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

Activity Report 2022
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 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. This is essential to address the spatial and temporal variability of atmospheric composition.

Within GAW, an elaborate quality management framework was developed to achieve these goals. Central facilities supporting the quality assurance and control (World- and Regional Calibration Centres, Central Calibration Laboratories), providing scientific and technical guidance (Quality Assurance/Science Activity Centres), and allowing access to data of the global network (World Data Centres) were implemented.

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 2022.

1. System- and performance audits

The following GAW stations were audited in 2022:

Jeju Gosan (JGS)	O_3, CO, CH_4, CO_2 and N_2O	2nd audit
Anmyeon-do (AMY)	O_3, CO, CH_4, CO_2 and N_2O	3rd audit
Zeppelin Mountain (ZEP)	O_3, CO, CH_4, and CO_2	5th audit
La Réunion (RUN)	O_3, CO, CH_4, and CO_2	1st audit
Pha Din (PDI)	O_3, CO, CH_4, and CO_2	1st audit

The audit at the Mt. Cimone Station, which was planned for 2022, had to be postponed to 2023 due to renovation work at the station, and the audits at the two Korean sites (JGS and AMY) were made instead. To ensure traceability of ozone measurements at Mt. Cimone and other Italian GAW stations, the two ozone reference standards of Mt. Cimone and the calibration laboratory in Bologna were certified at WCC-Empa.

Furthermore, the following calibration and comparison activities were made in 2022 to support GAW stations and the WMO/GAW programme in general:

MeteoSwiss (Mt. Kenya)	O_3 analyser calibration
University of Bristol (GB Stations and Mace Head)	GHG and CO (standard calibration)

WCC-Empa conducted the second system- and performance audit at the regional GAW station **Jeju Gosan**. The station is classified as a regional station but is strategically very important due to its location. It is well embedded in international activities (e.g. AGAGE) and features a large measurement programme. Furthermore, the National Institute of Meteorological Sciences (NIMS), responsible for Jeju Gosan, operates the calibration laboratory for all Korean GAW station. The audit included parallel measurements for CO, CO_2, and CH_4 over a period of four months. The results of the comparisons were within the WMO/GAW network compatibility goals (CH_4 and CO_2) or extended compatibility goals (CO) at the relevant amount fractions. The data quality objectives were only partly met for O_3 and N_2O, and WCC-Empa made recommendations to improve the measurements.

The audit at Jeju Gosan was combined with an audit at the regional GAW station **Anmyeon-do** (AMY), which is strategically important because pollution outflow from continental Asia can be well detected at this site. The audit at AMY followed up on issues of the last audit in 2017, and further recommendations were made to continuously improve surface ozone measurements. The results of the comparisons were within the WMO/GAW network compatibility goals (CH_4 and CO_2) or extended compatibility goals (CO and N_2O) at the relevant amount fractions. Therefore, only minor recommendations were made regarding CO and GHG measurements.

Excellent results meeting the WMO/GAW network compatibility goals (O_3, CH_4 and CO_2) were found during the audit at the global GAW station **Zeppelin Mountain**. Comparisons for CO were slightly exceeding the extended WMO/GAW network compatibility goal. However, an issue regarding the ozone inlet system was found, which was immediately corrected during the audit. The good results of the GHG as well as the remaining bias of the CO measurements were confirmed by parallel measurements over seven weeks.

The audit at the global GAW station **La Réunion** (RUN) was jointly conducted with the ICOS mobile laboratory. The audit revealed a problem with the ozone analyser (ozone breakthrough through the scrubber) which was not detected by the RUN staff. This was fixed during the audit, and the instrument has been calibrated against the WCC-Empa reference. The preliminary results for the other parameters were within the WMO/GAW network compatibility goals (CH_4 and CO_2) and extended goal (CO). These results were confirmed by parallel measurements between RUN, the ICOS mobile laboratory, and WCC-Empa over a period of six weeks.

Operator training was the main focus of the audit at the regional GAW station **Pha Din**. The GHG, CO and ozone measurements were established in 2014 as part of the Capacity Building and Twinning for Climate Observing Systems (CATCOS) project with support by the Swiss Agency for Development and Cooperation (SDC) and MeteoSwiss as the coordinating partner. The audit confirmed that the measurements are still operational, and results within the WMO/GAW network compatibility goals (O_3, CH_4 and CO_2) and extended goal (CO) were found. An issue with a faulty interface board of the ozone instrument could be fixed during the audit, and calibration standards were provided by WCC-Empa for the continuation of the GHG and CO measurements. However, the instrumentation is reaching the end of its expected lifetime, and replacement needs to be considered especially for the GHG analyser.

