounds (VOCs) (alkanes, aromatics) are measured with a time resolution of two hours. Daily samples are taken to quantify particulate sulphur. 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 (PNC) between 0.18 and 18µm are available since November 2016.

These measurements have a long history, produce high-quality time series, and are internationally well renowned. Recently, the observations also became part of two European initiatives, the Integrated Carbon Observation System (ICOS) Research Infrastructure and the European Research Infrastructure for the observation of Aerosol, Clouds, and Trace gases (ACTRIS), which were both established under the European Strategy Forum on Research Infrastructures (ESFRI) umbrella. ESFRI, launched by the European Commission, facilitates the development of research infrastructures in Europe.

ICOS is a research infrastructure for quantifying and understanding the greenhouse gas balance of Europe and its neighbouring regions. It provides long-term observations measuring greenhouse gas fluxes from ecosystems and the oceans, and greenhouse gas concentrations in the atmosphere. Those data are key to understand the present state and to predict future behaviour of the global carbon cycle and greenhouse gas emissions. ICOS became operational in November 2015 with the formal establishment of the Integrated Carbon Observation System European Research Infrastructure Consortium (ICOS ERIC). ICOS was also recognized as European Landmark Infrastructure in 2016 in recognition of being a clear reference pillar of scientific excellence and of competitiveness within the European Research Area. ICOS ERIC consists of 12 European member and observer countries with currently 135 registered stations distributed in national networks of atmospheric, ecosystem, and marine sites. Switzerland contributes one ecosystem station, Davos, and one atmospheric station, Jungfraujoch, to ICOS. Partners of the ICOS-Switzerland consortium are ETH Zurich, WSL, the University of Bern, Empa, MeteoSwiss and the University of Basel. ICOS stations take advantage of considerable 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. At Jungfraujoch, Empa is in charge of ICOS-compliant continuous in-situ greenhouse gas observations, namely CO_2, CH_4, N_2O, CO and the isotopes of ^{13}C and ^{18}O of CO_2. All ICOS stations have to undergo a rigorous assessment prior to receiving the official ICOS label. Key requirements are a sound setup of the observations, the adequate use and operation of suitable equipment and a robust data management. The labelling process started in December 2014 and was successfully completed in May 2018 (see Fig. 1) when Jungfraujoch was awarded the status of an ICOS class 1 station (see Fig. 2). Class 1 stations are committed to the most ambitious set of parameters.

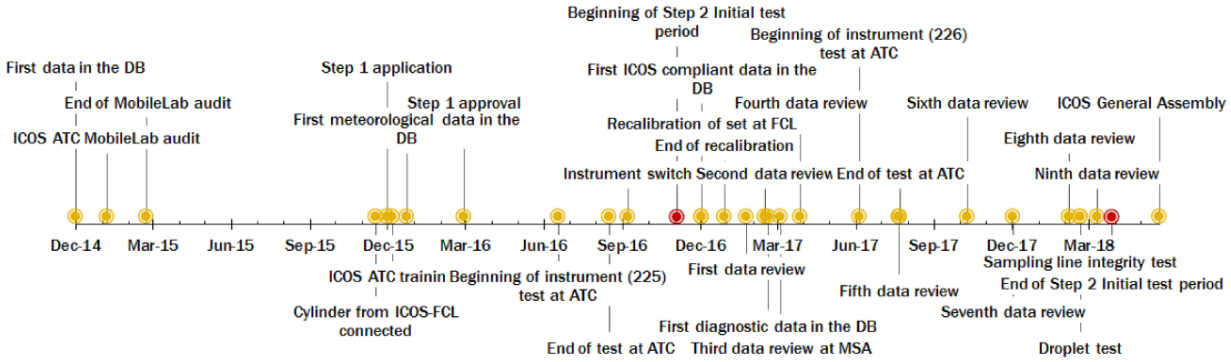

Figure 1. Timeline of the ICOS labelling process for Jungfraujoch. Major actions are highlighted as yellow dots. The assessment is a two-stage process; start and end of the second stage are highlighted in red. Figure taken from the internal labelling report.

Figure 2. Approval of Jungfraujoch being ICOS compliant.

Prior to and during the three-year evaluation period, new equipment was purchased and implemented, reference gases were retrieved from the ICOS Central Calibration Laboratory, sampling and calibration strategies were adapted and auxiliary parameters were newly recorded. These activities ensure that all measurements are in compliance with the ICOS Atmospheric Station Specification Document (Laurent, 2017).

Raw data of CO_2, CH_4, N_2O and CO are sent daily to the Atmospheric Thematic Centre (ATC) in Gif-sur-Yvette (France) where data from all atmospheric stations are automatically processed (Hazan et al., 2016), followed by a visual inspection by the instrument operators on the ATC server. In addition, twice a year all data are jointly reviewed by the Atmospheric Monitoring Station Assembly before the processed data are then forwarded to the Carbon Portal in Lund (Sweden). The Carbon Portal is the gateway to all observational data, derived services and products from ICOS. Releases of level 2 (i.e. final, quality-controlled) data for atmospheric stations are planned twice a year. Most recently, ICOS data from 11 labelled atmospheric stations were released in August 2018 providing hourly averaged mole fractions of CO_2, CH_4 and CO, meteorological observations, and two weekly integrated samples of $^{14}CO_2$ (Colomb et al., 2018). Updates of near real-time data, i.e. only automatically quality checked data, are accessible daily in the ICOS Carbon Portal; illustrations on the last calibrations and the long-term evolution of the instruments' responses based on repeated calibration tank analysis (see Fig. 3) can be found on a public webpage hosted by ATC (https://icos-atc.lsce.ipsl.fr/JFJ).

