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ACTIVITY REPORT 2023
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 hundred registered stations contribute to the GAW programme. GAW data from all over the globe must be appropriately documented, consistent, traceable to common reference scales, and of known and adequate quality. Meeting these quality objectives is essential to address the spatial and temporal variability of atmospheric composition, which is necessary for retrieving robust averages, detecting regional gradients and long-term trends, and for verification of models and satellite retrievals.

Since the establishment of the GAW programme in 1989, an elaborate quality management framework was developed. Cornerstones are so-called Central Facilities responsible for quality control, scientific guidance, and data curation and dissemination. Next to other facilities, four Quality Assurance/Science Activity Centres (QA/SACs) fulfill 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. QA/SAC-CH is closely linked to the World Calibration Centre, also hosted by Empa (WCC-Empa), and well embedded into Empa's Laboratory for Air Pollution / Environmental Technology's monitoring and research activities. QA/SAC-CH focuses on surface ozone, carbon monoxide, methane, and carbon dioxide measurements, but it also provides technical and scientific support in general.

For 2023, QA/SAC-CH's planned 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 areas is given below.

Science Activities, including QA/QC

Data-driven approach for timely data review

The timely and autonomous detection of instrument malfunctioning at GAW station level is often inexistent, thus, issues are only detected with significant delay and, consequently, interventions tend to be late, causing avoidable data gaps. In April 2023, QA/SAC-CH began the development of a novel, data-driven tool for a timely data review and the identification of suspicious

measurements. This tool should motivate station operators to apply regular and timely quality control, i.e. to assess the quality of the data much more frequently than the common yearly intervals of submission to the data centres. Several approaches were tested using data from the World Data Centre for Greenhouse Gases, the World Data Centre for Reactive Gases, and the Integrated Carbon Observation System (ICOS) Carbon Portal. Two purely data-driven approaches are currently pursued: (i) an outlier detection method (Subsequence Local Outlier Factor - Sub-LOF) is applied to time series of hourly data, and (ii) a combined statistical autoregressive and moving average model (Seasonal Autoregressive Integrated Moving Average - SARIMA) is used to forecast and compare monthly averages. In addition, modelled trace gas time series from numerical forecasts of the Copernicus Atmosphere Monitoring Service (CAMS) are downscaled to the respective station coordinates with random forest regressors and are compared with recent trace gas observations. First results were presented at the Data Science @ Empa workshop and the ICOS Switzerland Annual Meeting, both in Dübendorf, and the Swiss Geoscience Meeting in Mendrisio.

Scientific interpretation of GAW data

A comprehensive **review of ground-based, airborne, and satellite-based carbon dioxide (CO_2) observations** was compiled in 2023 by a global team of CO_2 experts, including Martin Steinbacher. The manuscript was published in 'Oxford Research Encyclopedia of Climate Science' (Ramonet et al., 2023). The paper highlights the importance of accurate long-term measurements of atmospheric CO_2 concentrations to understand the role of human activities on the greenhouse effect, and the interactions between anthropogenic emissions and the natural carbon cycle.

QA/SAC-CH participated in a study led by the Institute of Atmospheric Sciences and Climate (CNR-ICAC) in Italy on **the evaluation of the impact of the COVID-19 economic downturn on surface ozone (O_3) concentrations at several high-elevation sites across North America and Western Europe**. The paper, published in 'Atmospheric Chemistry and Physics' (Putero et al., 2023), discusses the persistent negative surface O_3 anomalies seen at nearly all 41 investigated stations in 2020. Systematic differences in the surface O_3 recovery in 2021 were found due to intense wildfires in western North America in 2021 that contributed to widespread air pollution and positive O_3 anomalies while negative anomalies still occurred over Europe.

Martin Steinbacher co-authored a **study investigating potential challenges when using methane (CH_4) to carbon monoxide (CO) ratios as a benchmark to verify bottom-up CH_4 inventories**. The annual aggregation of the proxies, the CO bottom-up inventory used as input, and the sensitivity of the results to the different subsets of the atmospheric observations were identified as critical issues. The results were published in 'Atmospheric Measurement Techniques' (Fratticioli et al., 2023).

