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ANNUAL ACTIVITY REPORT 2020 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 2020, 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 and operation of new measurement techniques

In July 2020, a new laser spectrometer for nitrogen dioxide (NO_2) was installed at the GAW station Jungfraujoch next to the traditional state-of-the-art instrumentation, i.e. detection with chemiluminescence after photolytic conversion of NO_2 to NO. The first months of operation of the novel type of NO_2 analyser confirm the precedent laboratory tests, which showed good sensitivity and precision. In addition, the longer-term test at Jungfraujoch also revealed a very good reliability combined with a low required maintenance, which makes the spectrometer a suitable instrument for remote locations. Several calibration strategies are still under evaluation

due to stability and gas handling issues when using low concentration NO_2 references in high pressure cylinders. The results will be shared with the GAW community, e.g. through integration into the upcoming nitrogen oxides measurement guidelines.

In August 2020, a new nitrous oxide (N_2O) analyser, based on cavity ringdown spectroscopy (CRDS), was also installed at Jungfraujoch. CRDS is a well-established technique for carbon dioxide (CO_2), methane (CH_4) and carbon monoxide (CO) observations, but is available for N_2O monitoring only for a short time. The optical properties of N_2O require performing CRDS in the mid-infrared spectral range, which increases the complexity of the instrument. Nevertheless, the first few months of operation yield satisfactory results showing highly accurate measurements with an instrument of stable sensitivity and very good robustness.

Scientific interpretation of GAW data

QA/SAC-CH was involved a couple of investigations dealing with data from Jungfraujoch and other GAW stations. In most cases, studies were conducted by highly international author teams.

QA/SAC-CH contributed to the analysis of trends and changes in trends of surface and free tropospheric ozone in remote locations, investigated by two teams and published in the peer-reviewed literature in 2020. Parrish et al. (2020) focused on remote locations in the Northern Hemisphere and found a consistent pattern throughout the selected stations with ozone maxima in the mid-2000s and a slow decrease since then. Cooper et al. (2020) analysed 27 globally distributed remote locations on both hemispheres. There, statistical analysis resulted in nearly evenly split positive and negative trends for the Northern Hemisphere and predominantly positive trends for the Southern Hemisphere since 1995. The differences in the retrieved patterns can be explained by the selections of different stations, different treatments (filtering) of the data, and different fitting approaches.

In addition, a detailed analysis of persistent (multi-months) episodes of elevated near-surface ozone concentrations in Northern Italy was published by Cristofanelli et al. (2020). The ozone record from Jungfraujoch was used as reference data for identification and interpretation of the persistent episodes. We could conclude that the observed anomalies were most likely caused by a variability of both regional and long-range atmospheric transport and specific European near-surface O_3 patterns.

A global analysis of climate-relevant aerosol properties retrieved from the network of Global Atmosphere Watch (GAW) near-surface observatories was published by Laj et al. (2020). The paper presents data from 89 stations of the in-situ aerosol GAW network. It aims at giving an overview of the state of the operation in the network for a reference year and at providing the relevant information to define a fully traceable ground-based aerosol measurements network.

In the summer of 2018, a widespread drought developed over Northern and Central Europe, which influenced the CO_2 exchange between the atmosphere and terrestrial ecosystems in various ways. A publication documented the fingerprint of the summer 2018 drought in Europe on ground-based atmospheric CO_2 measurements (Ramonet et al., 2020).

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 by Yu et al. (2020). 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.

Following up on the activities within the scope of the CATCOS (Capacity Building and Twining for Climate Observing Systems) project, a manuscript is currently under review at "Atmospheric

Chemistry and Physics" (Ngyuen et al., 2020). As a result of an joint effort of scientists from Germany, Vietnam, Russia, Taiwan and Switzerland (including QA/SAC-CH), the publication analyses the impact of large-scale biomass burning on the aerosol composition and trace gases concentrations at Pha Din (Vietnam).

In addition, QA/SAC-CH contributed to several other publications, which are currently in the review process. They deal with the development of the Integrated Carbon Observation System (ICOS) (Heiskanen et al., submitted to Bulletin of the American Meteorological Society), the evaluation and optimization of ICOS atmosphere station data as part of the labeling process (Yver-Kwok et al., submitted to Atmospheric Measurement Techniques), the assessment of potential local contamination at Jungfraujoch, based on simultaneous Jungfraujoch and Jungfrau-East Ridge observations (Affolter et al., submitted to Environmental Research Letters), and the assimilation of satellite-based column-averaged CO_2 mole fractions and its validation using in-situ observations (Kong et al., submitted to Atmospheric Environment).

