

Dr. Christoph Zellweger  
Empa  
Überlandstrasse 129  
CH-Dübendorf, Switzerland

phone: +41-58-765 4328 / 1111  
fax: +41-58-765 1122  
mailto: christoph.zellweger@empa.ch

## Annual Activity Report 2021 of WCC-Empa

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.

Within GAW, an elaborate quality management framework was developed to achieve these goals. In support of the programme, central facilities responsible for quality control, scientific and technical guidance, and data hosting and dissemination of the global network were established. Empa, in collaboration with MeteoSwiss, is running the World Calibration Centre for Surface Ozone, Carbon Monoxide, Methane and Carbon Dioxide (WCC-Empa) as a contribution to the GAW programme since 1996. The main task of WCC-Empa is to perform system- and performance audits at GAW stations to ensure traceability within the network, but also to provide technical and scientific support in general. This is done in close collaboration with the Quality Assurance/Science Activity Centre Switzerland (QA/SAC-CH), also hosted by Empa. Both WCC-Empa and QA/SAC-CH are well embedded in the activities of the Empa Laboratory for Air Pollution / Environmental Technology. They have strong synergies with the Swiss National Air Pollution Monitoring Network, the group for Climate Gases, the group for Emissions and Isotopes, the Laser Spectroscopy group, and the group for Atmospheric Modelling and Remote Sensing at Empa. This report gives an overview of the activities of WCC-Empa for the year 2021.

### 1. System- and performance audits

The following GAW stations were audited in 2021:

Pallas (PAL)	O <sub>3</sub> , CO, CH <sub>4</sub> , CO <sub>2</sub> and N <sub>2</sub> O	5 <sup>th</sup> audit
Mt. Kenya (MKN)	O <sub>3</sub> , CO, CH <sub>4</sub> , and CO <sub>2</sub>	9 <sup>th</sup> audit
Jungfraujoch (JFJ)	O <sub>3</sub> , CO, CH <sub>4</sub> , CO <sub>2</sub> and N <sub>2</sub> O	4 <sup>th</sup> audit
Cape Point (CPT)	O <sub>3</sub> , CO, CH <sub>4</sub> , and CO <sub>2</sub>	7 <sup>th</sup> audit

The audits at the GAW stations Pha Din (Vietnam) and Zeppelin Mountain (Norway) were also planned for 2021, but had to be postponed due to Covid-19 related travel restrictions. WCC-Empa has been in contact with both stations, and the audits at the two sites are now scheduled for 2022. The JFJ and MKN stations were audited instead of these two stations.

Furthermore, the following calibration and comparison activities were made in 2021 to support GAW stations and the WMO/GAW programme in general:

University of Bristol (GB Regional Stations and Mace Head)	GHG and CO (standard calibration)
British Antarctic Survey (Antarctica)	GHG and CO (standard calibration)

WCC-Empa conducted the fifth system- and performance audit at the global GAW station **Pallas**. The audit started due to travel restrictions with remote support from WCC-Empa in March 2021, at the same time as the station audit by the ICOS mobile laboratory. It was concluded with a physical visit at the site in July 2021. The audit included parallel measurements for CO, CO<sub>2</sub>, and CH<sub>4</sub> over a period of four months. The results of the comparisons were within the WMO/GAW network compatibility goals (O<sub>3</sub>, CH<sub>4</sub>, and CO<sub>2</sub>) or extended compatibility goals (CO and N<sub>2</sub>O). Due to the good results, only minor recommendations were made, addressing mainly data submission and a few instrumental issues.

WCC-Empa joined a mission of MeteoSwiss to the Kenia Meteorological Department (KMD) and the global GAW station **Mt. Kenya** in September 2021. Two new ozone analysers (for KMD and MKN) were purchased by MeteoSwiss. These instruments were audited/calibrated at KMD using the KMD ozone standard with traceability to the ozone reference of WCC-Empa. One of the ozone analysers was then installed at MKN, and the parallel measurement with the existing ozone instrument showed agreement, well within the WMO/GAW network compatibility goals. At MKN, the Picarro instrument (CO, CH<sub>4</sub> and CO<sub>2</sub>) was upgraded to the latest operating system and software version. Afterwards, a comparison was made using standards provided by WCC-Empa, and agreement within the extended WMO/GAW network compatibility goals was found for all parameters. The visit at MKN included also training of the station staff, and ongoing remote support is provided by WCC-Empa and QA/SAC Switzerland throughout the year.

The audit at **Jungfraujoch** included parallel measurements for CO, CO<sub>2</sub>, and CH<sub>4</sub> over a period of two months, in addition to the regular performance audit with travelling standards. Preliminary results show good agreement with the WMO/GAW network compatibility goals.

