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ANNUAL ACTIVITY REPORT 2019 OF QA/SAC SWITZERLAND

The Global Atmosphere Watch (GAW) programme, coordinated by the World Meteorological Organization (WMO), is a truly international endeavour driven by the need to understand and control the increasing influence of human activity on the global atmosphere. Several hundreds of registered stations contribute to the GAW programme. GAW data from all over the globe need to be consistent, traceable to common reference scales, of known and adequate quality, and require appropriate documentation. Meeting these quality objectives is essential to properly address the spatial and temporal variability of atmospheric composition in order to allow for retrieving robust averages, detecting regional gradients and long-term trends, and for verification of models and satellite retrievals.

An elaborate quality management framework was developed to achieve these goals. In support of the programme, Central Facilities responsible for quality control, scientific guidance and data hosting and dissemination of the global network were implemented. Among others, four Quality Assurance/Science Activity Centres (QA/SACs) exist to perform network-wide data quality and science-related functions. The Quality Assurance/Science Activity Centre Switzerland (QA/SAC-CH) was established at Empa in collaboration with MeteoSwiss in 2000. Being closely linked to the World Calibration Centre also hosted by Empa (WCC-Empa), QA/SAC-CH mainly focuses on surface ozone, carbon monoxide, methane and carbon dioxide measurements but is also broader in scope and provides technical and scientific support in general.

For 2019, QA/SAC-CH's program proposed activities in four main areas:

- Science Activities including QA/QC (Quality Assurance / Quality Control)
- Training, Twinning, and Capacity Building
- Contribution to GAW Outreach
- Cross-cutting Activities

A detailed account on progress in each of these activities is given below.

Science Activities including QA/QC

Evaluation of new measurement techniques

In 2019, a new laser spectrometer for fast and continuous observations of nitrogen dioxide (NO_2) was acquired. The instrument was thoroughly tested in the laboratory and several modifications were implemented by the manufacturer on our request. Currently, its suitability for field application is evaluated at the Swiss National Air Pollution Monitoring Site in Dübendorf. Once the tests can be concluded satisfactorily, the analyser will be moved to the GAW site Jungfraujoch

where it is supposed to run side-by-side to the current NO_2 chemiluminescence analyser. It is planned to dismantle the current analyser after several months of parallel observations.

A comprehensive analysis summarizing the improvements in measurement performance for atmospheric carbon monoxide (CO) and nitrous oxide (N_2O) observations over the last 15 years was published in *Atmospheric Measurement Techniques* (Zellweger et al., 2019). This publication was led by WCC-Empa in collaboration with scientists from Germany, France and South Korea.

Tropospheric Ozone Assessment Report

The mission of the TOAR activity ("Tropospheric Ozone Assessment Report: Global metrics for climate change, human health and crop/ecosystem research") is to provide an up-to-date scientific assessment of tropospheric ozone's global distribution and trends from the surface to the tropopause. Martin Steinbacher is part of the team of scientific experts. The assessment is published as a special feature in *Elementa*. During the first TOAR phase (2014-2019), 8 peer-reviewed publications were released. Martin Steinbacher co-authored three of them. Among those, there was the 72-pages review paper published in 2019 providing a critical assessment of measurement uncertainties of early and present ozone observations (Tarasick et al., 2019).

Scientific interpretation of GAW data

The continuous growth in atmospheric N_2O concentrations at Jungfraujoch was studied by Yu et al. (2019). Time series of continuous N_2O concentrations and N_2O isotopes derived from discrete samples taken at Jungfraujoch followed by off-line analysis were analysed to better constrain the atmospheric sources and sinks of N_2O. The study indicates that the atmospheric N_2O increase is due to isotopically light N_2O sources (like e.g. fertilizer use) and that the seasonal variation of N_2O isotopic composition in the background atmosphere is important when determining interannual trends.

