Quality Assurance / Science Activity Centre Switzerland
Empa, Laboratory for Air Pollution / Environmental Technology
Ueberlandstrasse 129
CH-8600 Dübendorf, Switzerland

Dr Martin Steinbacher
phone: +41 (0)58 765 4048
email: martin.steinbacher@empa.ch

ANNUAL ACTIVITY REPORT 2021 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) 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. 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. Thus, QA/SAC-CH mainly focuses on surface ozone, carbon monoxide, methane, and carbon dioxide measurements but also provides technical and scientific support in general.

For 2021, 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

The nitrogen dioxide (NO_2) measurements with a novel quantum cascade laser spectrometer at the GAW station Jungfraujoch continued throughout 2021, only interrupted by a one-month break when all measurements had been shut down due to a comprehensive renovation of the Jungfraujoch laboratory facilities. The additional measurements confirmed the very good reliability combined with a low required maintenance, which makes the spectrometer a suitable instrument for remote locations. The evaluation of the calibration strategy has been concluded

and a new calibration unit has been installed in December. Data processing algorithms will be finalized in 2022.

Ongoing measurements of nitrous oxide (N_2O) with cavity ringdown spectroscopy (CRDS) revealed a superiority of this implementation of the technique versus the previously used off-axis integrated cavity output spectroscopy. The CRDS instrument run at Jungfraujoch outperforms in terms of stability, requires less space and produces less noise. Thus, this instrument is considered to be the optimal choice for future N_2O observations.

A comprehensive summary of instrument evaluations and mode of operation for greenhouse gas observations is published by Yver-Kwok et al. (2021). The manuscript reports on the optimization of the European ICOS (Integrated Carbon Observation System) network. ICOS goes beyond previous monitoring networks in terms of data quality and standardization. In addition, ICOS can serve as a role model for individual stations by replicating the harmonized station setup. Martin Steinbacher, as chair of the ICOS Monitoring Assembly and operator of the Jungfraujoch measurements, is co-author of this study. A more general view on ICOS' achievements is given in an article in the *Bulletin of the American Meteorological Society* (Heiskanen et al.; 2021).

Scientific interpretation of GAW data

The impact of large-scale biomass burning on the aerosol composition and trace gases concentrations at Pha Din was investigated by a team of scientists from Germany, Vietnam, Russia, Taiwan and Switzerland (including QA/SAC-CH). The article was published in *Atmospheric Chemistry and Physics* (Nguyen et al., 2021).

A team led by colleagues from LSCE (Laboratoire des sciences du climat et de l'environnement) developed an approach aiming at quantifying the impacts of synoptic-scale atmospheric transport events and at better understanding the regional carbon cycling implications of extreme seasonal occurrences such as droughts. In contrast to other existing statistical approaches, the algorithm developed here does not try to disentangle background and non-background conditions but identifies signatures from strong or persistent meteorological patterns that may last a few days to weeks. The approach is particularly useful when applied to several stations within a network to spot common features or measurement artefacts. Martin Steinbacher is one of the co-authors of the study.

The carbon dioxide (CO_2) time series at Jungfraujoch was investigated by Affolter et al. (2021) along with the measurements at the nearby Jungfraujoch East Ridge station. A comparison of the two time series shows a good agreement between both sites, especially at night. Daytime CO_2 spikes are predominantly observed at JFJ, especially in summer, but less so at the East Ridge site. Boundary layer injections explain most of the daily variability. However, a possible influence of local anthropogenic contamination on the CO_2 measurements at Jungfraujoch, namely through the high number of visitors, especially in summer, or activities inherent to the infrastructure of the site, cannot be excluded.

A combination of measurements of CO_2 concentrations, $^{13}CO_2$ isotope observations and atmospheric transport simulations was used to better understand the regional contributions to CO_2 at Jungfraujoch (Pieber et al., 2021). The study concludes that Jungfraujoch is subject to only small regional anthropogenic contributions, due to its remote location (elevated and far from major anthropogenic sources) and the limited planetary boundary layer-influence during winter. During summer, however, signatures are primarily seen from ecosystem CO_2 contributions, which are dominated by rather nearby sources (within 100 km).

