SYSTEM AND PERFORMANCE AUDIT OF METHANE AND CARBON DIOXIDE AT THE

REGIONAL GAW STATION ANMYEON-DO REPULIC OF KOREA OCTOBER 2014

Submitted to the World Meteorological Organization by

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WCC-Empa Report 14/2

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EXECUTIVE SUMMARY AND RECOMMENDATIONS

The first system and performance audit by WCC-Empa[1] at the Regional GAW station Anmyeon-do was conducted from 27 - 29 October 2014 in agreement with the WMO/GAW quality assurance system (WMO, 2007b). Monitoring and research activities at the Anmyeon-do (AMY) regional GAW station are coordinated by the Korea Global Atmosphere Watch Center (KGAWC), which is run by the Korea Meteorological Administration (KMA) as one of the Korean contribution to the GAW programme.

No previous audits at the Anmyeon-do GAW observatory have been conducted by WCC-Empa. An audit for nitrous oxide was conducted by the WCC-N_2O in 2013.

The following people contributed to the audit:

Dr. Christoph Zellweger	Empa Dübendorf, WCC-Empa
Dr. Bok-Haeng Heo	KGAWC Director
Dr. Chulkyu Lee	KGAWC, GAW Country Contact
Ms. Haeyoung Lee	KGAWC, Scientist, Measurement leader of GHGs
Mr. Hong-Woo Choi	KGAWC, Technician, GHG measurements

This report summarises the assessment of the Anmyeon-do GAW station in general, as well as the methane and carbon dioxide measurements in particular.

The report is distributed to the AMY station, the Korean GAW Country Contact and the World Meteorological Organization in Geneva. The report will be posted on the internet.

The recommendations found in this report are graded as minor, important and critical and are complemented with a priority (*** indicating highest priority) and a suggested completion date.

Station Location and Access

The Anmyeon-do GAW Station is located on an island on the west coast of the Korean Peninsula. The station building itself is located on a hill at an elevation of 46 m above sea level, and comprises a 40 m tower. To the west the station is exposed to the open sea, with the Chinese mainland in a distance of 300-400 km. To the east of the station are several small farms producing mainly rice and sweet potatoes. Large parts of the area as well as the immediate surroundings of the station are covered by pine forests. The station is infrequently affected by local pollution, mainly during summer due to recreational activities, and autumn due to burning of crop residues.

Further information is available from the GAW Station Information System (GAWSIS) (http://gaw.empa.ch/gawsis) and the Korea GAW Center (KGAWC) website (http://www.climate.go.kr/home/Eng/htmls/KGAWC/sub1.html).

Station Facilities

The facilities at the site consist of a large building, which comprises spacious laboratories, workshops, meeting rooms and offices. The AMY research station is an ideal platform for continuous atmospheric research as well as measurement campaigns.

[1]WMO/GAW World Calibration Centre for Surface Ozone, Carbon Monoxide, Methane and Carbon Dioxide. WCC-Empa was assigned by WMO and is hosted by the Laboratory for Air Pollution and Environmental Technology of the Swiss Federal Laboratories for Materials Testing and Research (Empa). The mandate is to conduct system and performance audits at Global GAW stations every 2 – 4 years based on mutual agreement.

Air Inlet System

A common air inlet system for greenhouse gas (GHG) measurements is installed at AMY. Air is pumped from the 40 m tower to the laboratory building, and automatically dried to a dew point of -80°C using two cryogenic traps alternating every 24 hours. The stainless steel manifold is pressurized to approx. 2 bar, and instruments are directly connected to this manifold. The inlet system was found to be adequate during the WCC-Empa audit.

Station Management and Operation

The Anmyeon-do GAW station is operated by Environmental Meteorology Research Division in National Institute of Meteorological Sciences (NIMS), which is part of the Korea Meteorological Administration (KMA). At the time of the audit, the AMY site was operated by the Korea GAW Center (KGAWC). The station is visited during weekdays by approximately 10 -15 scientists, technical and administrational staff. The operation and maintenance of the station is well organized, with clear assignments of responsibilities. Nevertheless, it remains important that also staff with a scientific background is directly involved in the daily operation of the AMY station.

Recommendation 1 (, important, ongoing)**
KGAWC should explore all possibilities for training of station operators and scientists. Participation in GAWTEC as well as other training courses is highly recommended, and the knowledge needs to be shared between KGAWC staff.

Methane and Carbon Dioxide Measurements

Measurements of methane and carbon dioxide at Anmyeon-do commenced in 1999, and continuous data series are available since then. Initially, these measurements were made using a GC/FID system (Agilent 6890N) for CH_4, and an NDIR instrument (Siemens Ultramat) for CO_2. In 2011, a Picarro G2301 CRDS instrument was installed, and since the beginning of 2012, data of this instrument is considered for submission to the WMO/GAW data centre. Comparisons of the two different analytical systems for methane were published (KMA, 2013).

Instrumentation. Picarro G2301, including a cryogenic drying system. Ambient air is sampled from the top of the 40 m tower. Calibrations are manually made once per week.

Standards. A set of 4 NOAA standards is available for the calibration of the Picarro instrument. A list of the available standards is given in the Appendix.

Recommendation 2 (, important, 2015 and ongoing)**
WCC-Empa recommends implementing the possibilities of automatic measurement of standard gases. It is recommended to run regular span checks with at least two working standards. Furthermore, the use of a target cylinder is recommended.

Intercomparison (Performance Audit). The comparison involved repeated challenges of the AMY instruments with randomised CH_4 and CO_2 levels from travelling standards. The results of the comparison measurements for the individual measurement parameters are summarised and illustrated below.

