



**World
Meteorological
Organization**

SYSTEM AND PERFORMANCE AUDIT OF SURFACE OZONE

AT THE

GLOBAL GAW STATION

ASSEKREM

ALGERIA

OCTOBER 2015



**GLOBAL
ATMOSPHERE
WATCH**

Submitted to the World Meteorological Organization by

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 **Empa**
Materials Science and Technology

WCC-Empa Report 15/3

WCC-Empa Report 15/3

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EXECUTIVE SUMMARY AND RECOMMENDATIONS

Due to travel warnings issued by several countries for the Southern Sahara area, where the Global GAW station Assekrem (ASK) is located, an audit on the site is currently not possible. WCC-Empa therefore decided to exchange the ozone analyser by sending a replacement instrument to ensure continuation of the ASK ozone time series. For carbon monoxide, this was not possible due to the lack of a spare instrument at Empa and also because of the complexity of the measurement set-up. This third performance audit by WCC-Empa¹ at the Global GAW station Assekrem was conducted remotely between July and October 2015 in agreement with the WMO/GAW quality assurance system (WMO, 2007). Measurements at the Assekrem (ASK) GAW station are coordinated by the Office National de la Météorologie (ONM).

Previous audits at the Assekrem GAW station were conducted in February 2003 (Zellweger et al., 2003) and May 2007 (Zellweger et al., 2007).

The following people contributed to the audit:

Dr. Christoph Zellweger	Empa Dübendorf, WCC-Empa
Mr Mohamed Mimouni	ONM Tamanrasset, Station Manager

This report summarises the assessment of the Assekrem GAW station in general, as well as the surface ozone and carbon monoxide measurements in particular.

The report is distributed to the ASK station manager, the Algerian 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 station is located on the summit of the second highest peak of the Hoggar mountain range at an altitude of 2710 m a.s.l. in the Saharan desert. The site is very remote at a distance of 50 km from Tamanrasset. Access to the station is currently difficult due to security issues in the region.

Further information about the ASK station is available from the GAW Station Information System (GAW SIS) (<http://gaw.empa.ch/gawsis>).

Station Facilities

The station facilities could not be assessed during the remote audit. However, no significant changes were made, and recommendation made in the previous audit report remain valid (Zellweger et al., 2007).

¹WMO/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.

Measurement Programme

The measurements programme at ASK is limited to reactive gases (surface ozone and carbon monoxide) and the NOAA/GMD flask sampling programme, and expansion with new measurement parameters is under the current situation difficult. However, all possible opportunities to enlarge the measurement programme at the site should be explored.

Recommendation 1 (*, Important, ongoing)**

It is recommended to continue with the current measurements, and explore all opportunities for expansion of the programme.

Air Inlet System

The air inlet system was not assessed during the remote audit but remains unchanged since the last audit.

Station Management and Operation

The station is managed by the Département Météorologique Régional Sud of the Office National de la Météorologie (ONM). Recommendation made in the previous audit report remain valid (Zellweger et al., 2007).

Surface Ozone Measurements

The surface ozone measurements at Assekrem were established in 1997, and continuous time series are available since then.

Instrumentation. The station is equipped with one ozone analysers (TEI 49C). The instrumentation is adequate for its intended purpose. The instrument in operation from 2006 until October 2015 was provided by WMO and Empa. Due to lack of any calibration since the last WCC-Empa audit in 2007, it was decided to replace this instrument by another TEI-49C provided by WCC-Empa. Both the existing and the replacement instruments were calibrated at Empa as part of the current performance audit.

Standards. No ozone standard is available in Algeria.

Recommendation 2 (*, Important, 2016)**

An ozone standard needs to be purchased to ensure continuous operation and appropriate calibration of the ASK ozone measurements.