Technology watch and evaluation of emerging techniques

Following up on laboratory **tests on a variety of novel commercial nitrous oxide (N_2O) analysers** in 2022, tests continued in 2023 with a mid-Infrared Laser Spectrometer from Aeris Technologies. Erratic short-term changes in instrument sensitivity were found. A design of a temperature-controlled housing for an improved thermal stabilization was initiated to reduce the observed signal variation.

Training, Twinning, and Capacity Building

GAW station support

QA/SAC-CH responded to a wide range of requests from GAW stations for support regarding measurements and data management. Priority was given to QA/SAC-CH's long-term twinning partners, especially to the **Indonesian Agency for Meteorology, Climatology and Geophysics** (BMKG) and the **Kenya Meteorological Department** (KMD) and the **CATCOS** (Capacity Building and Twinning for Climate Observing Systems) stations, i.e. Pha Din (Vietnam), El Tololo (Chile), and Cholpon Ata (Kyrgyz Republic).

Throughout the year, repeated virtual meetings took place with BMKG with respect to its plans to organise an 'International BMKG - WMO Training on Greenhouse Gas Monitoring and Data Analysis in Indonesia', supported by the GAW secretariat and WMO's Education and Training Office. A program description and a tentative agenda were jointly compiled. The training is foreseen for fall 2024. Involvement of QA/SAC-CH in teaching is foreseen. BMKG operates and processes the observations at **Bukit Koto Tabang** (BKT) largely autonomously. Technical QA/SAC-CH support is only requested occasionally. QA/SAC-CH reviewed the data from BKT prior to submission to the world data centres. Martin Steinbacher was invited to give a remote presentation entitled 'Requirements and benefits of long-term greenhouse gas observations' on the occasion of the 25th anniversary of the BKT station in March.

In 2023, no serious issues were experienced with the trace gas (CO_2, CH_4, CO, O_3) observations at **Mount Kenya** (MKN) GAW station, operated by KMD with Swiss support, which thus provided high quality data with only moderate data gaps. Surface O_3 observations still run in duplicate for direct quality control. Data were submitted to the World Data Centres for Greenhouse Gases and Reactive Gases. QA/SAC-CH contributed to a joint effort of researchers from Sweden, the Netherlands, Switzerland and Kenya analysing isotopic signatures and concentration measurements of carbon monoxide at MKN and Nairobi to better understand the main sources of CO in the region. The paper was published in 'Atmospheric Chemistry and Physics' (Kirago et al., 2023). Empa, MeteoSwiss and KMD are also partners in the consortium of European Commission's Horizon Europe infrastructure project 'KADI (Knowledge and climate services from an African observation and Data research Infrastructure)'. The project paves the way to develop science and science-based services in Africa that are needed to sharpen common action on climate change as outlined in the Paris Agreement and the UN Sustainable Development Goals. A scientist (Leonie Bernet) was hired part-time for KADI. Her tasks are mainly within the context of the pilot on lessons learned from existing long-term atmospheric and ecosystem observations in East Africa, and on the analysis of the time series from Mount Kenya. Since Leonie Bernet started in December 2023, significant progress is expected in 2024.

The **Cholpon Ata** station (Kyrgyz Republic) was visited by QA/SAC-CH jointly with WCC-Empa for a station and performance audit in June 2023. A refresh of the operator training was provided. An issue with the ozone scrubber in the ozone analyser was found and fixed. Data prior to the visit could be corrected based on regular quality assurance performed by the local operator from **Kyrgyzhydromet**. In 2023, data coverage for the whole suite of trace gases (CO_2, CH_4, CO, O_3) is excellent. An issue with the uninterruptible power supply unit that protects the instrumentation from frequent power outages and fluctuations in the power supply occurred in December 2023. Replacement is in planning and will likely require support through Empa's Storehouse for Twinning Stations.