Since the last audit by WCC-Empa at the **Cape Point** station in 2015, several instruments were replaced, and all gas chromatographic systems were decommissioned. The audit included parallel measurements for CO, CO<sub>2</sub>, and CH<sub>4</sub>, which are currently ongoing. Preliminary results showed agreement within the WMO/GAW network compatibility goals for CH<sub>4</sub>, and within the extended goals for CO and CO<sub>2</sub>. The station currently faces issues with the budget for investments and maintenance. This resulted in the discontinuation of the N<sub>2</sub>O measurements, and only one of originally three ozone analysers is currently operational at CPT. Furthermore, several issues were found with the ozone measurements, and some of the data need to be re-evaluated due to incorrect calibrations with a faulty ozone standard. Support has been provided by WCC-Empa to solve these issues.

The above audits included a review of data series available from the corresponding World Data Centres. Furthermore, WCC-Empa requested for an update of the information available in GAWSIS.

## 2. Contribution to expert teams

**Scientific Advisory Group for Reactive Gases (SAG-RG):** WCC-Empa actively participated in the SAG-RG online meeting from April 2021, and gave a presentation on "*Accurate Monitoring of Surface Ozone - CCQM-GAWG Task Group on Ozone Cross-Section Change Management*" during one of the virtual SAG meetings to update the SAG-RG on the planned change in the ozone cross section value.

**Expert Team on Atmospheric Composition Measurement Quality (ET-ACMQ):** Two virtual meetings were held in 2021. A work plan has been made, and WCC-Empa committed contributions to the topics "Evaluation and Update of GAW-QA/QC Tools", and "Evaluation and

Harmonization of QA/QC procedures (CCL-WCC/RCC-QA/SAC and their conformity with Metrology)".

**Expert Team on Measurement Uncertainty (ET-MU):** Five virtual meetings were held in 2021, which were all followed by WCC-Empa. So far, limited contributions mainly to the topic of "Harmonisation of the terminology related to measurement uncertainty" could be made.

**CCQM-GAWG Task Group on Ozone Cross-Section Change Management:** Following the recommendation of participants in the CCQM GAWG Workshop on Accurate Monitoring of Surface Ozone, 5-9 October 2020 at the BIPM, the Gas Analysis Working Group of the CCQM has established a Task Group to manage the change of the Ozone Cross-Section value used worldwide for surface ozone measurements. Christoph Zellweger was assigned to lead the Task Team "Guidance Development", which should give practical guidance for users of instruments in the field on how to deal with the change in cross section value, and processes to be followed to ensure their instruments are making measurements using the new cross section value correctly, and how to report results in any transitional period. The whole process will take several years, and the implementation of the new value is not expected before 2024.

### 3. Capacity building and technical / scientific meetings

- WCC-Empa participated in the 2<sup>nd</sup> Edition of the GAWTEC & YESS Webinar Series on Reactive Gases with a course on the "Measurements of Tropospheric Ozone". The recording is available from the GAWTEC, the YESS, and the Empa GAW website (<https://youtu.be/DksbpztnQU>).
- WCC-Empa produced a tutorial video about the handling of high pressure gas regulators. The video is available on the Empa GAW website (<https://youtu.be/wliMuzs2OJc>), and was successfully used to give guidance to the Mt. Kenya station operator during a standard gas exchange. More tutorial videos are currently in production.
- WCC-Empa trained operators of the GAW stations Mt. Kenya and Cape Point in ozone and greenhouse gas measurement techniques during the audits.
- WCC-Empa remotely supported the operators of the GAW stations Pha Din (disk image of the CRDS analyser to re-assume measurements), Bukit Kototabang (issues with GHG calibrations could be solved, support regarding ozone calibration), and Mt. Kenya (continued support, and monthly feedback regarding the GHG and CO measurements).
- WCC-Empa continued to provide input for both the GAW and GCOS Rolling Review of Requirements (RRR) processes coordinated by a joint WMO GAW/GCOS Task Team on Atmospheric Composition Observational Requirements.
- Due to the Covid-19 pandemic, some of the planned meetings (e.g. GGMT, TECO2021) were cancelled in 2021. WCC-Empa participated at the following scientific online meetings:
  - Global Monitoring Annual Conference (eGMAC 2021), online, May 2021. Oral presentation: *The revised CO<sub>2</sub> calibration scale at the World Calibration Centre WCC-Empa.*
  - GAW Symposium, online, June 2021. Poster presentation: *WCC-Empa activities improve data availability and data quality.*
  - BMKG Webinar on Climate and Air Quality, online, August 2021. Oral presentation: *World Calibration Centre WCC-Empa: Audits at Bukit Kototabang and world-wide.*
  - Swiss National GAW/GCOS Symposium, online, September 2021. Poster presentation: *World Calibration Centre WCC-Empa Supporting Global Research and Policies.*

#### 4. Technical work

**Surface Ozone:** The electronic, hardware and software upgrade for the NIST Standard Reference Photometer (SRP) was installed for one of the two SRPs available at Empa. The upgrade was made with remote support from NIST, and also involved staff of the NABEL network. Inter-comparisons between SRP#15 and #23 were made to ensure the stability of the WCC-Empa ozone reference over time, and also included comparisons before and after the upgrade of SRP#15.

SRP#15 was re-certified through a comparison with SRP#14 at the Federal Institute of Metrology (METAS) before the upgrade. Another comparison/re-certification with the upgraded instrument is currently ongoing.