Intercomparison (Performance Audit). The ozone analyser of ASK (at the site from 2006-2015) and the replacement instrument (in operation since October 2015) were both calibrated against the WCC-Empa Standard Reference Photometer (SRP). The result of the comparisons is summarised below with respect to the WMO GAW Data Quality Objectives (DQOs) (WMO, 2013). The following equations characterise the bias of the instruments, and the result of the comparison is further illustrated in the figures below.

Station analyser (in operation from 2006-2015):

TEI 49C #56109-306 (BKG +0.0 ppb, COEF 1.015):

$$\text{Unbiased O}_3 \text{ mixing ratio (ppb): } X_{\text{O}_3} \text{ (ppb)} = 0.9901 * [\text{OA}] + 1.17 \quad (1a)$$

$$\text{Expanded standard uncertainty (ppb): } U_{\text{O}_3} \text{ (ppb)} = \text{sqrt} (0.85 \text{ ppb}^2 + 7.3\text{e-}05 * X_{\text{O}_3}^2) \quad (1b)$$

Station analyser (in operation since October 2015):

TEI 49C #3255000001334 (BKG -0.3 ppb, COEF 1.012):

Unbiased O₃ mixing ratio (ppb): X_{O_3} (ppb) = 0.9976 * [OA] + 0.07 (1b)

Standard uncertainty (ppb): U_{O_3} (ppb) = sqrt (0.88 ppb² + 7.2e-05 * X_{O₃}²) (1c)

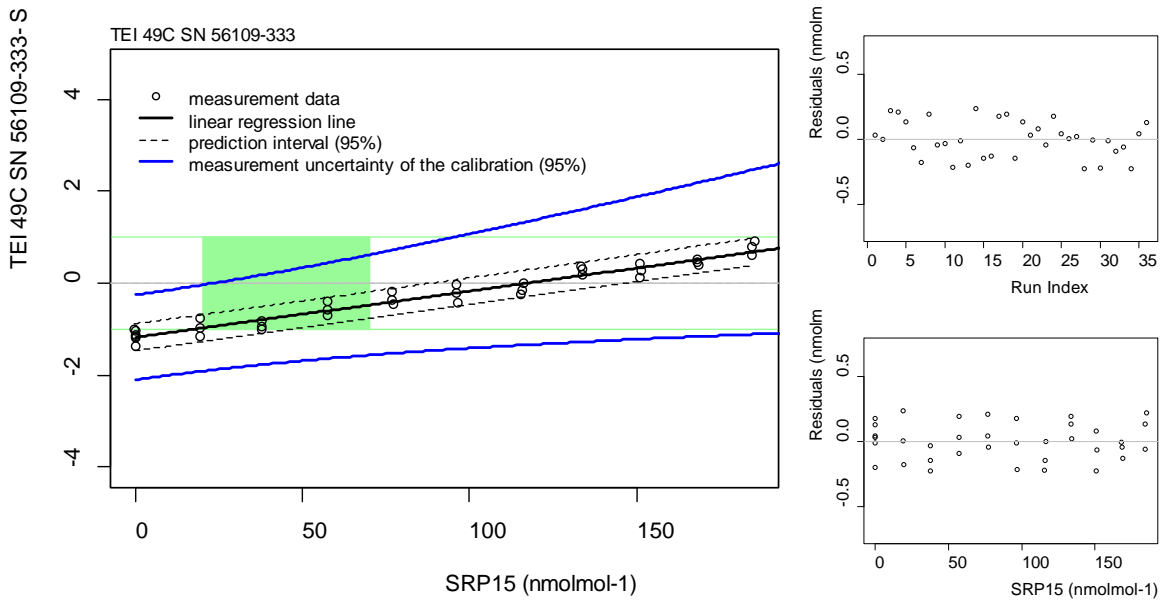


Figure 1. Left: Bias of the ASK ozone analyser in service from 2006 till October 2015 (TEI 49C #56109-306) with respect to the SRP as a function of mole fraction. Each point represents the average of the last 10 values at a given level. The green lines correspond to the DQOs, and the green area to the mole fraction range relevant for ASK. The blue lines refer to the uncertainty of the calibration excluding the uncertainty of the absorption coefficient. The dashed lines about the regression lines are the Working-Hotelling 95% confidence bands. Right: Regression residuals of the ozone comparisons as a function of time (top) and mole fraction (bottom).