A joint analysis of surface ozone records from 27 globally distributed remote locations (including Jungfraujoch) was led by Owen Cooper to reassess the multi-decadal ozone trends since the beginning of the continuous high-quality observations in the 1980s and 1990s. Despite the length of the available time series and the subsequent likelihood to detect robust trends due to the changes in ozone precursors, it was shown that the 27 remote locations cannot provide a global mean surface ozone trend, however, they are useful for examining regional trends and for evaluating chemistry-climate models. The publication was submitted to *Elementa* in fall (Cooper et al., 2019). Reviews were received in November. Currently, replies to the reviewers are prepared and resubmission is foreseen in January 2020.

An analysis of persistent (multi-months) episodes of elevated near-surface ozone concentrations in Northern Italy was performed by an Italian-Swiss author team (Cristofanelli et al., 2019). It mainly compares surface ozone time series from the Italian site Mt. Cimone (CMN) and Jungfraujoch. Jungfraujoch is considered a reference for the background conditions of continental Europe; good agreement is found for the most of the time with the record from CMN but long-lasting episodes with significantly higher values at CMN were observed between 2004 and 2008. The publication could show that the appearance of the ozone anomaly at CMN was coherent with variability in atmospheric transport and photochemical ozone production over regions strongly influencing the ozone levels at CMN. The publication was submitted to *Elementa* in June. Reviews were received in October. Currently, replies to the reviewers are prepared and resubmission is foreseen in January 2020.

Availability of GAW data and metadata

The transfer of the GAW repository for reactive gases from the World Data Centre for Greenhouse Gases (WDCGG) to the newly established World Data Centre for Reactive Gases (WDCRG), the redesign of the WDCGG structure, and the increasing number of other data and metadata repositories led to an increasingly complex situation in terms of data submission, data availability and data retrieval. Discussions were held particularly with WDCRG representatives, the chair of the GAW Scientific Advisory Group (SAG) for Greenhouse Gases and the data manager of the TOAR database. During 2019, the situation in terms of data availability of surface ozone data at WDCRG improved, and metadata compiled as part of the TOAR project are supposed to be made available as a web service soon. However, the situation at WDCGG remains an issue in terms of response time when accessing WDCGG data via the internet and in terms of nomenclature used.

Analysis of observations in data sparse regions

The analysis of available data from data sparse regions like stations equipped during the CATCOS (Capacity Building and Twinning for Climate Observing Systems) project focused in 2019 on data from the Pha Din station in Northern Vietnam. The article, jointly written by colleagues from the Paul Scherrer Institute in Switzerland, QA/SAC-CH and colleagues from Vietnam and published in *Aerosol and Air Quality Research*, investigated the effects of large-scale biomass burning in Southeast Asia on the aerosol and trace gas observations in Vietnam (Bukowiecki et al., 2019).

WMO/IAEA Meeting on CO2, Other Greenhouse Gases, and Related Measurement Techniques

Martin Steinbacher attended the 20th WMO/IAEA Meeting on Carbon Dioxide, Other Greenhouse Gases, and Related Measurement Techniques (GGMT-2019) in Jeju Island (South Korea). He was member of the GGMT Advisory Committee and gave an oral presentation entitled "Training, twinning, and capacity building in support of greenhouse gas observations in data sparse regions". The presentation advocated more coordinated international efforts to improve the effect of capacity building activities in developing countries. Several discussions were held during the conference and an intensified collaboration with Japanese colleagues was established.

Training, Twinning, and Capacity Building

Requests for support

QA/SAC-CH responds to various requests from GAW stations for support regarding measurements and data management. In 2019, support was given in particular to the Indonesian Agency for Meteorology, Climatology and Geophysics (BMKG) and the Kenya Meteorological Department (KMD) during and after the station visits (jointly with WCC-Empa) in January (Indonesia) and December (Kenya), respectively.