Martin Steinbacher also provided conceptual input to a Japanese-led study investigating the sensitivity of biomass burning emissions estimates to land surface information (Saito et al., 2021). Different types of global biomass burning emissions were fed into an atmospheric tracer transport model. Simulated atmospheric CO concentrations were compared with ground-based and satellite observations. The distribution of simulated CO concentrations shows substantial differences among the biomass burning emissions estimates and the observations.

In addition, QA/SAC-CH was involved in several investigations dealing with data from Jungfraujoch and other GAW stations. Studies were either conducted by Swiss colleagues (Brunner et al., 2021a, b) or international author teams (Lacher et al., 2021; Schneider et al., 2021).

GAW Quadrennial Symposium 2021

Martin Steinbacher actively participated in the virtual GAW Quadrennial Symposium in late June 2021. A poster entitled "International collaboration in supporting observations in data sparse regions – lessons learnt from the Quality Assurance / Science Activity Centre Switzerland" was presented in the session "Filling critical gaps in observations". An oral presentation entitled "Interaction of QA Central Facilities and the GAW observation network" was given in the session "Quality assurance in GAW: common methods and approaches". Martin Steinbacher was also member of the panel discussion on "Young scientist and capacity building in GAW". The presentations and their associated discussions have shown that quality assurance and capacity development are central pillars in the current GAW strategy. QA/SAC-CH's activities in this respect are well perceived and highly appreciated by the GAW community.

GAW Quality Management

As part of the reorganisation of GAW's quality management framework, an Expert Team on Atmospheric Composition Measurement Quality (ET-ACMQ) was established in late 2020 to harmonise the quality assurance (QA) and quality control (QC) processes across the six GAW focal areas. While QA/SAC-CH was initially only invited as Central Facility to a joint ET-ACMQ – GAW Central Facilities meeting, Martin Steinbacher also participated in follow-up ET-ACMQ conference calls and continued to promote the activities and achievements of the different QA/SACs. As a result, Herman Smit (current chair of ET-ACMQ) invited Martin Steinbacher to join EC-ACMQ as regular member. A decision by the Environmental Pollution and Atmospheric Chemistry Scientific Steering Committee (SSC-EPAC) is pending.

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 partners, especially to the Indonesian Agency for Meteorology, Climatology and Geophysics (BMKG) and the Kenya Meteorological Department (KMD).

In support of BMKG's discussions of the future direction of climate and air quality monitoring in Indonesia (modalities, infrastructure, challenges, etc.), QA/SAC-CH participated in and contributed to a 2-day webinar entitled "Towards Excellence in Climate and Air Quality Services: Sustaining the Past, Strengthening the Present, Powering the Future". Martin Steinbacher gave an invited talk on "Continuous atmospheric composition observations and beyond - from measurements to climate services", which stimulated vivid discussions and was well received. The online workshop was attended by more than 450 participants. BMKG made considerable efforts in terms of data

processing in the recent past. Submission of its data from Bukit Koto Tabang is now largely in the hands of BMKG; QA/SAC-CH is only consulted for an inspection of the final data prior to submission to the data centres. Discussions are ongoing about the expansion of the Indonesian monitoring network. Specific discussions have been held with the new station manager at Bariri (Central Sulawesi). A more general exchange took place with respect to BMKG's expansion plans to establish a series (6 to 7) of new monitoring stations across Sumatra, particularly for greenhouse gases and an observation-based estimation of the island's greenhouse gas emissions.

Progress has been also made at the Mount Kenya GAW stations, operated by KMD. With support from QA/SAC-CH, WCC-Empa and KMD, continuous time series of CO_2 and CH_4 were submitted for the first time to the World Data Centre for Greenhouse Gases. The submission of CO and O_3 data was continued. Since the installation of the new greenhouse gas analyser in December 2019, data quality and data coverage is good, minor issues remain with respect to the online access of the station and consequently with the real-time transfer of the data. Since the joint visit of the Mount Kenya station by WCC-Empa and MeteoSwiss in September 2021, two surface ozone analyzers are running in parallel. Currently, QA/SAC-CH evaluates the duplicate records and assesses them in terms of data quality and potential offsets.