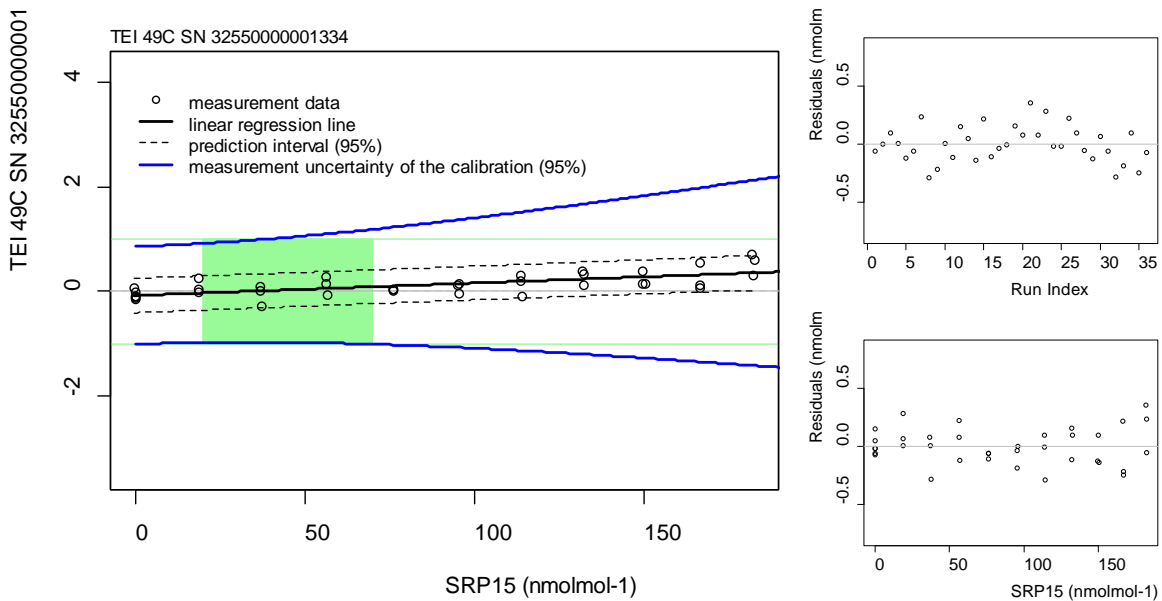


Figure 2. Same as above for the replacement instrument (TEI 49C #3255000001334) which is in service since October 2015.

The results of the comparison can be summarised as follows:

The instrument that was in service between 2006 and October 2015 (TEI 49C #56109-306) was reading slightly low but still within the WMO/GAW compatibility goals of ± 1 ppb in the relevant mole fraction range of 20-70 ppb ozone. The calibration of the instrument slightly changed since the WCC-Empa audit in 2007. At that time, no significant deviation was observed. Due to the lack of other calibrations, a linear interpolation from 2007 until October 2015 should be considered to correct the ozone data. The replacement instrument is in good calibration, and no correction is necessary.

Carbon Monoxide Measurements

Carbon monoxide measurements at Assekrem commenced in 2006 and continuous time series are available since then.

Instrumentation. Assekrem is equipped with a Horiba APMA 360 NDIR CO analyser. The instrument is reaching the end of the expected lifetime, and replacement should be initiated.

Recommendation 3 (, important, as soon as possible)**

The carbon monoxide instrument needs to be replaced, preferably with a more sensitive measurement technique (e.g. CRDS).

Standards. The station is equipped with two carbon monoxide standards. One standard has a mole fraction of approx. 1 ppm CO in air and is used for direct calibrations of the instrument. The other standard has a mole fraction of approx. 50 ppm CO in air and is used for automatic span checks after dilution with zero air. With this equipment, adequate calibration of the carbon monoxide measurements is possible. All standards have been delivered to the station by WCC-Empa, and no local supplier is available.