ICOS Science Conference

Martin Steinbacher participated in the virtual 4th ICOS Science Conference in September. He gave a talk entitled "The importance of training for long-term operation of atmospheric greenhouse gas observations" in the session "Educational tools & methods". Throughout the session, there was a common understanding that virtual events and online resources need to be pursued, especially in times like the current pandemic when travel restrictions do not allow to meet in person.

Consultation of QA-Central Facilities

The quality management framework of the Global Atmosphere Watch is currently reorganised as part of the extensive reform of the World Meteorological Organisation. It is planned to harmonise quality assurance (QA) and quality control (QC) processes across the six GAW focal areas. To do so, a new expert team (the Expert Team on Atmospheric Composition Measurement Quality (ET-ACMQ)) is about to be established. As a first step, a Joint GAW Web Meeting of the ET-ACMQ and the QA-Central Facilities took place from September 24 to 29, 2020. QA/SAC-CH actively participated in the virtual meeting and presented an overview of the existing Quality Assurance / Science Activity Centres.

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. Priority is given to QA/SAC-CH's twinning partner, especially to the Indonesian Agency for Meteorology, Climatology and Geophysics (BMKG) and the Kenya Meteorological Department (KMD).

In preparation of future improvements of the observational climate and air quality network in Indonesia, BMKG has initiated a focus group discussion inviting several international experts to discuss and receive inputs on the above mentioned topics. A virtual conference with more than 100 participants was held on November 12, 2020. Martin Steinbacher was invited to participate as one of the international experts and gave a presentation on "Long-term observations of atmospheric trace gases: challenges, implementation and operation". Following the event, a recommendation letter for the attention of BMKG was written by the experts.

After the joint visit of the global GAW station Mount Kenya in December 2019 by experts from Empa, MeteoSwiss and the Paul Scherrer Institute, operation and maintenance of the observations by KMD staff were closely followed and supported, resulting in data coverages of the trace gas measurements of more than 75%. Ozone data were (re-)processed based on the latest findings during the station visit and submitted to the World Data Centre for Reactive Gases.

Ongoing support was given to the stations implemented during the CATCOS (Capacity Building and Twinning for Climate Observing Systems) project. The sites are Pha Din (Vietnam), El Tololo (Chile), and Cholpon Ata (Kyrgyz Republic). Several issues required remote advice for trouble shooting, provision of spare parts and consumables, support in data processing and submission to the international data repositories. Costs for consumables (inlet filters for ozone analyser at Cholpon Ata) were covered by QA/SAC-CH; larger expenses, like pumps and a drying unit for Pha Din could be charged on the GCOS trust fund, based on a trust fund agreement with the WMO-GCOS (Global Climate Observing System) office in Geneva. However, support through the trust fund will end in February 2021. Kyrgyzhydromet and QA/SAC-CH jointly prepared the application for the inclusion of Cholpon Ata station in the Global Atmosphere Watch (GAW) Programme, which is currently under evaluation.

In response to other requests for support, assistance was e.g. provided to (a) MetMalaysia (advice for new instrumentation), (b) the Meteorologische Dienst Suriname (ozone instrument malfunctions) (c) the Servicio Meteorológico Nacional in Argentina (review of ozone data prior to submission to the GAW data centre), (d) BMKG (support in data submission to the international data repositories), (e) the Egyptian Meteorological Authority (support in calibration and quality control strategies, advice for networks upgrades), (f) Universidad Mayor de San Andrés in La Paz, Bolivia (inlet design for an urban background station in La Paz), (g) Ricerca sul Sistema Energetico in Italy (recommendations for inlet flushing pumps for high-altitude stations).

First GAWTEC webinar

Both GAWTEC sessions foreseen to be held at Zugspitze in 2020 were cancelled due to the Covid-19 pandemic. Instead, the GAWTEC organizers and the GAW secretariat initiated a webinar series, hosted by the Young Earth System Scientists community. Martin Steinbacher was invited to give the opening lecture of the first webinar series about "Greenhouse Gases and Atmospheric Composition Measurements". He talk was entitled "The Importance of Quality Assurance and Quality Control for long-term in-situ atmospheric composition observations". The presentation was attended by more than 175 people from 35 countries.

Update of GAW webpage at Empa

The QA/SAC-CH webpage at Empa was updated and additional material (such as posters, slide desks, and the annual activity reports) was added for public access.