At the Indonesian global GAW station Bukit Koto Tabang (BKT), the setup of the new greenhouse gas analyser was checked and optimized. Moreover, calibration gases and a calibration unit for automatic quality control of the greenhouse gas analyser was provided and installed during the audit. Staff was taught in sound operation of the equipment. Since then, continuous high-quality CO_2, CH_4 and CO data are recorded with very good data coverage. Surface ozone data were revisited, screened and submitted to the World Data Centre for Reactive Gases. BMKG's Citeko Meteorological Stasion-Bogor was supported with teaching material for lectures for BMKG employees from air quality stations. The Japanese National Institute for Environmental Studies

(NIES) recently started greenhouse gas and air quality observations at three station in the Jakarta-Bogor area in collaboration with BMKG and other Indonesian partners. In November, NIES organized a dedicated training for Indonesian staff in Tsukuba, Japan. Martin Steinbacher contributed to the course by giving a remote lecture on "Quality Control of Trace Gas Observations".

At the global GAW station Mount Kenya, a new greenhouse gas analyser including a new calibration unit was implemented by WCC-Empa and QA/SAC-CH. Checklists were prepared for regular maintenance and training was provided on-site. The first weeks of operation show very satisfactory results.

Limited ongoing support was given to the stations implemented during the CATCOS (Capacity Building and Twinning for Climate Observing Systems) project. The measurements at Pha Din (Vietnam), El Tololo (Chile), and Cholpon Ata (Kyrgyz Republic) are still ongoing. Several issues required remote advice for trouble shooting, provision of spare parts, support in data processing and submission to the international data repositories. Costs for spare parts like an instrument fan for the greenhouse gas analyser and a new pump for the ozone instrument in El Tololo were covered through a trust fund agreement with the WMO-GCOS (Global Climate Observing System) office in Geneva.

In response to other requests for support, assistance was e.g. provided to (a) the Servicio Meteorológico Nacional in Argentina (review of ozone data prior to submission to the GAW data centre), (b) the Egyptian Meteorological Authority (programmatic advice for measurement programme and adequate instrumentation at a planned site on the Sinai peninsula), (c) the Universidad Mayor de San Andrés in La Paz, Bolivia (provision of a sulphur dioxide analyser and a dedicated calibration unit for the GAW station Chacaltaya), (d) the Surveillance de la Qualité de l'Air de la Région Auvergne-Rhône-Alpes and the Plateau Rosa station (advice for inlet design and adequate inlet material), and (e) the Paul Scherrer Institute, Switzerland (calibration of a Cavity Ringdown Laser Spectrometer for greenhouse gas observations during the MOSAiC (Multidisciplinary drifting Observatory for the Study of Arctic Climate) expedition in the Arctic).

Slides were prepared and provided to WMO for a training on air quality measurements as part of a CCAC (Climate and Clean Air Coalition) training in Africa.

Provision of backward trajectories for GAW stations

The operational calculation of atmospheric trajectories (every four hours) for a large set of GAW monitoring stations along with the provision of freely available and easily accessible trajectory images on the internet (see http://lagrange.empa.ch/FLEXTRA_browser/) is ongoing and provides a valuable input for many station operators for data evaluation and interpretation.

Contribution to GAW Outreach

Report of the GGMT-2019 conference

Martin Steinbacher (QA/SAC-CH), Andrew Crotwell (National Oceanic and Atmospheric Administration) and Haeyoung Lee (Korea Meteorological Administration) were assigned as editors of the report of the GGMT-2019 conference. Drafting of the report – being considered as the key reference for technical information on greenhouse gas measurements within the GAW programme – was initiated during the GGMT conference in September. Chapter leads were

assigned and input is gathered in late 2019 / early 2020. The final report is expected to be published as a GAW report in late 2020.

GAW/GCOS Rolling Review of Requirements

QA/SAC-CH supported the WMO GAW/GCOS Task Team on Atmospheric Composition Observational Requirements by reviewing the atmospheric composition observational requirements parameters as part of the Rolling Review of Requirements activities.