The following equation characterises the instrument bias. The result is further illustrated in Figure 1 and Figure 2 with respect to the relevant mole fraction range (white area) and the WMO/GAW compatibility goals (green area) and extended compatibility goals (yellow area) (WMO, 2014).

PICARRO G2301 #857-CFADS2177:

Unbiased CH_4 mixing ratio:	X_{CH4} (ppb) = (CH_4 - 8.0 ppb) / 0.99548	(1a)
Remaining standard uncertainty:	u_{CH4} (ppb) = sqrt (0.3 ppb^2 + 1.30e-07 * X_{CH4}^2)	(1b)
Unbiased CO_2 mixing ratio:	X_{CO2} (ppm) = (CO_2 + 0.18 ppm) / 1.00079	(2a)
Remaining standard uncertainty:	u_{CO2} (ppm) = sqrt (0.01 ppm^2 + 3.28e-08 * X_{CO2}^2)	(2b)

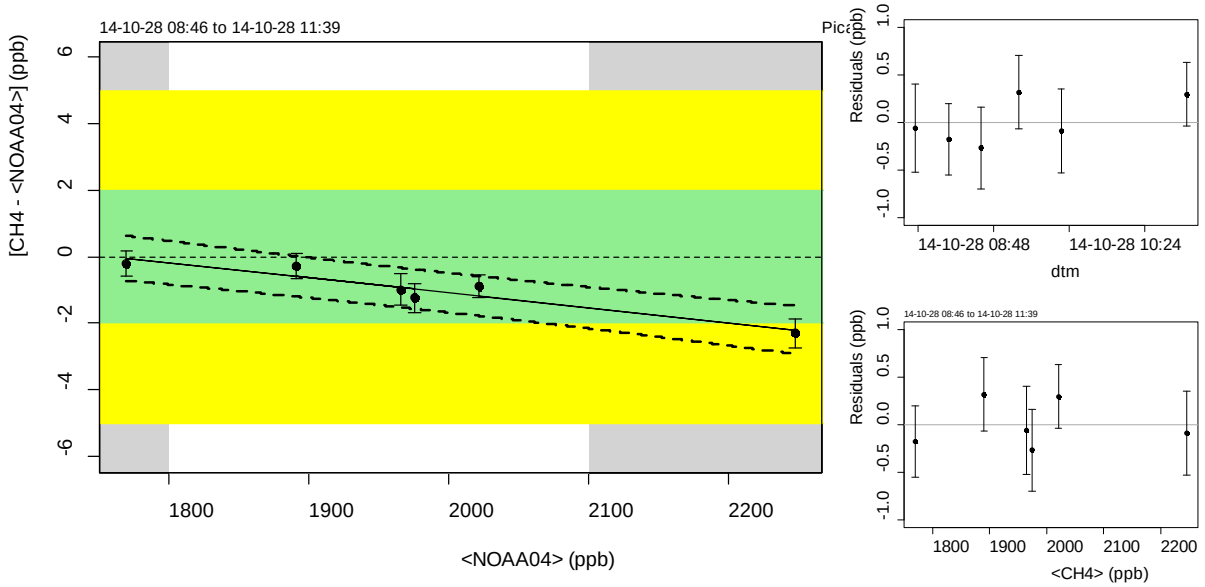

Figure 1. *Left: Bias of the PICARRO G2301 #857-CFADS2177 methane instrument with respect to the WMO-X2004 CH_4 reference scale as a function of mole fraction. The white area represents the mole fraction range relevant for AMY, whereas the green and yellow areas correspond to the compatibility goals and extended compatibility goals. Each point represents the average of data at a given level from a specific run. The error bars show the standard deviation of individual measurement points. The dashed lines around the regression lines are the Working-Hotelling 95% confidence bands. Right: Regression residuals (time dependence and mole fraction dependence).*

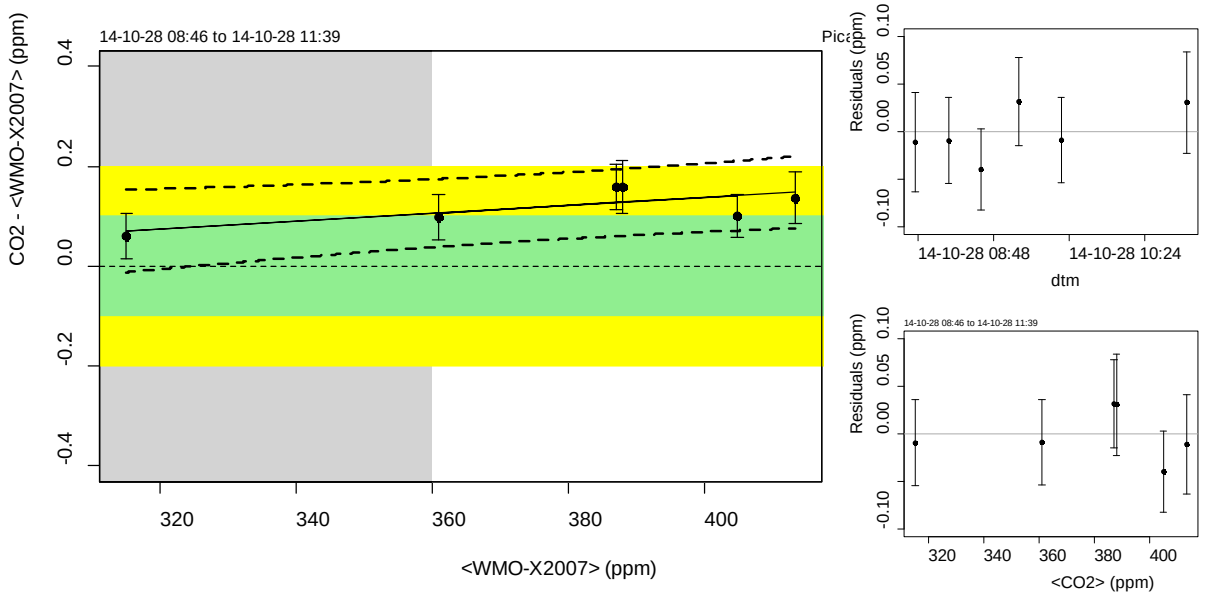

Figure 2. *Same as above for CO_2.*

The results of the comparisons can be summarised as follows:

Agreement within the WMO/GAW compatibility goals of ±2 ppb was found in the relevant mole fraction range of methane. The bias was slightly larger for CO_2; however, all results were within the extended WMO/GAW compatibility goal of ±0.2 ppm. Probably, these results could be further improved by the introduction of an automatic calibration scheme, and drift correction between calibrations.

The results of the comparison show that the CO_2/CH_4 instrumentation is fully adequate and no further immediate action is required.

Parallel Measurements of Ambient Air

The audit included parallel measurements of CO_2 and CH_4 with a WCC-Empa travelling instrument (TI) (Picarro G2401 SN # 1497-CFKADS2098). The TI was running from 27 October 2014 through 13 January 2015. The TI was connected to a spare sample port of the AMY manifold (description see above). To account for the effect of remaining water vapour, a correction function as described by Rella et al. (2013) was applied to the WCC-Empa CRDS data. Details of the calibration of the TI are given in the Appendix. The following figures show the results of the ambient air comparisons.

Methane:

The following figure shows the comparison of the AMY methane instruments with the WCC-Empa TI. The average bias was small and within the WMO/GAW Data Quality Objectives (DQOs); a slightly negative bias of 0.98 ppb was found. This is in perfect agreement with the results of the TS comparisons, and fully confirms that the whole measurement set-up is appropriate.

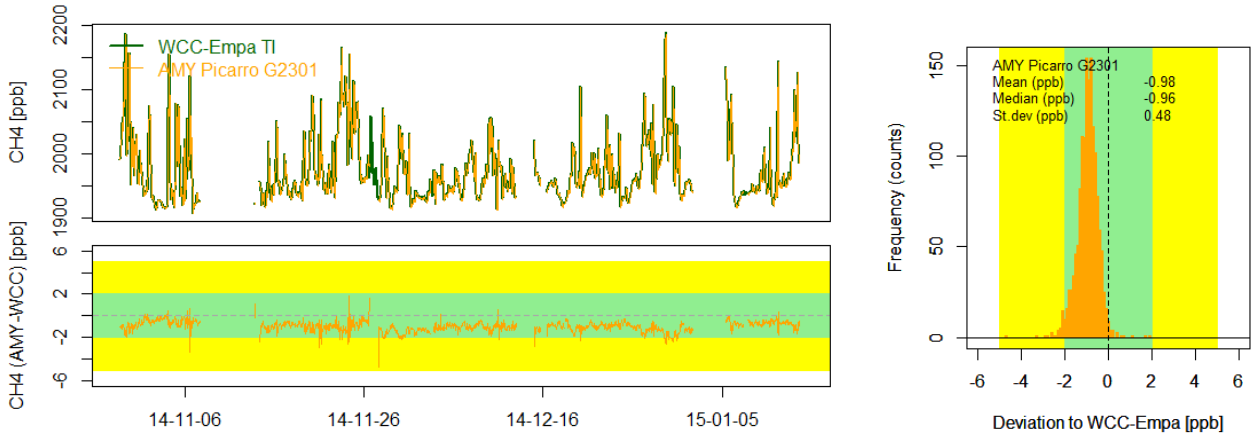

Figure 3. *Upper left panel: CH_4 time series (1-h averages) measured at AMY with the Picarro G2401 travelling instrument and the AMY Picarro G2301 analyser. Lower left panel: Deviation of the AMY system compared to the travelling instrument. Right panel: Frequency distribution of the deviations. The green and yellow areas refer to the WMO/GAW DQOs and extended DQOs.*

Carbon dioxide:

Figure 4 shows the comparison of the Picarro G2301 analyser with the WCC-Empa TI. The average bias was also small and within the WMO/GAW DQOs; however, significant jumps in the data series were observed. Most likely, these changes of the bias were caused by the manual weekly calibration of the AMY instrument, which might be insufficient to fully account for instrument drift. Therefore, automatic calibrations should be implemented for both CO_2 and CH_4, as recommended above.