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 meetings, and at an in-person meeting at WMO in October 2022. The SAG-RG was continuously updated by WCC-Empa on the progress regarding the change of the ozone cross section. WCC-Empa suggested to update the ozone measurement guideline (WMO, 2013), which was agreed by the SAG.

Expert Team on Atmospheric Composition Measurement Quality (ET-ACMQ): WCC-Empa actively participated in the two online meetings in 2022, but was not able to attend the in-person meeting during TECO-2022. WCC-Empa provided input to an overview of the activities of the central facilities, and informed the expert team on the ozone cross section change. The revision of the ozone measurement guideline will be coordinated with members from ET-ACMQ in collaboration with the SAG-RG.

Expert Team on Measurement Uncertainty (ET-MU): Four virtual meetings were held in 2022. WCC-Empa gave a presentation on "*Global Atmosphere Watch and Measurement Uncertainties*" during one of the meetings, and contributed to a document on terminology.

CCQM-GAWG Task Group on Ozone Cross-Section Change Management: WCC-Empa actively participated in three online meetings in 2022, and prepared a first guidance document regarding metadata provision for data submitters. The document is currently under review, and is planned to be published on the BIPM website. Since a number of standard documents such as ISO guides need to be revised due to the cross section change, the implementation date of the cross section change of January 2024 has most likely to be postponed.

3. Capacity building and technical / scientific meetings

- Global Monitoring Annual Conference (eGMAC 2022), online, May 2022. Online attendance.
- WCC-Empa gave an oral presentation about "*Accurate measurements of greenhouse gases – what we can learn from over 100 audits in 25 years*" at the WMO/BIPM workshop "Metrology for Climate Action" in September 2022. The presentation resulted in several recommendations aimed to improve measurements. The workshop report is planned to be published in 2023.
- 21st expert meeting on Greenhouse Gas Measurement Techniques (GGMT-2022). Oral presentation: *What can we learn from over 100 audits in 25 years regarding accurate measurements of greenhouse gases?*
- WCC-Empa trained operators of the GAW stations Jeju Gosan, Anmyeon-do, Zeppelin Mountain, Pha Din and La Réunion in ozone and greenhouse gas measurement techniques during the audits.
- WCC-Empa remotely supported the operators of the GAW stations Mt. Kenya with the calibration of a third ozone analyser, provision of standard gases, and monthly feedback regarding the GHG and CO measurements. Furthermore, remote support was provided to Ushuaia (advice on measurement programme, selection of instruments), Izaña (ozone calibration), Hohenpeissenberg (advice regarding new ozone inlet), Danum Valley (GAWSIS issues), Cape Point (ozone calibration, shipment logistics) and Bariri, Indonesia (GHG data).

4. Technical work

Surface Ozone: The electronic, hardware and software upgrade for the NIST Standard Reference Photometers (SRP) was finalized, and both SRPs are now upgraded. 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.

SRP#15 was re-certified through a comparison with SRP#14 at the Federal Institute of Metrology (METAS) after the upgrade. The WCC-Empa SRP was used as the master instrument since the main METAS SRP has not yet been upgraded. Upgrade of the METAS SRP is planned for 2023.

WCC-Empa successfully passed a surveillance audit by the Swiss Accreditation Service as a calibration laboratory for ozone measuring instruments.

Greenhouse Gases and Carbon Monoxide: Re-analysis of the WCC-Empa CO_2 calibration standards purchased over the last 20 years indicated drift in two of the more recent CO_2 standards. These standards were returned to NOAA for re-analysis, which confirmed the drift. This has been communicated to NOAA, since the drift was potentially caused by shorter cylinder conditioning time between filling and analysis at NOAA.

WCC-Empa is using CO standards with a higher amount fraction (~3 ppm) in combination with zero air for the assignments of CO values to travelling standards. This method reduces the influence of CO drift, and allows to quantify the drift in the NOAA reference standards. This calibration approach was presented at the GGMT-2022 meeting and the WMO/BIPM workshop "Metrology for Climate Action", and corresponding recommendations were made.

WCC-Empa participated in an ongoing round robin experiment between NOAA, the ICOS flask and calibration laboratory, the ICOS mobile lab, the Max Planck Institute for Biogeochemistry, and WCC-Empa. The results of the 2022 comparison are in line with previous experiments, and confirm traceability of WCC-Empa to the WMO/GAW reference for CO, CH_4, CO_2, and N_2O.