Empa, MeteoSwiss and KMD are partners in a consortium that prepared a project proposal entitled "Knowledge and climate services from an African observation and Data research Infrastructure". The proposal was submitted to the European Commission as part of its Horizon Europe infrastructure calls. The project aims at paving the way to develop the best available 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. QA/SAC-CH will be mainly involved in a pilot on lessons learned from existing long-term atmospheric and ecosystem observations.

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, support in data processing and submission to the international data repositories. The ozone analyser at Cholpon Ata could be repaired in due time by the local operator with spare parts provided and guidance of QA/SAC-CH. Major issues were experienced at the PhaDin station when several integral parts of the setup failed. Repair is ongoing but delayed due to access restrictions also for the local technical support.

The Cholpon Ata station was accepted by the GAW secretariat as regional GAW station in March. Through a joint Kyrgyzhydromet and QA/SAC-CH effort, the station was registered in GAWSIS, and CO_2, CH_4, CO and O_3 data were submitted for the first time to the respective GAW data centres. Public availability of the data is a big advancement as Central Asia is a very data sparse region. The support of the WMO-GCOS (Global Climate Observing System) trust fund for small expense at CATCOS stations ceased in February 2021. If required, costs for replacement parts need to be covered by alternative funds such as Empa's Storehouse for Twinning Stations.

QA/SAC-CH supported a proposal of the World Radiation Center of the Physikalisch-Meteorologisches Observatorium in Davos to initiate precision filter radiometer (PFR) measurements at the Pha Din station. Unfortunately, the proposal was not funded by the Swiss National Science Foundation for funding.

Martin Steinbacher reviewed a research proposal, which was submitted to the National Research and Development Agency (ANID) of the Ministry of Science, Technology, Knowledge and Innovation of Chile. The project aims at evaluating the past, present and future of ozone and

precursors in the subtropics of Chile. Long-term data from the El Tololo stations will be investigated. Thus, the project complements some of the CATCOS activities. Overall, a positive evaluation was given, but some modifications of the project were suggested.

In 2021, Martin Steinbacher was invited to review of the Cape Grim Science Program Reactive Gases program. The measurements at the global GAW station Cape Grim are operated by CSIRO (Commonwealth Scientific and Industrial Research Organisation) with support from the Australian Bureau of Meteorology The review process included review of provided documentation, (virtual) participation of Martin Steinbacher at the Cape Grim Annual Science Meeting, a conference call of the reviewers with the science team, and a report which was jointly drafted by the four reviewers.

In addition, assistance was provided in response to other requests for support, e.g. to (a) Koninklijk Nederlands Meteorologisch Instituut (KNMI) (technical advice in support of their surface ozone observations in Suriname), (b) Aeronautica Militare in Italy (support of their greenhouse gas observations at Monte Cimone), (c) the Servicio Meteorológico Nacional in Argentina (review of ozone data prior to submission to the GAW data centre), (d) Rudjer Boskovic Institute in Croatia (advice for suitable instrumentation for CO_2 observations), (e) Universidad Mayor de San Andrés in La Paz, Bolivia (calibration of low cost CO_2 analyzers and setup of O_3 instrumentation at urban background stations).

Capacity Development Task Team

Martin Steinbacher was invited to join the new Capacity Development Task Team, which was launched in February 2021 under the coordination of Julie Nicely, member of the Environmental Pollution and Atmospheric Chemistry Scientific Steering Committee (SSC-EPAC). The task team aims at documenting past and ongoing capacity development efforts across all focal GAW areas, at coordinating future activities across relevant sub-groups, and at establishing best practices in capacity development. Collection of information started in spring, and virtual meetings took place during the GAW symposium in June and during a conference call in October. Coordination was also launched with the Group on Earth Observations' Capacity Development Working Group through exchange with one of its group members, Yves-Alain Roulet from MeteoSwiss.