In 2023, QA/SAC-CH interacted intensively with the **Vietnam Hydrological and Meteorological Administration** (VNMHA) in support of their observations at **Pha Din**. The O_3 analyser was reliable since its repair during the joint WCC-Empa and QA/SAC-CH station visit in November 2022. However, the CO_2/CH_4/CO instrument failed shortly after the station visit in late 2022, and several efforts were made to repair the analyser throughout 2023. The remote support of the manufacturer identified a hardware failure that cannot be solved remotely. An on-site repair by the local staff failed, and the instrument was dismantled and brought to the VNMHA headquarters in Hanoi where additional parts were replaced without success. Due to the age of the analyser, a repair of the instrument at the manufacturer's premises in the United States is discouraged. Thus, a replacement of the analyser is required to continue the observations. QA/SAC-CH analysed the international landscape for resource mobilization and drafted a generic 'Resource Mobilisation and Instrument Lifecycle' document for MeteoSwiss and VNHMA. In terms of scientific data analysis, **observations at Pha Din (Vietnam) were evaluated jointly with Vietnamese colleagues to study the influence of biomass burning on air quality on the Indochinese Peninsula in Southeast Asia**. Carbon monoxide (CO) data were compared with two atmospheric transport and chemistry simulations (Copernicus Atmospheric Monitoring Service (CAMS) global reanalysis and FLEXPART backward simulations). The simulations confirmed the large impact of biomass burning at Pha Din in spring and indicated that mostly very fresh biomass burning plumes were sampled when large carbon monoxide peaks were observed. The results were published as a chapter in a book on Vegetation Fires and Pollution in Asia (Pieber et al., 2023).

The measurements at **El Tololo** (Chile) suffer from instrumental issues with the cavity ringdown laser spectrometer and internet connection problems that did not allow for extended remote interventions. The local operator is responsive, but his line managers at the **Dirección Meteorológica de Chile**'s (DMC) headoffice do not profoundly support the observations. The CO_2/CH_4/CO instrument reached its end of life, remote support by the manufacturer cannot be expected anymore due to the age of the instrument, and a replacement is required. Discussions and search for funding opportunities were launched. Similar to the situation in Vietnam, a resource mobilization strategy needs to be developed jointly with DMC.

Operators of ozone observations in Morocco, Egypt, Algeria and Saudi Arabia were trained during a one-week **training course** organised by the Regional Calibration Centre for Total Ozone hosted by the Spanish State Meteorological Agency (AEMET) within the context of the GAW Sand and Dust Storm Warning Advisory and Assessment System (SDS-WAS). QA/SAC-CH contributed to the course with a remote lecture entitled 'Rationale for surface ozone measurements'.

In 2023, WCC-Empa and QA/SAC-CH produced a series of **technical tutorials** for station operators. The videos provide insight into the handling of pressure regulators for high-pressure cylinders and the determination of potential water vapour interference for greenhouse gas analysers. In addition, a number of videos show how to carry out the calibration, testing and repair of surface ozone analysers. The videos are available on Empa's GAW station support webpage, https://www.empa.ch/web/s503/gawsupport. The videos were promoted in the GAW newsletter reaching out to the whole GAW community.

Advise was given to colleagues from **Beijing University** in support of their plans to establish an atmospheric composition **monitoring station at the Chinese Mt. Everest base camp** at more than 5000 m asl. This was done during an International Workshop on High-Altitude Atmospheric Measurements at Jungfraujoch with participants from China, Finland, the Paul Scherrer Institute and QA/SAC-CH. Experience in high altitude trace gas observations was shared, a lab tour through

Empa's measurement facilities at Jungfraujoch was given, and a talk entitled 'Long-Term Trace Gas Measurements at Jungfraujoch' was presented.

In October, a delegation of the **Global Change Research Institute (CzechGlobe)** from the Czech Republic was visiting Empa to learn more about the operation and quality control of long-term greenhouse gas observations. Martin Steinbacher gave a tour through the GAW laboratory at Empa, which was highly appreciated. The visit was supported by the ATMOS-ACCESS programme and its related trans-national training service.

In addition, assistance was provided in response to **other requests for support**, e.g. to

(i) Max Planck Institute for Biogeochemistry: advice on assessment procedures for a laser spectrometer;
(ii) the Royal Netherlands Meteorological Institute (KNMI): advice on selection of surface ozone analyzers in the Netherlands and Surinam);
(iii) Universidad Mayor de San Andrés in La Paz, Bolivia: advice on calibration of surface ozone analyzers, and
(iv) the Egyptian Meteorological Authority: support in selection, operation, calibration and quality control strategies of greenhouse gas measurements.