Cross-cutting activities

Active role in ICOS

The Integrated Carbon Observation System (ICOS) Research Infrastructure aims at harmonizing high precision long-term observations of greenhouse gas concentrations in the atmosphere and their fluxes from ecosystems and the oceans. Being a contributing network to GAW, close links do exist between ICOS and the GAW network but the development of the infrastructure, such as the definition of standard operation procedures, needs to be proactively shaped to ensure consistency with the GAW guidelines. After several years of serving as deputy chair, Martin Steinbacher was elected as chair of the atmospheric ICOS Monitoring Assembly in November 2019 for two years. Through this mandate, he is also member of the ICOS Research Infrastructure Committee which is consulted by the ICOS Director General for scientific matters.

ICOS atmosphere level 2 final quality data were released via the ICOS Carbon Portal (https://www.icos-cp.eu/) in August 2019 after a joint review by the Monitoring Assembly in May (ICOS RI, 2019). This collection contains the quality controlled hourly averaged data for the mole fractions of CO_2, CH_4, CO and meteorological observations measured at the relevant vertical levels of the measurements stations, and where available ^{14}C in CO_2 in two-weekly integrated samples, for the period September 2015-April 2019.

Participation in RINGO project

Martin Steinbacher attended the annual meeting of the H2020 RINGO (Readiness of ICOS for Necessities of Integrated Global Observations) project in Southampton (UK) in March 2019. RINGO aims at cutting-edge science beyond the current ICOS activities and its transition into operationally run monitoring networks. RINGO also strives for the development of improved flask sampling strategies, advanced analysis of CO_2 isotope time series and the re-evaluation of historic CO_2 data. For the latter, 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.

Activities in support of the IG^{3}IS initiative

Martin Steinbacher participated in the Integrated Global Greenhouse Gas Information System (IG^{3}IS) workshop in Paris in October where user requirements and procedures for engagement in future IG3IS projects were discussed. He also contributed to the ongoing activity of preparing a proposal for an IG^{3}IS project in Morocco jointly with WMO, Moroccan and British colleagues. The proposal will be submitted to the Green Climate Fund for approval. The IG3IS Science Implementation Plan, also drafted with contributions from QA/SAC-CH and approved by the WMO Executive Council, was published as a WMO/GAW report (report #245).

Collaboration with the Advanced Global Atmospheric Gases Experiment (AGAGE)

Traditionally, the AGAGE network focusses on the continuous observation of halogenated greenhouse gases in the atmosphere, measured with mass spectrometry. In recent years, AGAGE started to also implement laser-based optical analysers for CH_4 and CO_2 observations. Martin Steinbacher attended the AGAGE meeting in Switzerland in April and shared his experience of continuous laser spectrometer operation within GAW and ICOS. His oral presentation was entitled "The use of cavity-enhanced laser spectrometers in the European Integrated Carbon Observation System (ICOS) Research Infrastructure".

Virtual Alpine Observatory (VAO)

In 2012, the "Virtual Alpine Observatory" (VAO) has been established as a network of European High Altitude Research Stations based in the Alps and similar mountain ranges, and now includes ten countries (Austria, Bulgaria, Czech Republic, France, Germany, Georgia, Italy, Norway, Slovenia and Switzerland). Regular VAO meetings and symposia replaced the previously organized GAW DACH (Germany, Austria, and Switzerland) gatherings. The next VAO Symposium which will take place in February 2020 in Bern. Martin Steinbacher is member of the scientific committee. Limited activity was required in 2019 as the abstract submission deadline, and thus the review of the abstracts and the programme compilation, was only due in January 2020.

Contribution to GCOS Switzerland

Martin Steinbacher is member of the Scientific Programme Committee of the Swiss GCOS/GAW Symposium on Earth System Cycles which will take place in September 2020. A first Committee meeting took place in November 2019. Programmatic input was given and a list of potential speakers was prepared.