Second GAWTEC webinar series

The GAW Training and Education Centre (GAWTEC) – jointly with the Young Earth System Scientists community – organized in 2021 its second webinar series dedicated to reactive gases. Martin Steinbacher was invited to give a lecture on "Carbon monoxide in the atmosphere – measurement techniques" The recording of the webinar is available online on the GAWTEC webpage (https://www.youtube.com/watch?v=sxo9ARpRg54&t) and can also be found on Empa's GAW webpage. First preparations for an in-person training at Zugspitze in spring 2022 were launched in fall 2021. It is foreseen to mainly invite European operators because intercontinental travel restrictions due to the Covid-19 pandemic may still apply. QA/SAC-CH was involved in identifying European stations with training needs.

Teaching at Zurich University of Applied Sciences ZHAW

In December, Martin Steinbacher was invited to give a 45-minute 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 80 bachelor students.

Update of GAW webpage at Empa

The QA/SAC-CH webpage at Empa was updated and a dedicated webpage "GAW station support" was created that allows to access a variety of useful material (such as videos, presentations, publications etc.) from a central portal.

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 https://lagrange.empa.ch/) is ongoing and provides a valuable input for many station operators for data evaluation and interpretation.

Contribution to GAW Outreach

GAW Measurement Guidelines

A series of videoconferences were held in 2021 among the (six) lead authors of the measurement guidelines for nitrogen oxides measurements, and progress was regularly reported to the Scientific Advisory Group (SAG) for Reactive Gases. An advanced draft version is subject to minor changes prior to be forwarded to the SAG for Reactive Gases for comments.

No progress was made in terms of the measurement guidelines for CO_2 observations due to missing leadership and guidance by the Scientific Advisory Group Greenhouse Gases. A lead author meeting was cancelled, which was planned as a side-meeting of the WMO/IAEA Meeting on Carbon Dioxide, Other Greenhouse Gases, and Related Measurement Techniques (GGMT-2021). GGMT-2021 was postponed due to the Covid-19 pandemic.

Article in ProClim Flash Magazine

ProClim Flash is a Swiss magazine published by the Swiss Academy of Sciences (SCNAT) focussing on climate and global change. In 2020, the GAW-CH consortium decided to publish regular contributions on various GAW-CH relevant subjects. QA/SAC-CH and WCC-Empa jointly wrote the first contribution to this series. The article gives an overview of the GAW programme in Switzerland and the Swiss contribution to quality assurance and knowledge transfer.

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 jointly with the Swiss Federal Office for the Environment (FOEN). 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 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. QA/SAC-CH also participated in WCC-Empa's audit at Jungfraujoch. However, it took a neutral role in the audit due to Martin Steinbacher's dual function as Jungfraujoch operator and QA/SAC-CH member.

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

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. In December 2021, Martin Steinbacher stepped down as chair of the atmospheric ICOS Monitoring Station Assembly (MSA) after 8 years of chairmanship and vice chairmanship. Through this mandate, he was also member of the ICOS Research Infrastructure Committee which consults the ICOS Director General for scientific matters. The MSA chair organized and chaired two virtual 2-day MSA meetings in 2021.

Scientific Programme Committee of the Swiss GCOS/GAW Symposium on Earth System Cycles

Martin Steinbacher was member of the Scientific Programme Committee of the Swiss GCOS/GAW Symposium on Earth System Cycles, which took place in September 2021. Since it was originally scheduled for fall 2020, much of the work took place in in 2020. However, the final symposium programme was compiled in 2021. During the symposium, Martin Steinbacher coordinated the discussions during the Carbon Cycle Session. After the symposium, he was also part of the author team of the Symposium White Paper that comprehensively summarizes the presentations, discussions, findings, and conclusions of the symposium. A draft version of the White Paper was completed in December 2021. QA/SAC-CH presented a poster at the symposium entitled "WMO/GAW Quality Assurance/Science Activity Centre Switzerland - Activities and Achievements".

Swiss Geoscience Meeting

After several years of being a co-convenor, Martin Steinbacher took in 2021 the lead to convene the session "Atmospheric Composition and Biosphere-Atmosphere Interactions" at the yearly Swiss Geoscience Meeting, supported by colleagues from Agroscope, the University of Bern and ETH Zurich. Convenorship tasks include the preparation of the call text, the selection of the presentations, compilation of the program schedule, and the chairing of the sessions.