Capacity Development Task Team

Martin Steinbacher is member of the **Capacity Development Task Team**, led by Julie Nicely, member of SSC-EPAC. The task team is committed to document past and ongoing capacity development efforts across all focal GAW areas, to coordinate future activities across relevant sub-groups, and to establish best practices in capacity development. The collection of relevant activities continued and the webpage 'Capacity Development at GAW' was updated. Led by Martin Steinbacher, a **GAW report, called 'Overview of and lessons learned from GAW's capacity development efforts'** was compiled. It is currently with the WMO Outreach Office for typesetting. A series of conference calls was held among the task team. Additionally, specific conference calls were held among a subgroup to prepare the GAW report.

Teaching at GAW and GAWTEC courses

A QA/SAC-CH teaching engagement at **GAWTEC** training #40 was foreseen in June 2023. Due to an overlap with the mission to Kyrgyzstan, the QA/SAC-CH contribution had to be withdrawn.

Teaching at Zurich University of Applied Sciences ZHAW

In November, Martin Steinbacher taught 4 hours on 'Air quality and air quality management' as part of the 'Environmental Chemistry and Analytics' course for environmental engineering bachelor students.

In December, Martin Steinbacher gave a lecture for (architecture) students of the Zurich University of Applied Sciences. The presentation entitled 'Air as a resource - air pollution and air quality management' was attended by about 50 bachelor students.

Contribution to the GAW Governance and GAW Outreach

Contribution to GAW Expert Teams and Scientific Advisory Groups

Martin Steinbacher is co-chair of the **Expert Team on Atmospheric Composition Measurement Quality (ET-ACMQ)**. The ET-ACMQ oversees the Quality Management Framework in general, facilitates the coordination and interaction among the different Central Calibration Facilities and

across all focal areas, and offers a platform for exchange (see Figure 1, designed by QA/SAC-CH). Consolidation of the quality assurance / quality control (QA/QC) efforts within GAW is mainly achieved through monitoring, evaluation, standardization and harmonization of common QA/QC components in the different observation networks. In 2023, the team's efforts mainly focused on the preparation of a compilation of descriptions of all Central Facilities to be published as a GAW report, and the provision of QA/QC-relevant input to the GAW Science and Implementation Plan 2024–2027. Next to regular teleconferences, a three-day in-person meeting was held in Santa Cruz de Tenerife in October.