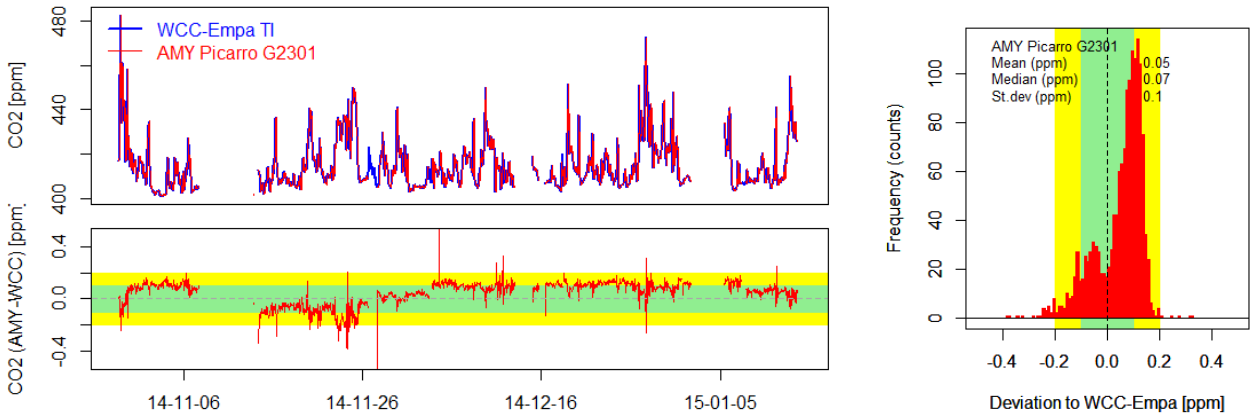

Figure 4. *Upper left panel: CO_2 time series (hourly averages) measured at AMY with the Picarro G2401 travelling instrument and the AMY Picarro G2301. Lower left panel: Deviation of the AMY system compared to the travelling instrument. Right panel: Frequency distribution of the deviations. The green and yellow areas refer to the WMO/GAW DQOs and extended DQOs.*

Data Acquisition and Management

CO_2 and CH_4 data are acquired using the Python based Picarro data acquisition system. For further data processing, the 5-second data is used (sync values). At the time of the audit, the data was re-processed at AMY. Final validated data is stored in a my-SQL database, and frequent backups to the KMA servers in Seoul are made. The system is fully adequate; however, it was noticed during the audit that the instrument time was approx. 1h 08 min behind local standard time. This was corrected before the start of the comparison campaign.

Recommendation 3 (*, critical, immediately)**
Automatic synchronization of the instrument and data acquisition times with time servers is needed. This has been implemented during the audit.

For each instrument, hand written and electronic log files are available. It is important that all relevant events and observations are recorded in these log files. WCC-Empa reviewed these files during the audit. It was found that these files were comprehensive.

Data Submission

CO_2 and CH_4 data (both from 1999-2013) have been submitted to the World Data Centre for Greenhouse Gases (WDCGG). Until now, reactive gases measurements are not considered as being part of GAW by KMA, and no data submission has been made.

Recommendation 4 (*, important, ongoing)
Data submission is one of the obligations of GAW stations. Available data should be submitted to the corresponding data centres, with a submission delay of maximum one year. This has been achieved in the past for CO_2 and CH_4, and continuation of this practice is encouraged.

Recommendation 5 (*, minor, as soon as possible)
GAWSIS needs to be updated to reflect the recent change in the measurement technique of the AMY GHG measurements.

Conclusions

The Regional GAW station Anmyeon-do comprises a very comprehensive set of measurements. The combination of long-term measurements, the large number of measured parameters and the location of the site make the AMY station a very important contribution to the GAW programme. The assessed GHG measurements were of high quality.

To date, not all of the parameters measured at AMY are considered as being part of the GAW programme by KMA, but KGAWC is working towards the integration of all measurements under the umbrella of GAW. WCC-Empa strongly encourages this process, since the available data would be a very valuable contribution to GAW.

The continuation of the Anmyeon-do measurement series as well as the inclusion of the reactive gases measurement programme as GAW parameters is highly recommended.

Summary Ranking of the Anmyeon-do GAW Station

System Audit Aspect	Adequacy[#]	Comment
Access	(5)	All year access possible
Facilities		
Laboratory and office space	(5)	Large laboratory facilities
Internet access	(5)	Reliable, sufficient bandwidth
Air Conditioning	(5)	Fully adequate
Power supply	(5)	Reliable
General Management and Operation		
Organisation	(5)	Well organised, clear responsibilities
Competence of staff	(4)	Good technical and scientific knowledge, international collaboration encouraged
Air Inlet System	(5)	Adequate system
Instrumentation		
CO_2/CH_4 (Picarro G2301)	(5)	Adequate instrumentation
Standards		
CO_2, CH_4	(4)	NOAA standards available, additional working standards recommended
Data Management		
Data acquisition	(5)	Fully adequate
Data processing (CO_2, CH_4)	(4)	Current praxis of weekly instrument calibration results in small jumps.
Data submission (CO_2, CH_4)	(5)	Timely, regular submission

[#]0: inadequate thru 5: adequate.

Dübendorf, November 2015

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WCC-Empa	QA/SAC Switzerland	Head of Department

APPENDIX

Regional GAW Station Anmyeon-do

Site description and measurement programme

Information about the Anmyeon-do GAW station is available on KGAWC website, and the station is also registered in GAWSIS.

https://www.climate.go.kr:8005/home/Eng/htmls/kgawc/sub3.html
http://gaw.empa.ch/gawsis/reports.asp?StationID=254

Organisation and Contact Persons

An overview of the organisation as well as contact persons is available from GAWSIS and the KGAWC website.

Methane and Carbon Dioxide Measurements

Monitoring Set-up and Procedures

Air Conditioning

All laboratories at AMY are fully air-conditioned to approx. 20°C.

Air Inlet System

Location of air intake: Air is sampled from the top of the 40 m tower.

Inlet protection: Funnel as rainwater protection.

Tubing / Material: Approx. 60 m ID 7.94 mm ½" tubing, Dekabon (Nitta Moore1300-10), flow rate approx. 17-20 l/min. From there short (max. 2 m) ¼" tubing to the instrument with a flow rate of approx. 0.5 l/min.

Inlet filter: Stainless steel inlet filter with a diameter of 4.7", and a pore size of 5 µm. The filter is changed monthly.