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) along with Andrew Crotwell (National Oceanic and Atmospheric Administration) and Haeyoung Lee (Korea Meteorological Administration) were assigned as editors of the report of the 20th WMO/IAEA Meeting on Carbon Dioxide, Other Greenhouse Gases, and Related Measurement Techniques (GGMT-2019), which was held in September 2019 on Jeju Island (South Korea). The report was finalized in 2020 and published as a GAW report (Crotwell et al., 2020).

GAW Measurement Guidelines

Zoe Loh (Commonwealth Scientific and Industrial Research Organisation, CSIRO), Andrew Crotwell (NOAA), Olivier Laurent (Laboratoire des sciences du climat et de l'environnement, LSCE), and Martin Steinbacher (QA/SAC-CH) and Olivier Laurent (Laboratoire des sciences du climat et de l'environnement , LSCE) were assigned as lead authors of the measurement guidelines for CO_2 observations. Progress was slower than anticipated but it is expected to re-gain momentum in 2021 prior to the tentatively scheduled next GGMT conference and a Scientific Advisory Group Greenhouse Gases meeting.

Two videoconferences were held in 2020 among the lead authors of the measurement guidelines for nitrogen oxides measurements to advance the report. The draft version was extensively revised and will be circulated to a wider audience once it is close to be finalized.

Cross-cutting activities

Interaction with the Swiss National Air Pollution Monitoring Network

Traditionally, there is a close collaboration between QA/SAC-CH and the Swiss National Air Pollution Monitoring Network (NABEL), which is run by Empa in a joint effort with the Swiss Federal Office for the Environment. NABEL stations are used as testbeds and provide reference data for the evaluation and assessment of novel instrumentation for long-term monitoring. Like in previous years, QA/SAC-CH oversaw the submission of the data global and regional GAW stations of the NABEL network (Jungfraujoch, Rigi, Payerne, and Beromünster) to the World Data Centres for Reactive Gases and Greenhouse Gases.

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. Martin Steinbacher serves as chair of the atmospheric ICOS Monitoring Station Assembly (MSA) since November 2019. Through this mandate, he is also member of the ICOS Research Infrastructure Committee which is consulted by the ICOS Director General for scientific matters. The MSA chair usually compiles the program of the regular MSA meetings and chairs the event. In 2020, the spring MSA meeting was held virtually due to the pandemic. No MSA meeting was organised in fall because of the ICOS Science Conference in September. Martin Steinbacher promoted ICOS as one of the authors of the report "Geosciences in Switzerland: Roadmap for Geosciences Research Infrastructures 2025–2028", which was prepared by an interdisciplinary group. The report was prepared in support of the Swiss Academy of Sciences,

which had been mandated by the State Secretariat for Education, Research and Innovation. The report will serve as a basis for the preparation of the Swiss Roadmap for Research Infrastructures 2025-2028.

Participation in RINGO project

The Horizon 2020 project RINGO (Readiness of ICOS for Necessities of Integrated Global Observations) ended by the end of 2020. The most relevant achievement in view of GAW was the reprocessing and harmonization of historic CO_2 time series, the compilation of past practices of quality assurance and quality control strategies, and the determination of a consistent approach to quantify the associated measurement uncertainties. A harmonized reprocessed dataset was made publicly available on the ICOS CarbonPortal as part of the "Drought 2018" initiative data collection. Attendance of the RINGO annual meeting was cancelled due to the pandemic.

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

Only little activity is reported with respect to the Integrated Global Greenhouse Gas Information System (IG^{3}IS) initiative. The initiative currently focusses largely on transport modelling studies and less on the long-term observations of greenhouse gas variability and trends. An IG^{3}IS steering community was assigned with Empa representation through an expert in modelling, Stephan Henne. In spring, several teleconferences were held among the IG^{3}IS office in Geneva, experts from the UK and Switzerland (including QA/SAC-CH), and colleagues from Morocco to advance a proposal for the implementation of integrated atmospheric composition services in Morocco for the attention of the Green Climate Fund. Finalisation of the proposal was lastly stalled due to organisational and administrative issues in Morocco.

Virtual Alpine Observatory (VAO)

The “Virtual Alpine Observatory” (VAO) is a network of European High Altitude Research Stations based in the Alps and similar mountain ranges from 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. International VAO Symposia are organized every second year. 2020's edition took place in Bern in February. Martin Steinbacher was member of the scientific committee and contributed a poster presentation, entitled "45 Years of Atmospheric in-situ Trace-Gases Observations at Jungfraujoch", to the programme. VAO is broad in scope and aims at going beyond purely scientific challenges by also envisaging a political and societal integration. Currently, the VAO consortium evaluates the possibility to become a European Grouping of Territorial Cooperation (EGTC). As an EGTC, application for funding will be facilitated.