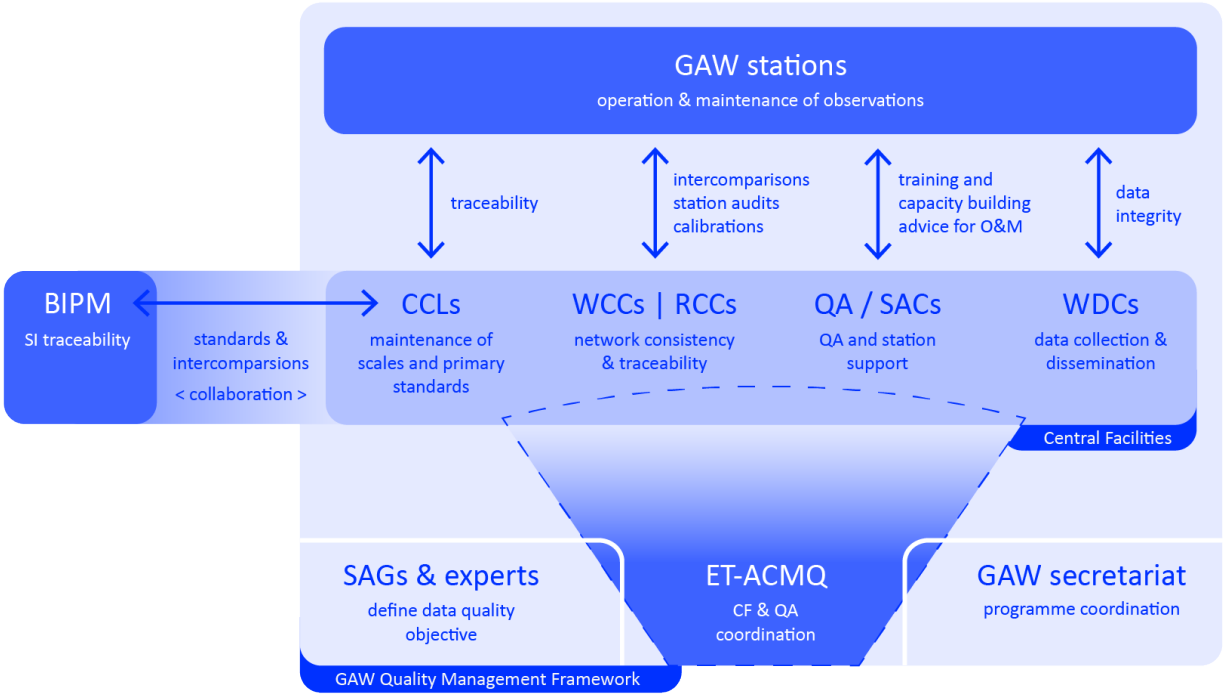

Figure 1: Elements of the GAW Quality Management Framework, main task and interactions among the bodies.

As an affiliate member of the GAW Scientific Advisory Group for Reactive Gases, Martin Steinbacher took part in a series of conference calls.

GAW Science and Implementation Plan 2024–2027

QA/SAC-CH was engaged in the preparation of the upcoming **GAW Science and Implementation Plan 2024-2027**. Martin Steinbacher participated in various conference calls of the extended Scientific Steering Committee, and he acted as objective lead for strategic objective D, entitled 'Enhance capacity throughout the GAW Programme and promote the use of atmospheric composition information and related services'. The implementation plan was approved by the WMO Executive Council in January and the World Meteorological Congress in May. In the second half of the year, QA/SAC-CH was engaged in the preparation of the annex of the Implementation Plan, which provides more specific information such as individual actions and the Terms of References of the different Scientific Advisory Groups and Expert Teams.

Global Greenhouse Gas Watch (G3W)

WMO's new Global Greenhouse Gas Watch (G3W) programme **aims at establishing internationally coordinated monitoring of greenhouse gas fluxes** to support the provision of

actionable information to the United Nations Framework Convention on Climate Change (UNFCCC) Parties and other stakeholders. In preparation of this activity, a Study Group on Greenhouse Gas Monitoring Infrastructure developed a concept. Martin Steinbacher was part of this study group and contributed to input data requirements (observational data requirements, data gaps, observing network design, financial support mechanisms). The concept was approved by the World Meteorological Congress in May 2023. Since then, the **G3W Implementation Plan is in preparation**. Martin Steinbacher was invited to join the writing team for the section on research and development of the plan. Finalization is foreseen in 2024. G3W workshops were held in Geneva in January and October. QA/SAC-CH participated in both of them. At the October edition, Martin Steinbacher presented a poster entitled ' The importance of training and capacity building within a future global greenhouse gas watch (G3W)'.

GAW Measurement Guidelines

Martin Steinbacher was nominated as the **chapter lead of 'Chapter 1: Calibration of GAW Measurements'** of the GAW report following the **'21th WMO/IAEA Meeting on Carbon Dioxide, Other Greenhouse Gases and Related Measurement Techniques (GGMT-2022)'**. The GGMT reports are considered as the key reference for technical information on greenhouse gas measurements within the GAW programme. After major revisions in the recent past, only moderate changes were made for the GGMT-2022 report, to be released in 2024.

No progress was made in 2023 for the **measurement guidelines for nitrogen oxides measurements**. A nearly complete version of the guidelines is available, but the coordinating lead author revisited the mathematical background of the correction for interferences and processes in the inlet, which led to a major delay. Due to the lengthy process, the whole document needs to be updated prior to release taking into account recent developments in measurement techniques. QA/SAC-CH stopped its engagement until clear signs for a reactivation of the drafting process are sent.

The drafting process of the **measurement guidelines for CO_2 observations** is ongoing. Fitst drafts for most of the chapters are available. Next steps are a consolidation and harmonization of the manuscript. Martin Steinbacher is part of the author team. His contributions were mainly on GAW station setup and station operating guidelines. Regular conference calls were held to coordinate among the different authors.