Humidity trap: Two cooling traps at -80℃, alternating every 24 h.

Residence time: Approx. 14 s

Instrumentation

A Picarro G2301 CO_2, CH_4 and H_2O analyser is available at AMY. Instrumental details are listed in Table 2. In addition, an Agilent 6890N GC/FID system available for the measurement of CH_4; data has been compared during the last 2-3 years with CRDS, and results were published. This instrument was not included in the audit since the Picarro is considered as the main CH_4 instrument.

Standards

Table 1 lists current standards for GHG calibrations available at AMY.

Table 1. Standards available at AMY for the calibration of GHG analyser.
Calibration scales: CH_4: WMO-X2004A, CO_2: WMO-X2007

Cylinder ID	Type	CH_4 (ppb)	CO_2 (ppm)	Start of use	End of use
CB09838	NOAA/ESRL	1673.89	351.72	2013	cont.
CB09738	NOAA/ESRL	1874.89	410.93	2013	cont.
CB08806	NOAA/ESRL	1995.39	448.67	2013	cont.
CB08819	NOAA/ESRL	1810.43	381.12	2013	cont.

Operation and Maintenance

Check for general operation:	Daily (Mon – Sun) by the station operator.
Inlet filter exchange:	Monthly.
Inlet pump exchange:	2-monthly.
Other:	As required.

In case of instrumental problems, Picarro support is contacted. Until now, no major problems occurred with the Picarro analyser.

Comparison with WCC-Empa travelling standards

All procedures were conducted according to the Standard Operating Procedure (WMO, 2007a) and included comparisons of the travelling standards at Empa before and after the comparison of the analyser. Details of the traceability of the travelling standards to the WMO/GAW Reference Standard at NOAA/ESRL are given in Table 6 below.

Setup and Connections

Table 2 shows details of the experimental setup during the comparison of the transfer standards and the station analyser. The data used for the evaluation was recorded by the station data acquisition system.

Table 2. Experimental details of the comparison.

Travelling standard (TS)	
WCC-Empa Traveling standards (6 l aluminium cylinder containing a mixture of natural and synthetic air), assigned values and standard uncertainties see Table 6.	
Station Analysers (OA)	
Model, S/N	PICARRO G2301 #857-CFADS2177
Principle	CRDS
Drying system	Cryogenic traps, -80°C
Comparison procedures	
Connection	The TS were connected to the sample inlet of the Picarro G2301.

Results

The results of the assessment are shown in the Executive Summary (Figures and Equations), and the individual measurements of the TS are presented in the following Tables.

Table 3. CH_4 aggregates computed from single analysis (1-min mean and standard deviation) for each level during the comparison of the Picarro G2301 #857-CFADS2177 (OA) with the WCC-Empa TS.

Date / Time	TS Cylinder	TS (ppb)	sdTS (ppb)	OA (ppb)	sd OA (ppb)	N	OA-TS (ppb)	OA-TS (%)
(14-10-28 08:46:00)	140515_FB03350	1965.67	0.08	1964.68	0.47	36	-0.99	-0.05
(14-10-28 09:07:20)	110511_FB03382	1769.73	0.08	1769.51	0.38	36	-0.22	-0.01
(14-10-28 09:28:00)	140514_FB03899	1975.31	0.11	1974.07	0.43	36	-1.24	-0.06
(14-10-28 09:52:00)	130819_FB03865	1891.17	0.10	1890.90	0.39	36	-0.27	-0.01
(14-10-28 10:19:00)	100212_FA02773	2247.74	0.19	2245.45	0.44	36	-2.29	-0.10
(14-10-28 11:39:00)	120803_FA02769	2021.75	0.04	2020.86	0.34	36	-0.89	-0.04

Table 4. CO_2 aggregates computed from single analysis (1-min mean and standard deviation) for each level during the comparison of the Picarro G2301 #857-CFADS2177 (OA) with the WCC-Empa TS.

Date / Time	TS Cylinder	TS (ppm)	sdTS (ppm)	OA (ppm)	sd OA (ppm)	N	OA-TS (ppm)	OA-TS (%)
(14-10-28 08:46:00)	140515_FB03350	413.38	0.02	413.52	0.05	36	0.14	0.03
(14-10-28 09:07:20)	110511_FB03382	315.17	0.04	315.23	0.05	36	0.06	0.02
(14-10-28 09:28:00)	140514_FB03899	404.88	0.04	404.98	0.04	36	0.10	0.02
(14-10-28 09:52:00)	130819_FB03865	387.02	0.02	387.18	0.05	36	0.16	0.04
(14-10-28 10:19:00)	100212_FA02773	360.96	0.03	361.06	0.04	36	0.10	0.03
(14-10-28 11:39:00)	120803_FA02769	387.93	0.03	388.09	0.05	36	0.16	0.04

WCC-Empa Traveling Standards

Greenhouse gases and carbon monoxide

WCC-Empa refers to the primary reference standards maintained by the Central Calibration Laboratory (CCL) for Carbon Dioxide and Methane. NOAA/ESRL was assigned by WMO as the CCL for the above parameters. WCC-Empa maintains a set of laboratory standards obtained from the CCL that are regularly compared with the CCL by way of traveling standards and by addition of new laboratory standards from the CCL. For the assignment of the mole fractions to the TS, the following calibration scales were used:

CO: WMO-X2004 scale (Novelli et al., 2003)
CO_2: WMO-X2007 scale (Zhao and Tans, 2006)
CH_4: WMO-X2004 scale (Dlugokencky et al., 2005)
N_2O: WMO-X2006A scale (http://www.esrl.noaa.gov/gmd/ccl/n2o_scale.html)

More information about the NOAA/ESRL calibration scales can be found on the GMD website (www.esrl.noaa.gov/gmd/ccl). The scales were transferred to the TS using the following instruments:

CO and N_2O: Aerodyne mini-cw (Mid-IR Spectroscopy using a Quantum Cascade Laser).
CO_2 and CH_4: Picarro G1301 (Cavity Ring Down Spectroscopy).