**Greenhouse Gases and Carbon Monoxide:** In 2021, the revision of the CO<sub>2</sub> calibration scale published by NOAA (Hall et al., 2020), and new data for all NOAA standards on the revised WMO-X2019 CO<sub>2</sub> scale became officially available. WCC-Empa implemented the new calibration scale, and a re-analysis of the calibration standards purchased over the last 20 years was made to assess the internal consistency of the revised scale. The results were presented during eGMAC 2021, and showed that the revised scale is an improvement compared to the former WMO-X2007 CO<sub>2</sub> scale. However, the re-analysis also pointed to a potential drift in two of the most recent CO<sub>2</sub> standards available at WCC-Empa, which has also been communicated to NOAA. These standards were returned to NOAA for re-certification.

WCC-Empa continued with the support of the Carbosense project (low cost CO<sub>2</sub> sensors) mainly through calibrations of reference standards.

#### 5. Publications

WCC-Empa contributed to the report "An update on low-cost sensors for the measurement of atmospheric composition" (WMO, 2021). The contributions were made in 2020, and the final report was published by WMO in 2021.

WCC-Empa contributions and expertise regarding quantification of nitrous oxide further lead to co-authorship in a scientific publication (Hill-Pearce et al., 2021).

The surface ozone audit data and the stability of the WCC-Empa ozone reference instruments from the last 25 years was further analysed. A publication is planned as soon as the data of the latest upgrade of the WCC-Empa ozone reference will become available.

#### 6. WMO-GEF Storehouse

The support of the Global Environment Facility (GEF) stations with remaining funds of the GAW GEF project continued. In 2021, the GAW stations Assekrem (Algeria) and Mt. Kenya were supported. At MKN, small spare parts (Swagelock items) and inlet filters for the ozone instrument were provided. ASK was also supported with inlet filters, and an ozone instrument was sent to Algeria. Unfortunately, the instrument has not yet arrived, and WCC-Empa is trying to solve the issue. With the remaining funds, continued support for the next one or two years depending on the needs of the stations is secured. An overview of the activities and the budget of the Storehouse project are available from WCC-Empa on request.

#### 7. Storehouse for Twinning Stations

The GAW / CATCOS station Issyk-Kul was supported by supplying an external pump for the ozone measurements. Pumps were also purchased for the GAW / CATCOS station Pha Din. Furthermore, a decommissioned Empa ozone analyser was serviced and is now ready for shipment to the GAW

station Cape Point. It was noted during the audit that the only remaining analyser of Cape Point is in a bad condition, and needs replacement. The Cape Point station also applied for funds to purchase new analysers. However, this process is rather time consuming, and the support of the storehouse for twinning stations would help to prevent a data gap in one of the longest ozone time series in the Southern Hemisphere.

### **Acknowledgements**

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### **References**

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## Workflow 2021

### 1st quarter 2021

- Remote support of GAW stations (mainly MKN, BKT, and PDI) throughout the year.
- Comparisons between Standard Reference Photometers SRP#15 and #23.
- Tutorial video for pressure regulator handling.
- Implementation and consistency check of the revised CO<sub>2</sub> calibration scale.
- Input for the GAW and GCOS Rolling Review of Requirements (RRR) processes.

### 2nd quarter 2021

- Contribution to WMO/GAW and BIPM Expert Teams throughout the year.
- GHG and CO standard calibration, British Antarctic Survey (Antarctica).
- Participation / oral presentation at eGMAC 2021.
- Participation / poster presentation at GAW symposium.

### 3rd quarter 2021

- System and performance audits at the global GAW station Pallas (O<sub>3</sub>, CO, CH<sub>4</sub>, N<sub>2</sub>O, CO<sub>2</sub>, parallel measurements) (4. – 8. July).
- System and performance audit / maintenance visit at the global GAW station Mt. Kenya (O<sub>3</sub>, CO, CH<sub>4</sub>, CO<sub>2</sub>) and at KMD (31. August – 7. September).
- Participation / oral presentation at the BMKG Webinar.
- Participation / poster presentation at Swiss National GAW/GCOS symposium.
- SRP re-certification at METAS.

### 4th quarter 2021

- System and performance audits at the global GAW station Jungfrauoch (O<sub>3</sub>, CO, CH<sub>4</sub>, N<sub>2</sub>O, CO<sub>2</sub>, parallel measurements) (1. – 2. November).
- System and performance audits at the global GAW station Cape Point (O<sub>3</sub>, CO, CH<sub>4</sub>, CO<sub>2</sub>, parallel measurements) (16. – 19. November).
- GHG and CO standard calibration, British Antarctic Survey (Antarctica).
- Contribution to GAWTEC online courses.
- GHG and CO standard calibration, University of Bristol (GB Regional Stations, Mace Head).
- Hardware, electronic and software update of SRP#15.

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Laboratory Air Pollution / Environmental Technology

Project manager

Head of the Department

Dr. C. Zellweger

Dr. B. Buchmann