WCC-Empa supported of the ICOS Cities project (low cost CO_2 sensors) mainly through calibrations of reference standards.

5. Publications

WCC-Empa implemented the newest upgrade on its NIST Standard Reference Photometers, and more than 20 years of comparison data is now available. Data has been analysed, and is currently prepared for a publication on the long-term stability of the ozone reference in combination with results of GAW station audits.

6. WMO-GEF Storehouse

The support of the Global Environment Facility (GEF) stations with remaining funds of the GAW GEF project continued. In 2022, the GAW station Mt. Kenya was supported by provision of two additional calibration standards for the GHG/CO instrument, Swagelok items, and the calibration and shipment of an ozone analyser.

An overview of the activities and the budget of the Storehouse project are available from WCC-Empa on request.

7. Storehouse for Twinning Stations

Cape Point received a refurbished ozone analyser, and the ozone standard of the station has been repaired and calibrated at Empa.

New pumps were installed at the GAW / CATCOS station Pha Din for the ozone and GHG analysers. A Nafion drying system was implemented at PDI to protect the GHG instrument and to improve CO measurements. Two additional calibration standards (GHG and CO) were provided to PDI. In addition, a temperature/pressure/humidity logger was donated to PDI, and the ozone analyser was repaired (new interface board).

The Cholpon Ata station was supported by shipment of a pump to Kyrgyzstan.

Acknowledgements
WCC-Empa is financially supported by MeteoSwiss and Empa.

References

WMO: Guidelines for Continuous Measurements of Ozone in the Troposphere, WMO TD No. 1110, GAW Report No. 209, World Meteorological Organization, Geneva, Switzerland, 2013.

Proposed WCC-Empa tasks 2022 and progress overview

The table below gives an overview of the tasks proposed by WCC-Empa for the year 2022, and the status as of 31 December 2022.

Task #	Short description	Status	Remarks
W22-1	Audit Pha Din	Done	November 2022
W22-2	Audit Zeppelin	Done	September 2022
W22-3	Audit La Réunion	Done	October
W22-4	Audit Mt. Cimone	Postponed	Audits at JGS and AMY instead
W22-5	SAG-RG	Done	Ongoing membership
W22-6	ET-ACMQ	Done	Ongoing membership
W22-7	ET-MU	Done	Ongoing membership
W22-8	CCQM-GAWG Task Group	Done	Ongoing membership
W22-9	Operator training	Done	PDI, RUN, JGS, AMY
W22-10	New video tutorials	In progress	Work ongoing, will be finalised in 5/23
W22-11	NOAA/GMD annual meeting	Done	Participation
W22-12	GGMT2022	Done	Oral presentation
W22-13	BIPM Workshop	Done	Oral presentation
W22-14	TECO2022	Cancelled	WCC participation was not possible, presentation by QA/SAC
W22-15	SRP#23 upgrade	Done	Both SRPs upgraded to latest version
W22-16	Internal SRP-SRP comparisons	Done	Several comparison in 2022
W22-17	SRP re-certification @METAS	Done	SRP#15 certified at METAS
W22-18	BIPM O_3 key comparison	Postponed	METAS comparisons in 2022
W22-19	SAS audit	Done	Passed, only minor nonconformities
W22-20	WMO round robin	Postponed	Delayed, cylinders not yet received
W22-21	Revised CO_2 scale	Done	Fully implemented at WCC-Empa
W22-22	Parallel measurements	Done	JGS, ZEP, RUN
W22-23	N_2O audits	Done	JGS, AMY
W22-24	Future WCC-N_2O	In progress	KIT/IMK-IFU resigned in late 2022
W22-25	O_3 Publication by WCC-Empa	In progress	Work ongoing, will be finalised 2023
W22-26	GAW GEF Storehouse	Done	Continued support of GEF stations
W22-27	Twinning Storehouse	Done	Continued support of twinning stations

Dübendorf, April 2023

Laboratory Air Pollution / Environmental Technology

Head of the Department

Brigitte Buchmann

Digital unterschrieben von Brigitte Buchmann
Datum: 2023.04.12 13:08:32 +02'00'

Dr. B. Buchmann

Project manager

Digitally signed by Christoph Zellweger
Date: 2023.04.05 11:20:23 +02'00'

Dr. C. Zellweger