Table 5 gives an overview of the WCC-Empa laboratory standards that were used for transferring the CCL calibration scales to the WCC-Empa TS. For internal consistency among the available LS at WCC-Empa, new values have been assigned to the NOAA standards for some tanks. The results including estimated standard uncertainties of the WCC-Empa TS are listed in Table 6, and Figure 5 shows the analysis of the TS over time. A number of individual analysis results dating from before the audit was averaged. During this period, the standards remained usually stable with no significant drift. If drift is present, this will lead to an increased uncertainty of the TS.

Table 5. NOAA/ESRL laboratory standards at WCC-Empa.

Cylinder	CO	sd	CH_4	sd	N_2O	sd	CO_2	sd	CO	sd	CH_4	sd	N_2O	sd	CO_2	sd
	NOAA assigned values								WCC-Empa assigned values							
	(ppb)		(ppb)		(ppb)		(ppm)		(ppb)		(ppb)		(ppb)		(ppm)	
CC339523	347.9	0.3	1854.60	0.13	322.52	0.12	396.88	0.06	350.9	0.3	1855.31	0.03	322.52	0.02	396.94	0.02
CC339524	390.7	0.2	1980.28	0.30	355.42	0.16	795.42	0.06	394.1	0.4	1981.77	0.04	355.42	0.02	796.36	0.04
CC311846	166.4	0.1	1805.24	0.12	338.27	0.11	377.86	0.04	167.2	0.3	1805.31	0.11	338.27	0.01	377.84	0.02

Table 6. Calibration summary of the WCC-Empa travelling standards.

TS	CO (ppb)	sdCO (ppb)	CH_4 (ppb)	sdCH_4 (ppb)	CO_2 (ppm)	sdCO_2 (ppm)	N_2O (ppb)	sdN_2O (ppb)
100212_FA02773	58.94	0.91	2247.74	0.19	360.96	0.03	313.29	0.07
110511_FB03382	64.30	0.51	1769.73	0.08	315.17	0.04	311.49	0.04
120803_FA02769	133.94	0.29	2021.75	0.04	387.93	0.03	346.65	0.07
130819_FB03865	155.29	0.41	1891.17	0.1	387.02	0.02	319.99	0.02
140515_FB03350	182.56	0.1	1965.67	0.08	413.38	0.02	328.49	0.03
140514_FB03899	245.74	0.49	1975.31	0.11	404.88	0.04	328.57	0.03