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. In 2021, a pre-proposal called "Observation and understanding of the complex climate forcings and their effects on the alpine earth system from the ground to the upper atmosphere" was prepared for the attention of the Bavarian Ministry for the Environment. The next VAO symposium is scheduled for March 2022 in Germany.

Contribution to GEO/GEOSS and 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.

In 2021, strategic input was provided through the review of the GCOS Status Report 2021, which is one of the pillars of the future 2022 GCOS Implementation Plan. GCOS Status Report 2021 was released in November.

Martin Steinbacher is co-author of the perspective paper "Towards a definition of Essential Mountain Climate Variables" (Thornton et al., 2021), which was one of the outcomes of the 2019

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 presentation on "Swiss roadmaps for research infrastructures 2023" was given by Martin Steinbacher at the annual Swiss GEO/GEOSS national coordination meeting in May.

Tropospheric Ozone Assessment Report (TOAR) activity

The second phase of the Tropospheric Ozone Assessment Report (TOAR) activity was launched in fall 2020. In 2021, two multi-day virtual gatherings took place to advance the efforts in several working groups. QA/SAC-CH actively participated in these workshops and repeatedly emphasized and promoted the importance and availability of ground-based in-situ ozone observations. Phase 2 gives more emphasis on satellite-borne observations and global modelling activities. However, surface ozone data is an important but sometime neglected piece in the global, 3-dimensional puzzle.

Review and consultation engagements for other activities

The Swiss Academy of Sciences SCNAT has been mandated by the State Secretariat for Education, Research and Innovation SERI to initiate Round Tables to explore, identify and coordinate needs for Large Research Infrastructures (RIs) in the different disciplines of natural sciences, including Geosciences. As output, community roadmaps for large research infrastructures were drafted that serve as a basis for the Swiss Roadmap for Research Infrastructures 2025-2028, prepared by SERI and handed to the Federal Council and Parliament for approval (and hopefully federal funding). Martin Steinbacher was deputy coordinator (along with Athanasios Nenes (EPFL and Urs Baltensperger (PSI)) of the atmosphere subgroup for the Geosciences roadmap. The report "Geosciences in Switzerland: Roadmap for Geosciences Research Infrastructures 2025–2028" was released in March 2021 (Eugster et al., 2021) as one of seven discipline-specific roadmaps.

The series of Global Environment Outlooks of the United Nations Environment Programme provides regular assessments of the current state of the environment and the most pressing challenges humanity is currently facing. Martin Steinbacher was involved in the preparation of the most recent, sixth edition, in 2015 to 2019. In fall 2021, consultations started on the findings of the feasibility study for the Future of the Global Environment Outlook, and views were provided on the potential assessment options for the future of GEO and their implementation.

Martin Steinbacher was invited to join 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 (Integrated Carbon Observation System) for developing a pilot for a new comprehensive and sustainable framework for access to distributed atmospheric facilities.

Martin Steinbacher supported the Swiss GCOS Office in preparing the chapter on "Research and systematic observation" of the quadrennial National Communication towards the United Nations Framework Convention on Climate Change (UNFCCC).

Martin Steinbacher reviewed proposals for (a) the German Research Foundation, which intends to advance the observations of the IAGOS-CARIBIC (In-service Aircraft for a Global Observing System - Civil Aircraft for Regular Investigation of the Atmosphere Based on an Instrument Container) research infrastructure, and (b) the National Science Centre in Poland. The latter project aims at improving the availability of air quality information in Poland.

Martin Steinbacher also completed a six-day training course on "Leadership in Science" at the University of Applied Sciences and Arts in Windisch, Switzerland.