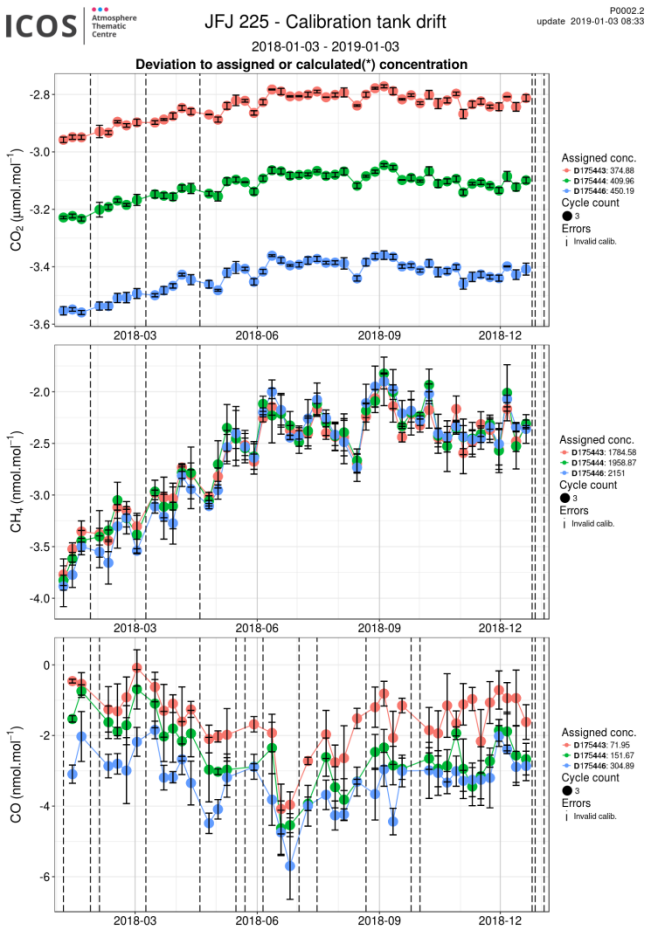

Figure 3. Evolution of the sensitivity of the instrument at Jungfraujoch measuring CO_2 (top), CH_4 (middle) and CO (bottom) according to calibration tank analyses over one year. Correction functions are determined based on the deviations to the assigned values and are accordingly applied to the ambient air data.

Pre-ICOS methane and nitrous oxide data from a number of European stations (including Jungfraujoch) were recently reprocessed and harmonized within the InGOS (Integrated non-CO_2 Greenhouse gas Observation System) project (Bergamaschi et al., 2018). Earlier CO_2 data are currently re-evaluated within the RINGO (Readiness of ICOS for Integrated Global Observations) project. To do so, common procedures for uncertainty estimates are developed for earlier years of CO_2 observations when calibration strategies were still less standardized as they are now. The revised InGOS dataset is available on the ICOS Carbon Portal, which will also include the final RINGO dataset. The release of newly quality-controlled historic greenhouse gas data will augment the value of the recent ICOS data through its extension into the past.

ACTRIS is dedicated to secure and improve long-term coordinated aerosol, cloud and trace gas observations. ACTRIS did not reach ERIC status yet but was recently adopted on the ESFRI roadmap for Research Infrastructures. ACTRIS is still in the preparatory phase followed by a construction and commissioning phase. Full operation is planned in 2025. Partners of the ACRTIS-Switzerland consortium are PSI, Empa, MeteoSwiss, ETH Zurich, PMOD, and the University of Bern. Swiss ACTRIS sites will be Jungfraujoch, Payerne, and Beromünster. Empa is in charge of the continuous observations of volatile organic compounds (VOCs) and nitrogen oxides at all three sites. Furthermore, Empa will be part of the ACTRIS Centre for Reactive Trace Gases In Situ Measurements (CiGas) and takes care of the quality assurance of VOCs measured within the research infrastructure.

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Collaborating partners / networks

Bundesamt für Umwelt (BAFU) / Federal Office for the Environment (FOEN)
Belgian Institute for Space Aeronomy, Brussels
Climate and Environmental Physics, University of Bern
Environmental Geosciences, University of Basel
Institut d'Astrophysique et de Géophysique, Université de Liège
Institute for Atmospheric and Climate Science, ETH Zurich
Laboratory for Atmospheric Chemistry, Paul Scherrer Institut
MeteoSchweiz
World Meteorological Organisation (WMO)
ACTRIS – Aerosol, Clouds, and Trace Gases Research Network
EMEP – European Monitoring and Evaluation Programme
GAW – Global Atmosphere Watch
ICOS – Integrated Carbon Obervation System Research Infrastructure
IG3IS – Integrated Global Greenhouse Gas Information System
NABEL – Swiss National Air Pollution Monitoring Network
RINGO – Readiness of ICOS for Necessities of Integrated Global Observations

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