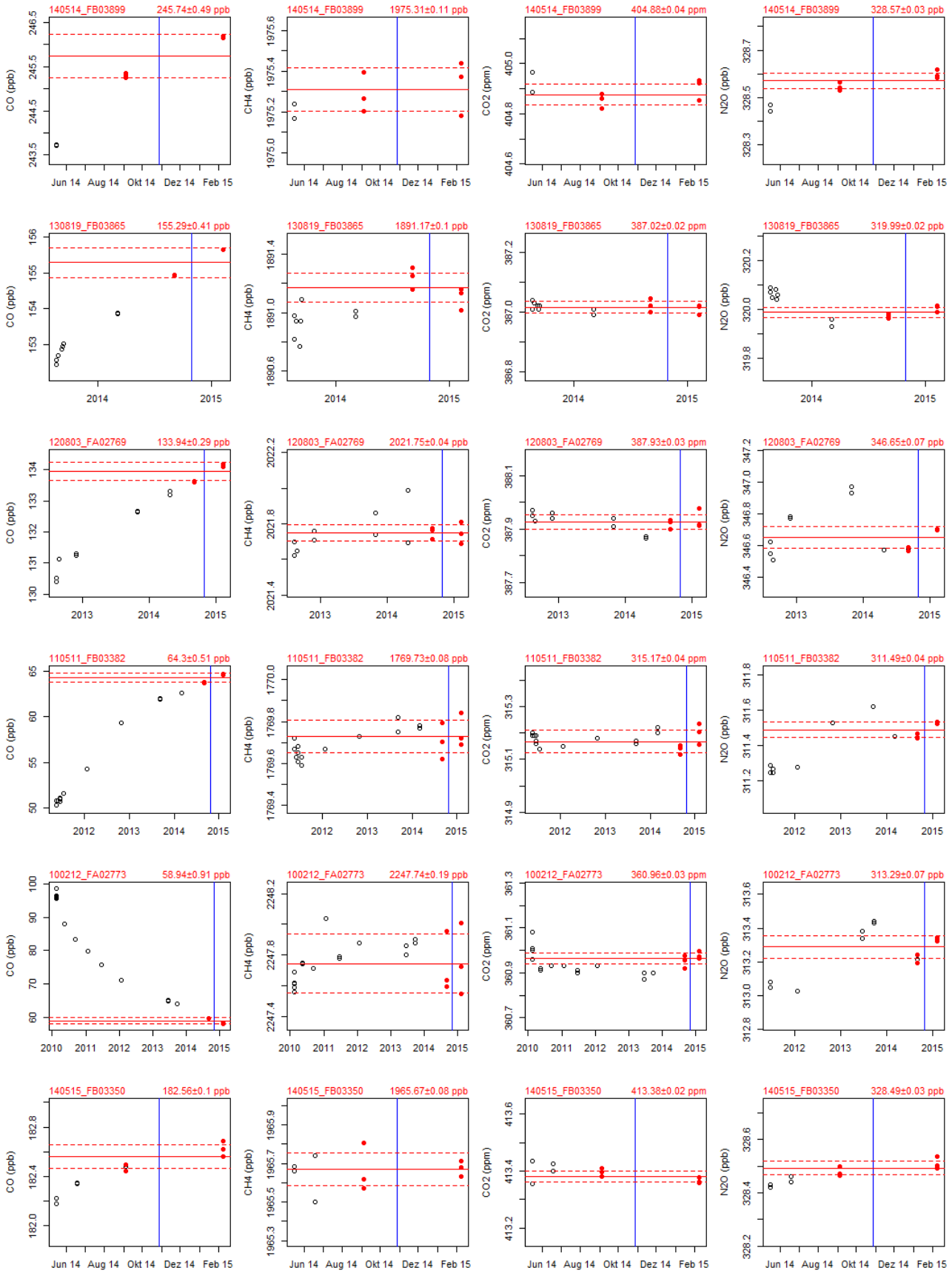

Figure 5. *Results of the WCC-Empa TS calibrations. Only the values of the red solid circles were considered for averaging. The red solid line is the average of the points that were considered for the assignment of the values; the red dotted line corresponds to the standard deviation of the measurement.*

Calibration of the WCC-Empa travelling instrument

The calibration of the WCC-Empa travelling instrument is shown in the following figures. For CH_4 and CO_2, the Picarro G2401 was calibrated every 30 h using one of the TS as a working standard (100212_FA02773), and two additional TS (140514_FB03899, 130819_FB03865) were used as target cylinders. Based on the measurements of the working standard, a drift correction using a loess fit was applied to the data, which is illustrated in the below figure. The maximum drift between two WS measurements was approx. 2 ppb for CH_4 and <0.15 ppm for CO_2. The two target cylinders were within half of the WMO GAW compatibility goals for all measurements.

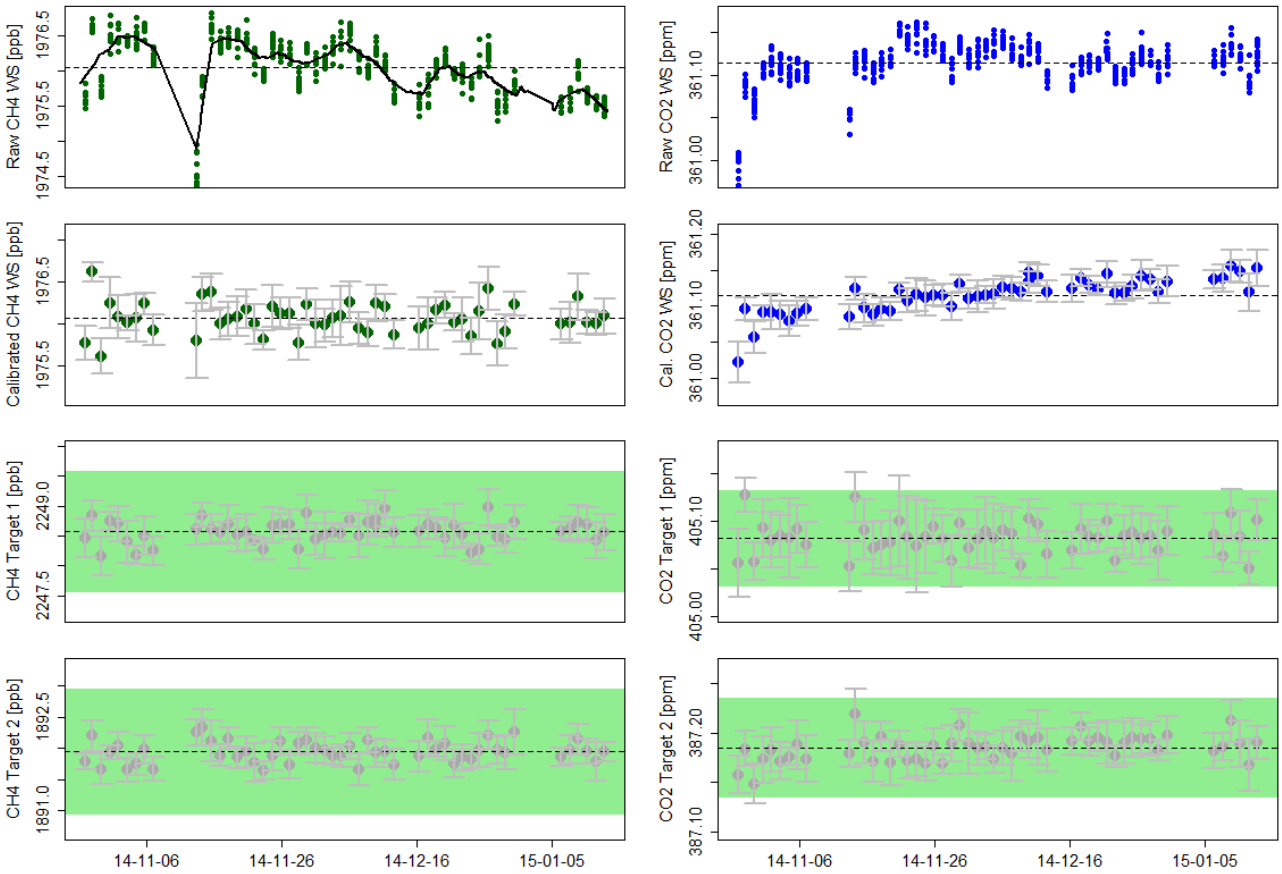

Figure 6. *CH_4 (left panel) and CO_2 (right panel) calibrations of the WCC-Empa-TI. The upper panel shows raw 1-min values of the working standard and the loess fit (black line) used to account for drift. The second panel shows the variation of the WS after applying the drift correction. The two lower most panels show the results of the two target cylinders. Individual points in the three lower panels are 10-min averages, and the error bars represent the standard deviation. The green area represents half of the WMO/GAW compatibility goals.*