Cross-cutting activities

Interaction with the Swiss National Air Pollution Monitoring Network

There is a close collaboration between QA/SAC-CH and the Swiss National Air Pollution Monitoring Network (NABEL), which is run by Empa jointly 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. QA/SAC-CH supervised the data submission of the 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. To ensure consistency with the GAW guidelines, it

is important to actively shape the relevant documents and measurement strategies, such as the standard operation procedures, data formats, auxiliary parameters, etc. Martin Steinbacher participated in two 3-day atmospheric ICOS Monitoring Station Assembly (MSA) meetings in May and November 2023. He is also member of the ICOS MSA's working groups for Quality Management and Spike Detection.

Martin Steinbacher co-authored a **paper on an ICOS-wide effort to optimize automatic methods for the detection of spikes in greenhouse gas time series** due to local emissions leading to short but intense variability in the measured GHG signals. Two approaches were applied to greenhouse gas time series with 1-min time resolution from 10 monitoring sites. Due to the broad range of station characteristics from remote to suburban, none of the methods appeared to provide a perfect identification of the spike events. Further activities will be required to consolidate the fitness for purpose of the two proposed methods. The findings were published in 'Atmospheric Measurement Techniques' (Cristofanelli et al., 2023).

German-Austrian-Swiss (D-A-CH) GAW cooperation

In January 2023, a German-Austrian-Swiss (D-A-CH) GAW meeting took place in Munich. The meeting strengthened the collaboration among the GAW stations and the central facilities in the D-A-CH region. QA/SAC-CH contributed to the meeting with a talk about 'WMO/GAW Quality Assurance / Science Activity Centre Switzerland'.

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). VAO is broad in scope and aims at going beyond purely scientific challenges by also embracing a political and societal integration. VAO is part of the European Alpine Convention as well as the Alpine Strategy of the EU. Martin Steinbacher attended the VAO symposium in March 2023 and gave a talk on 'Atmospheric Trace Gas in-situ Observations at Jungfraujoch – Benefits and Challenges of Serving Multiple Programmes'.

Swiss Geoscience Meeting

Martin Steinbacher took again the lead to convene the session 'Atmospheric Composition and Biosphere-Atmosphere Interactions' at the Swiss Geoscience Meeting in Mendrisio, supported by colleagues from Agroscope, and ETH Zurich. Convenorship tasks included the preparation of the call text, the selection of the presentations, compilation of the program schedule, and the chairing of the sessions. The session was well attended and the presentations stimulated a wide range of discussions and interactions.

Contribution to GEO/GEOSS

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 and GAW activities is crucial to avoid duplications and inconsistencies. Thus, a thorough monitoring of GEO operations is desirable. The national GEO process is currently being re-organized due to various personnel and organizational changes. Therefore, the annual coordination meeting was cancelled in 2023. QA/SAC-CH is in regular contact with the staff from the Mountain Research Initiative (MRI) in Bern, which leads the GEO Mountains Initiative of the GEO Work Programme 2023-2025. Martin Steinbacher attended the 'MRI Mountains Observatories Working Group and GEO Mountains Workshop in Central Asia' in April and 'the GEO Mountains Workshop on Interdisciplinary Monitoring, Data, and Capacity Sharing Across East

Africa' in October. For the workshop in Central Asia, Martin Steinbacher contributed a presentation entitled 'Air quality and aerosol monitoring in the mountains of Central Asia as part of the WMO's Global Atmosphere Watch programme'.

Contribution to the Swiss Commission for Atmospheric Chemistry and Physics (ACP)

Martin Steinbacher is elected member of the Swiss Commission for Atmospheric Chemistry and Physics (ACP) of the Swiss Academy of Sciences. In this function, he attended the spring and fall meetings in Bern and Zurich, respectively, and represented the ACP commission as session chair at the Swiss Chemical Society Spring Meeting 2023 on 'Chemistry and Physics of the Atmosphere'.

Contribution to ATMO-ACCESS

Martin Steinbacher was part of the Access Evaluation Panel within the ATMO-ACCESS project for a fair merit review of user requests to access atmospheric research facilities in Europe. ATMO-ACCESS is the organized response of ACTRIS (Aerosol, Clouds, and Trace Gases Research Infrastructure), IAGOS (In-service Aircraft for a Global Observing System), and ICOS for developing a pilot for a new comprehensive and sustainable framework for access to distributed atmospheric facilities. As part of this mandate, he reviewed two proposals in 2023. As part of the ATMO-ACCESS' trans-national training service, he also trained colleagues from the Czech Republic (see above).