Contribution to GEO/GEOSS and GEO GNOME

The Group on Earth Observations (GEO) and GEO's ambitions to build a Global Earth Observation System of Systems (GEOSS) are important players in the international environmental arena. Coordination of GEO activities and GAW activities is crucial to avoid duplications and inconsistencies. Thus, a thorough monitoring of GEO operations is desirable. Martin Steinbacher was invited by the Swiss Federal Office for the Environment to participate in the „Nationales Koordinationstreffen GEO/GEOSS" in March 2019 to discuss with the new director of the GEO secretariat Gilberto Camara who also joined the meeting. Moreover, he participated in the workshop 'Essential Climate Variables for Observations in Mountains' organized by the Mountain Research Initiative in Bern under the umbrella of GEO's Global Network for Observations and Information in Mountain Environments (GEO GNOME). One of the key objectives was the identification of the dominant physical processes relevant for mountain climate change and of the relevant Essential Climate Variables required to monitor and understand such processes.

Acknowledgements

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Peer-reviewed publications

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Contributions to scientific conferences, workshops and meetings

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Pieber S.M., B. Tuzson, D. Brunner, S. Henne, A. Jordan, H. Moossen, M. Rothe, M. Steinbacher, L. Emmenegger, A decade of continuous high altitude atmospheric CO2 isotope ratio (δ13C, δ18O) measurements at Jungfraujoch, CH, European Geoscience Union General Assembly, Vienna, Austria, 7 – 12 April 2019. (pico talk)

Pieber S.M., D. Brunner, S. Henne, A. Jordan, H. Moossen, M. Rothe, M. Steinbacher, B. Tuzson, L. Emmenegger, A decade of continuous and discrete trace gas and stable isotope ratio measurements at Jungfraujoch: method comparison. RINGO Annual Scientific Meeting, Southampton, UK, 20 – 22 March 2019. (talk)

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Steinbacher, M., The use of cavity-enhanced laser spectrometers in the European Integrated Carbon Observation System (ICOS) Research Infrastructure, AGAGE Meeting, Weggis, Switzerland, 29 April 2019. (talk)

Steinbacher, M., Update on the Integrated Carbon Observation System (ICOS), HFJSG Users Meeting, Bern, Switzerland, 24 May 2019. (talk)

Steinbacher, M., C. Zellweger, L. Emmenegger, B. Buchmann, WMO/GAW Quality Assurance / Science Activity Centre Switzerland (QA/SAC – CH), Landesausschuss-Sitzung GAW-CH, MeteoSchweiz, Zürich, 06 November 2019. (talk)

Steinbacher, M., C. Zellweger, L. Emmenegger, B. Buchmann, Training, twinning, and capacity building in support of greenhouse gas observations in data sparse regions, GGMT-2019, Seogwipo, Jeju-do, South Korea, 01 – 05 September 2019. (talk)

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Steinbacher, M, Updates on ICOS RI, ICOS CH National Meeting, Birmensdorf, Switzerland, 12 September 2019. (talk)

Steinbacher, M., Quality Control of Trace Gas Observations, NIES technical training course on greenhouse gases and air pollutants monitoring in Indonesia, Tsukuba, Japan, 24 – 30 November 2019. (talk)

Workflow 2019

1st quarter 2019

- system and performance audit and training at the GAW station Bukit Kototabang, Indonesia
- attendance of the RINGO annual meeting, Southampton, UK
- provision of a SO_2 analyser for the Chacaltaya station, Bolivia

2nd quarter 2019

- attendance of the AGAGE meeting, Weggis, Switzerland
- participation in the GEO GNOME workshop, Bern, Switzerland
- publication on large-scale biomass burning in Southeast Asia and its effects on air quality

3rd quarter 2019

- attendance of GGMT-2019, Jeju Island, South Korea

4th quarter 2019

- attendance of the IG^{3}IS workshop in Paris
- organisation of the ICOS Atmospheric Monitoring Station Assembly, Bologna, Italy
- system and performance audit and training at the GAW station Mount Kenya, Kenya
- preparation of the Swiss GAW/GCOS-symposium (as member of the scientific committee)

continuous activity

- support of GAW stations
- cooperation with other projects such as ICOS, RINGO, IG3IS, VAO, ACTRIS, AGAGE

Dübendorf, January 2020 Laboratory Air Pollution / Environmental Technology

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