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Methane Audit Executive Summary (AMY)

0.1	Station Name:	Anmyeon-do
0.2	GAW ID:	AMY
0.3	Coordinates/Elevation:	36.53833°N 126.33000°E (46 m a.s.l.)
Parameter:		Methane

1.1	Date of Audit:	2014-10-28
1.2	Auditor:	Christoph Zellweger
1.3	Staff involved in audit:	Ms. Haeyoung Lee, Mr. Hong-Woo Choi
1.4	WCC-Empa CH_4 Reference:	NOAA laboratory standards (WMO-X2004 scale)
1.5	CH_4 Transfer Standard [TS]	TS calibrated against the WCC-Empa laboratory standards
1.6	Station Analyser:	
1.6.1	Analyser Model:	PICARRO G2301 #857-CFADS2177
1.6.2	Range of calibration:	1770 – 2248 ppb
1.6.3	Coefficients at start of audit	NA
1.6.4	Calibration at start of audit (ppb):	$CH_4 = (0.99548 \pm 0.00078) \cdot X_{CH4} + (8.0 \pm 1.5)$ ppb
1.6.5	Unbiased CH_4 mixing ratio (ppb) at start of audit:	X_{CH4} (ppb) = (CH_4 - 8.0 ppb) / 0.99548
1.6.6	Standard uncertainty after compensation of calibration bias at start of audit (ppb):	u_{CH4} (ppb) = sqrt (0.3 ppb^2 + 1.30e-07 * X_{CH4}^2)
1.6.7	Coefficients after audit	NA
1.6.8	Calibration after audit (ppb):	NA
1.6.9	Unbiased CH_4 mixing ratio (ppb) after audit:	NA
1.6.10	Standard uncertainty after compensation of calibration bias after audit(ppb):	NA
1.7	Comments:	NA
1.8	Reference:	WCC-Empa Report 14/2

[CH_4]: Instrument readings; X: mixing ratios on the WMO-X2004 CH_4 scale.

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GAW QA/SAC Switzerland
Empa / Laboratory Air Pollution - Environmental Technology
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Carbon Dioxide Audit Executive Summary (AMY)

0.1	Station Name:	Anmyeon-do
0.2	GAW ID:	AMY
0.3	Coordinates/Elevation:	36.53833°N 126.33000°E (46 m a.s.l.)
Parameter:		Carbon Dioxide

1.1	Date of Audit:	2014-10-28
1.2	Auditor:	Christoph Zellweger
1.3	Staff involved in audit:	Ms. Haeyoung Lee, Mr. Hong-Woo Choi
1.4	WCC-Empa CO_2 Reference:	NOAA laboratory standards (WMO-X2007 scale)
1.5	CO_2 Transfer Standard [TS]	TS calibrated against the WCC-Empa laboratory standards
1.6	Station Analyser:	
1.6.1	Analyser Model:	PICARRO G2301 #857-CFADS2177
1.6.2	Range of calibration:	315 – 413 ppm
1.6.3	Coefficients at start of audit	NA
1.6.4	Calibration at start of audit (ppm):	CO_2 = (1.00079±0.00040) □ X_{CO2} - (0.18±0.15) ppm
1.6.5	Unbiased CO_2 mixing ratio (ppm) at start of audit:	X_{CO2} (ppm) = (CO_2 + 0.18 ppm) / 1.00079
1.6.6	Standard uncertainty after compensation of calibration bias at start of audit (ppm):	u_{CO2} (ppm) = sqrt (0.01 ppm^2 + 3.28e-08 * X_{CO2}^2)
1.6.7	Coefficients after audit	NA
1.6.8	Calibration after audit (ppm):	NA
1.6.9	Unbiased CO_2 mixing ratio (ppm) after audit:	NA
1.6.10	Standard uncertainty after compensation of calibration bias after audit(ppm):	NA
1.7	Comments:	NA
1.8	Reference:	WCC-Empa Report 14/2

[CO_2]: Instrument readings; X: mixing ratios on the WMO-X2007 CO_2 scale.

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LIST OF ABBREVIATIONS

AMY	Anmyeon-do GAW Station
BKG	Background
CRDS	Cavity Ring-Down Spectroscopy
DQO	Data Quality Objective
ESRL	Earth System and Research Laboratory
FID	Flame Ionization Detector
GAW	Global Atmosphere Watch
GAWSIS	GAW Station Information System
GAWTEC	GAW Training and Education Centre
GHG	Greenhouse Gases
KGAWC	Korea Global Atmosphere Watch Center
KMA	Korea Meteorological Administration
LS	Laboratory Standard
NA	Not Applicable
NIMS	National Institute of Meteorological Sciences
NOAA	National Oceanic and Atmospheric Administration
NDIR	Non-Dispersive Infrared
SOP	Standard Operating Procedure
TI	Travelling Instrument
TS	Traveling Standard
WCC-Empa	World Calibration Centre Empa
WCC-N_2O	World Calibration Centre for N_2O
WDCGG	World Data Centre for Greenhouse Gases
WMO	World Meteorological Organization