Acknowledgements

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Contributions to scientific conferences, workshops, meetings, and outreach

Brugnara, Y., M. Steinbacher, L. Emmenegger, Downscaling of global atmospheric composition forecasts, Data Science @ Empa, Dübendorf, Switzerland, 23 August 2023 (poster)

Brugnara, Y., M. Steinbacher, L. Emmenegger, Towards a quality control tool for worldwide atmospheric time series, ICOS-CH National Meeting, Dübendorf, Switzerland, 12 September 2023 (talk)

Brugnara, Y., M. Steinbacher, L. Emmenegger, Towards an automated quality control tool for atmospheric composition time series, 21st Swiss Geoscience Meeting, Mendrisio, 18 November 2023 (talk)

Steinbacher, M., C. Zellweger, L. Emmenegger, B. Buchmann, WMO/GAW Quality Assurance / Science Activity Centre Switzerland, GAW DACH Meeting, 23 January 2023 (talk)

Steinbacher, M., Requirements and benefits of long-term greenhouse gas observations, Commemoration of the 25 year operation of GAW Bukit Kototabang station, virtual and Bukit Koto Tabang, Indonesia, 20 March 2023 (talk)

Steinbacher, M., C. Hueglin, S. Reimann, B. Buchmann, L. Emmenegger, Atmospheric Trace Gas in-situ Observations at Jungfraujoch – Benefits and Challenges of Serving Multiple Programmes, Sixth Virtual Alpine Observatory Symposium, Grainau, Germany, 22 March 2023 (talk)

Steinbacher, M., Air quality and aerosol monitoring in the mountains of Central Asia as part of the WMO's Global Atmosphere Watch programme, GEO Mountains Workshop in Central Asia, virtual and Almaty, Kazakhstan, 18 April 2023 (talk)

Steinbacher, M., D. Steger, C. Zellweger, The role of data processing, comparison of final greenhouse gas data from Jungfraujoch processed by ATC and Empa, ICOS Atmosphere Monitoring Station Assembly Meeting, Brussels, Belgium, 16 May 2023 (talk)

Steinbacher, M., C. Zellweger, Greenhouse Gas Measurements in Cholpon Ata in contribution to World Meteorological Observation's Global Atmosphere Watch Programme, Meeting at Kyrgyzhydromet Headquarter, Bishkek, Kyrgyzstan, 29 June 023 (talk)

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QA/SAC-CH tasks 2023, progress overview

task #	short description	status	remarks
Q23-01	development of data science tools	in progress	under development
Q23-02	publication on very long-term CO2 trends	done	paper published
Q23-03	publication on ozone anomalies at remote high-altitude sites	done	paper published
Q23-04	activities within the ET-ACMQ	done	continuous activity
Q23-05	participation in the GAW D-A-CH meeting in Munich	done	January 2023
Q23-06	support of GAW and CATCOS stations	done	continuous activity
Q23-07	KADI project activities	done	project ongoing
Q23-08	station visit at Cholpon Ata, Kyrgyz Republic	done	June 2023
Q23-09	teaching at GAWTEC	withdrawn	overlap with audit
Q23-10	preparation of video training material	done	available online
Q23-11	GAW Implementation Plan 2024 - 2026	ongoing	draft accepted by congress
Q23-12	report on lessons learned from GAW's capacity development efforts	in progress	final version at WMO
Q23-13	publication of nitrogen oxides measurement guidelines	on hold	progress stalled
Q23-14	publication of carbon dioxide measurement guidelines	in progress	in drafting process
Q23-15	concept for GHG Monitoring Infrastructure	done	approved by WMO congress in May 2023
Q23-16	cooperation with projects like ICOS, ATMO-ACCESS, IG3IS, VAO, ACTRIS, AGAGE	ongoing	continuous activity
Q23-17	participation in the 6th VAO Symposium 2023 in Grainau	done	March 2023
Q23-18	organization of a session at the Swiss Geoscience Meeting in Mendrisio	done	November 2023
Q23-19	completion of the Certificate of Advanced Studies on 'Leadership in Science'	done	June 2023

Dübendorf, March 2024

Laboratory Air Pollution / Environmental Technology

Head of Laboratory

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