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Annual Activity Report 2019 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. This report gives an overview of the activities of WCC-Empa for the year 2019.

1. System- and performance audits

The following GAW stations were audited in 2019:

Bukit Kototabang (BKT)	O ₃ , CO, CH ₄ , and CO ₂	8 th audit
Izaña (IZO)	O ₃ , CO, CH ₄ , CO ₂ and N ₂ O	7 th audit
Ushuaia (USH)	O ₃ , CO, CH ₄ , and CO ₂	4 th audit
Mt. Kenya (MKN)	O ₃ , CO, CH ₄ , and CO ₂	8 th audit

Furthermore, the following calibration and comparison activities were made in 2019 to support GAW stations and the WMO/GAW programme in general:

University of Manchester / Leeds (GB Regional Stations)	GHG and CO (standard calibration)
Paul Scherrer Institute / MOSAiC project (polar expedition)	GHG and CO (standard calibration)

WCC-Empa conducted the eight system- and performance audit at the global GAW station **Bukit Kototabang**. GHG measurements were successfully re-established, and WCC-Empa provided training in data analysis. The station staff is now able to analyze the GHG data without external support and a complete GHG time series with a data availability of 96% is available since the audit. Results of the comparisons showed that most of the measurements comply now with the network compatibility goals of the GAW programme. The audit was complemented by parallel measurements for CO, CH₄, and CO₂ over a period of one month, which showed small differences

due to different air inlet locations. It is also noteworthy to mention that the new GHG instrument is now also used to calibrate GHG standards for other GAW stations in Indonesia.

The audit at the **Izaña** station followed up on issues with the ozone calibrations identified during the previous audit in 2013. These issues were solved, and the recommendations made by WCC-Empa have been implemented. Furthermore, a new measurement system for CO₂, CH₄ and CO was installed at the station. The assessment by WCC-Empa showed that the new system is superior to the previous analysers, and the results of the performance audit showed good compliance with the WMO/GAW network compatibility goals. This was also confirmed by parallel measurements, which were made over a period of one month. In 2018, the N₂O measurement system was complemented by a quantum cascade laser based analyser. This analyser was also for the first time independently checked, and results were in excellent agreement with the WMO/GAW reference. In addition, the organisation and responsibilities of the GHG and reactive gases measurement programmes at Izaña has completely been re-organised in 2018. The new staff responsible for the operation has been trained by WCC-Empa during the audit.

The audit at the **Ushuaia** station assessed for the first time the newly established continuous CO₂, CH₄ and CO measurements. Results showed good agreement with the WMO/GAW reference. However, the station staff was not yet able to correctly process and validate the data. Therefore, particular attention was paid to the training of the new station staff, both with regard to GHG and surface ozone measurements. The audit included parallel measurements, which showed good agreement between Ushuaia and WCC-Empa. This data set is currently used for further training in data processing.

During the audit at the **Mt. Kenya** station, a new Picarro G2401 instrument was installed together with a new calibration system. WCC-Empa further assessed the existing surface ozone and CO instrumentation. The audit showed that the ozone instrument failed in September 2019 due to leaking solenoid valves. Re-establishment of ozone measurements was possible using a spare instrument, which was repaired during the last audit in 2015. The existing CO instrument was replaced by the Picarro system. The audit at Mt. Kenya was conducted by a joint team from MeteoSwiss, PSI, and Empa, and covered all parameters measured at Mt. Kenya. The internal power system has significantly improved by a new UPS system installed by MeteoSwiss. A few issues, especially with regard to the internet connectivity, need still to be solved during upcoming station visits.

The audit in Kenya also included the ozone instruments at KMD, which were both within the data quality objectives of the GAW programme.

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 GAW SIS.

2. Capacity building and technical / scientific meetings

- WCC-Empa, together with QA/SAC Switzerland, trained operators of the GAW stations Bukit Kototabang, Izaña, Ushuaia and Mt. Kenya in ozone and greenhouse gas measurement techniques, QA/QC and data management during the audits.
- WCC-Empa provided 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.

- WCC-Empa contributed to the following scientific meetings:
 - EGU (Oral presentation, Quality control supporting climate policy and research: Assessing two decades of GAW audit results for N₂O and CO).
 - GGMT2019 (Oral presentation: Recent Activities and Achievements of WCC-Empa).

3. Technical and theoretical work / publications

Surface Ozone: Inter-comparisons between Standard Reference Photometers SRP#15 and #23 were made to ensure the stability of the WCC-Empa ozone reference over time.

The electronic, hardware and software upgrade of the SRP systems announced by NIST has been tested at BIPM. The hardware is now available, but the upgrade has not yet been released due to a delay in the software development. WCC-Empa will upgrade the SRPs as soon as the upgrade becomes available.

Greenhouse Gases and Carbon Monoxide: The WMO round robin experiment, which will be organised by the Central Calibration Laboratory (CCL) and was scheduled to start in 2019, has not yet been launched. The revision of the CO₂ calibration scale is also pending. WCC-Empa re-analysed all available standards from the CCL and communicated results to the CCL. The observed deviations are in line with the upcoming CO₂ scale revision, and preliminary values on the revised calibration scale were provided to WCC-Empa. NOAA acknowledged that the data provided by WCC-Empa is very useful, particularly since the results span a range of mixing ratios and time.

The GHG measurement system of the NABEL / GAW calibration laboratory was replaced by new instrumentation (Picarro G2401, financed by NABEL). WCC-Empa extensively tested the new instrument. The quality of the calibrations made at Empa will further improve with the new system, and redundant values for CO can now be obtained.

WCC-Empa supported the Carbosense project (low cost CO₂ sensors) with calibration and knowhow regarding water vapour correction.

Publications: WCC-Empa submitted a paper on "Recent advances in measurement techniques for atmospheric nitrous oxide and carbon monoxide observations" to Atmospheric Measurement Techniques. The manuscript was rated "very good / excellent" by the reviewers, and is now published (Zellweger et al., 2019).

Furthermore, WCC-Empa contributions and expertise lead also to co-authorship in scientific publications (Brewer et al., 2019; Yu et al., 2019).

4. Storehouse

The support of the Global Environment Facility (GEF) stations with remaining funds of the GAW GEF project continued. In 2019, funds from the storehouse project were used to supply calibration standards to the GAW stations Ushuaia and Mt. Kenya. In addition, a dryer was installed for the new GHG measurement system at USH, which will improve the accuracy of the measurements and protects the instrument from accidental damage due to water condensation. Currently, no funds are available, but a refill of USD 25000.- will be provided by WMO in 2020, which guarantees continued support for the next one or two years depending on the needs of the stations. An overview of the activities and the budget of the Storehouse project are available from WCC-Empa on request.

The funds of the storehouse are strictly limited to GEF stations; in order to minimize data gaps, it would be beneficial to have similar funding also for other stations (e.g. CATCOS stations).

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