Contribution to GCOS and GCOS Switzerland

Martin Steinbacher was invited as a member of the Scientific Programme Committee of the Swiss GCOS/GAW Symposium on Earth System Cycles, which was planned to take place in September 2020. Programmatic input was given, potential speakers were suggested and discussed within the committee, and a largely final symposium programme was compiled. However, the symposium was postponed to 2021 due to the Covid-19 pandemic. Martin Steinbacher also participated in public consultations on requirements for the so-called Essential Climate Variables (ECVs). GCOS currently specifies 54 ECVS that allow a sound characterization of Earth’ s climate.

Contribution to GEO/GEOSS and GEO GNOME / GEO Mountains

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. Strategic input was provided through participation in the GEO mid-term evaluation survey 2020 to support the review progress assessing the outcomes of implementations introduced in the GEO Strategic Plan 2016-2025. As a follow up of 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, recently renamed as GEO Mountains), a perspective paper was prepared by parts of the workshop participants entitled "Towards a definition of Essential Mountain Climate Variables". The manuscript is currently under review for "One Earth" (Thornton et al., 2020). The annual Swiss „Nationale Koordinationstreffen GEO/GEOSS" was cancelled due to the pandemic.

Tropospheric Ozone Assessment Report (TOAR) activity

A series of comprehensive review papers has been released during phase I of the Tropospheric Ozone Assessment Report (TOAR) activity, which was completed in 2019. QA/SAC-CH participated in the launch of phase II of TOAR during a first virtual gathering in September 2020. QA/SAC-CH plans to engage in some of the working groups that are about to start action after the next workshops scheduled for early 2021.

Acknowledgements

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Financial statement

The detailed expenses for the operation of QA/SAC Switzerland are given below. All expenditures are well within the estimated budget listed in the respective program. Furthermore the QA/SAC Switzerland activities require general Empa infrastructure (see also footnote in the budget).

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Contributions to scientific conferences, workshops and meetings

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Steinbacher, M, Updates on ICOS RI, ICOS CH National Meeting, virtual, 03 September 2020. (talk)

Steinbacher, M., WMO/GAW Quality Assurance / Science Activity Centres, Joint GAW Web Meeting of Expert Team- Atmospheric Composition Measurement Quality (ET-ACMQ) and QA-Central Facilities (QA-CF's), virtual, 29 September 2020. (talk)

Steinbacher, M, Long-term observations of atmospheric trace gases: challenges, implementation and operation, BMKG focus group discussion virtual conference, virtual, 12 November 2020 (talk)

Steinbacher, M., The Importance of Quality Assurance and Quality Control for long-term in-situ atmospheric composition observations, GAWTEC webinar, virtual, 07 December 2020. (talk)

Steinbacher, M., C. Hueglin, S. Reimann, D. Brunner, B. Buchmann, L. Emmenegger, 45 Years of Atmospheric in-situ Trace-Gases Observations at Jungfraujoch, 5th VAO Symposium, Bern, Switzerland, 4 – 6 February 2020. (poster)

Steinbacher, M., D. Steger, S. Pieber, B. Tuzson, R. Rüfenacht, L. Emmenegger, Update from ICOS-CH Atmosphere Network and Jungfraujoch, ICOS CH National Meeting, virtual, 03 September 2020. (talk)

Steinbacher, M., C. Zellweger, L. Emmenegger, B. Buchmann, The importance of training for long-term operation of atmospheric greenhouse gas observations, ICOS Science Conference, virtual, 15 – 17 September 2020. (talk)

Workflow 2020

1st quarter 2020

- attendance of the VAO symposium, Bern, Switzerland

2nd quarter 2020

- two publications on multi-decadal ozone trends across the globe
- organisation of the virtual ICOS Atmospheric Monitoring Station Assembly
- start of long-term evaluation of novel NO2 and N2O instrumentation

3rd quarter 2020

- publication of the GGMT-2019 report
- presentation at ICOS Science Conference (talk)
- publication on the drought 2018 event and its influence on atmospheric CO2 concentrations
- participation in the Joint GAW Web Meeting of Expert Team- Atmospheric Composition Measurement Quality (ET-ACMQ) and QA-Central Facilities (QA-CF's)

4th quarter 2020

- presentation at BMKG focus group discussion on air quality and greenhouse gas monitoring
- virtual teaching at GAWTEC webinar
- publication on persistent ozone anomalies in Northern Italy

continuous activity

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

Dübendorf, January 2021

Laboratory Air Pollution / Environmental Technology

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