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Contributions to scientific conferences, workshops, meetings, and outreach

Steinbacher, M., P. Cristofanelli, ICOS Atmosphere Monitoring Station Assembly, virtual, 01 – 02 February 2021. (organization)

Steinbacher, M., Swiss roadmaps for research infrastructures 2023, GEO/GEOSS national coordination meeting, virtual, 31 May 2021. (talk)

Steinbacher, M., Interaction of QA Central Facilities and the GAW observation network, GAW Quadrennial Symposium 2021, virtual, 28 June – 02 July 2021. (talk)

Steinbacher, M., Young scientist and capacity building in GAW, GAW Quadrennial Symposium 2021, virtual, 28 June – 02 July 2021. (panel discussion)

Steinbacher, M., C. Zellweger, L. Emmenegger, B. Buchmann, International collaboration in supporting observations in data sparse regions – lessons learnt from the Quality Assurance / Science Activity Centre Switzerland, GAW Quadrennial Symposium 2021, virtual, 28 June – 02 July 2021. (poster)

Steinbacher, M., S. Henne, Continuous atmospheric composition observations and beyond - from measurements to climate services, BMKG Symposium "Towards excellence in climate and air quality services: Sustaining the past, strengthening the present, empowering the future", virtual, 06 – 07 August 2021. (talk)

Steinbacher, M., C. Zellweger, Globale Langzeitbeobachtung der Atmosphäre, ProClim Flash #74, pp 18 -19, 2021. (article)

Steinbacher, M., C. Zellweger, L. Emmenegger, B. Buchmann, WMO/GAW Quality Assurance/Science Activity Centre Switzerland - Activities and Achievements, Swiss National GAW/GCOS Symposium, virtual, 13 – 14 September 2021. (poster)

Steinbacher, M, Updates on ICOS RI, ICOS CH National Meeting, virtual, 22 September 2021. (talk)

Steinbacher, M, Updates from ICOS-CH Atmosphere Network and Jungfraujoch, ICOS CH National Meeting, virtual, 22 September 2021. (talk)

Steinbacher, M, Discriminating free troposphere conditions and planetary boundary layer episodes at Jungfraujoch, ICOS CH National Meeting, virtual, 22 September 2021. (talk)

Steinbacher, M., Carbon monoxide in the atmosphere – measurement techniques, Global Atmosphere Watch Training and Education Centre (GAWTEC) webinar series, second edition, virtual, 04 November 2021. (talk)

Steinbacher, M., C. Ammann, S. Brönnimann, M. Gharun, U. Krieger, W. Eugster, Session "Atmospheric Composition and Biosphere-Atmosphere Interactions", 19th Swiss Geoscience Meeting, virtual, 20 November 2021. (organization)

Steinbacher, M., P. Cristofanelli, ICOS Atmosphere Monitoring Station Assembly, virtual, 01 – 02 December 2021. (organization)

Workflow 2021

1st quarter 2021

- publication on the evaluation and optimization of greenhouse gas data at European stations
- organisation of the virtual spring ICOS Atmospheric Monitoring Station Assembly
- publication on the assessment of local contamination at Jungfraujoch

2nd quarter 2021

- active participation in the GAW symposium (poster, talk, panel discussion)
- publication on the influence of biomass burning at Pha Din (Vietnam)
- registration and first submission of data from Cholpon Ata

3rd quarter 2021

- attendance of the Swiss GCOS/GAW symposium (poster, steering committee, author of the symposium white paper)
- publication on an algorithm to detect synoptic and seasonal scale anomalies in time series

4th quarter 2021

- organisation of the virtual fall ICOS Atmospheric Monitoring Station Assembly
- teaching activity at virtual GAWTEC webinar series
- organisation of a session at the Swiss Geoscience Meeting
- review of the Cape Grim Reactive Gases programme

continuous activity

- support of GAW stations
- cooperation with other projects such as ACTRIS, AGAGE, AtmoACCESS, GEO, GCOS, ICOS, IG3IS, VAO.

Dübendorf, January 2022

Laboratory Air Pollution / Environmental Technology

Head of Department

Project manager

Brigitte Buchmann

Digital unterschrieben von Brigitte Buchmann
Datum: 2022.03.22 09:58:26 +01'00'

Digitally signed by Martin Steinbacher
Date: 2022.03.21 17:01:17 +01'00'

Dr. B. Buchmann

Dr. M. Steinbacher