World Calibration Centre for Carbon Dioxide (Audits) – Supporting the Quality of the Global Observation System

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Outline

- History and mandate of WCC-CO₂ (Audits)
- System and performance audits
- Traceability of WCC-CO₂ to CCL
- Transfer of the WMO scale to travelling standards
- Evaluation of inter-comparison data
- Conclusions
History of WCC-Empa

- World Calibration Center for Surface Ozone, Carbon Monoxide and Methane
  - established 1995, 1 full-time staff
  - Surface Ozone 1996
  - Carbon Monoxide 1997
  - Methane 2000
  - Nitrous Oxide 2007 (collaboration with WCC-N2O)

See P2, Zellweger et al.

Audits (cumulative)

Joerg.klausen@empa.ch, 15th WMO/IAEA Meeting of Experts on CO2 etc., 7-10 September 2009, Jena, Germany
Scope
- Surface ozone, carbon monoxide,
- Methane, (nitrous oxide), carbon dioxide (from 2010)

Primary Tasks
- Ensure traceability of measurements at Global GAW stations to designated GAW Reference Standard
- Support stations with regards to instrument and/or measurement problems
- Capacity Building, "1:1"-Training
Towards a WCC-CO$_2$ (Audits)

- **2001-2008**  Stations audited by WCC-Empa have repeatedly requested that CO$_2$ be included.
- **Feb 2009**  Funding secured from MeteoSwiss with in-kind contributions from Empa to expand the scope of WCC-Empa.
- **March 2009**  Formal proposal for establishment of WCC-CO$_2$ (Audits) is submitted to WMO and SAG GG.
- **April 2009**  Proposal reviewed by SAG GG; recommendation is made to JSC OPAG-EPAG.
- **May 2009**  JSC OPAG-EPAC approves proposal; designates Empa as the WCC-CO$_2$ (Audits).
- **June 2009**  Practical preparations commence.
Mandate of WCC-CO$_2$ (Audits)

WCC-CO$_2$ (Audits) performs system and performance audits of continuous CO$_2$ measurements at Global GAW stations world-wide.

A **system audit** is a check of the overall conformity of a station with the principles of the GAW QA system. It involves an assessment of station siting, infrastructure, organization, operation, etc. The reference for conformity of a station will evolve as the GAW QA system evolves.

A **performance audit** is a voluntary check for conformity of a measurement where the audit criteria are the DQOs [data quality objectives] for that parameter. In the absence of formal DQOs, an audit will at least involve ensuring the traceability of measurements to the Reference Standard.

[GAW Strategic Plan 2007-2011]
Global Network of Continuous CO₂ Observations

![Map of Global Network of Continuous CO₂ Observations](image)

Legend:
- ▲ Global
- ● Regional
- ★ Contributing
GAW stations in scope of WCC-CO$_2$

X: audit not feasible
System Audit

PARTS OF THIS QUESTIONNAIRE
1. General audit information
2. Site and laboratory characteristics
3. Documentation of station
4. Organisation and personnel
5. Air inlet system
6. Instrumentation
7. Operation and maintenance
8. Standards
9. Data acquisition and processing
10. Data management and submission
11. Documentation
12. Actions to be taken after audit
Performance Audits and Traceability Chain
Traceability of WCC-CO$_2$ Lab Standards to CCL

- Currently, 3 NOAA certified standards
- Purchase 4 more in 2009
- Purchase 1-2 more every year
  - Maintain a range of 250 ~ 1000 ppbv CO$_2$
- Participate in round-robin exercises
- Constantly assess internal consistency of standards
- Return dubious standards to NOAA for re-calibration / re-certification

![Diagram showing traceability over time]

- send to CCL

\[ \hat{X} \quad \hat{X} \quad \hat{X} \quad \hat{X} \]

\[ X \quad X \quad X \quad X \]

\[ \text{time} \]
Isotope Issues

Issues

- Picarro CO₂ analyzer sensitive to $^{12}$C only
- NOAA CO₂ standards certified for total CO₂ and $\delta^{13}$C not necessarily the same in all of them
- Transfer of calibration to travelling standards needs correction

Approach (still to be refined)

- Characterize $\delta^{13}$C in cylinders using TDLS system available at Empa
- Use LICOR NDIR instrument in addition to Picarro
- Evaluate inter-comparison data considering type of instrument involved

See P16, Werner et al.
Uncertainty of CCL Standards – What’s in a word?

- Use of non-ISO terminology (formal issue)
- Certificate makes statements of reproducibility and repeatability
  - Okay for the CCL, but not useful for the user
  - Individual results should be used by the CCL to evaluate structure of residuals (e.g., drift); if residuals are okay, all data should be pooled
- Statements concerning other aspects of uncertainty are unclear (at least to me …)
- Present certificates make proper estimates of uncertainty difficult.

A (more) rigorous statement of uncertainties is needed in the certificate.

$$X_{CCL} = nnn.nn \pm ? \text{ ppm (k = 2)}$$
Uncertainty of Travelling Standards (TS)

- Calibration of transfer instrument using CCL standards
  - Fit slope and intercept ($\text{fit}_\text{exy}$)
  - Construct Working-Hotelling confidence interval for regression line
- (Inverse) prediction of travelling standards
  - Compute statistics of repeated measurements $Y_{TS}$
  - Invert regression line to get $X_{TS}$
  - Use confidence bands to obtain confidence limits
Evaluation of Station Analyzer (SA)

- Challenge station analyzer with TS
- Return travelling standards to WCC and check stability
  - Pool TS calibration data
- Evaluate measurements conducted at station
  - Fit slope and intercept (\texttt{fitexy})
  - Construct Working-Hotelling confidence interval for regression line
- Evaluate uncertainties determined at station
  - repeatability, drift of analyzer
- Evaluate bias of analyzer against DQOs
  - Issues with calibration
Conclusions

- **System audits**
  - offer a ‘second opinion’ and
  - provide documentation of procedures and design of system

- **Performance audits**
  - offer an additional means of ensuring traceability to the CCL
  - help unveil and resolve ‘issues’ with calibration
  - are evaluated using a rigorous statistical approach

- **Travelling standards**
  - carry a somewhat larger uncertainty than CCL lab standards
  - bring an entire set of ‘fresh’ standards to a station

- **Personal exchange of experience during an audit**
  - improves the quality of the observing systems
  - fosters identification of observers with their work
  - gives recognition to the work at the station

- **Assessment of uncertainty of observations requires more rigorous statements of uncertainty of CCL standards**
Acknowledgement

- Financial support from MeteoSwiss