Intercomparison (Performance Audit). The current remote performance audit only addressed surface ozone, and no CO comparisons were made. However, concurrent flask sampling by NOAA/GMD is made at ASK, and CO data of 2013 has been submitted to WDCGG by ONM and NOAA. The following figure shows a comparison of these two data series.

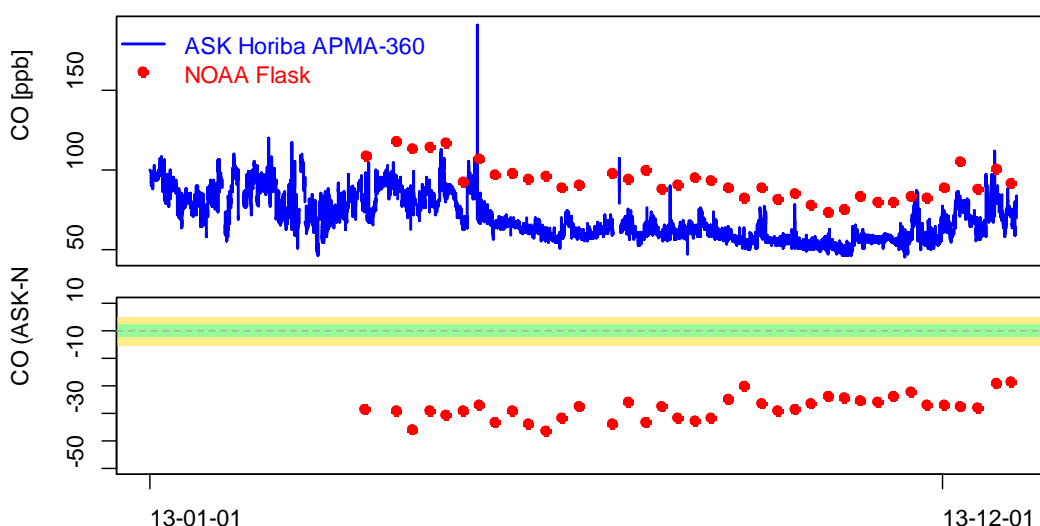


Figure 3. Upper panel: CO time series (1-h averages) measured at ASK with the Horiba APMA-360 instrument and results of the NOAA/GMD flask sampling programme. Lower panel: Deviation of the ASK instrument compared to the NOAA flask results. The green and yellow areas refer to the WMO/GAW compatibility goals and extended compatibility goals.

The temporal variation was relatively well captured by both the ASK measurements and the NOAA flask samples. However, ASK CO values were on average 27.9 ± 4.3 ppb lower compared to the NOAA flasks. Such low values are not expected and do not compare well with other data from similar latitudes (WDCGG, 2015). This is indicating that the Horiba APMA-360 analyser has either instrumental problems or is out of calibration. Data of the manual and automatic span checks (if available) need to be re-analysed, and the data needs to be corrected if possible.

Recommendation 4 (*, critical, as soon as possible)**

The ASK CO time series needs to be re-evaluated and corrected if possible. In case this is not possible, data must be withdrawn from WDCGG.

Recommendation 5 (*, critical, as soon as possible)**

The reason for the difference between the ASK CO measurements and the NOAA flask samples must be identified, and corrective actions are necessary to ensure compatibility of the ASK CO instrument.

Data Acquisition and Management

The system remained unchanged since the last WCC-Empa audit in 2007.

Data Submission

Surface O₃ (March 1997 – Dec 2014) and CO data (2013) have been submitted to the World Data Centre for Greenhouse Gases (WDCGG). It was noticed that invalid surface ozone data from the period 2001-07-27 till 2003-02-02 still resides at WDCGG. The recommendations made during the last ozone assessment (Klausen, 2007; Zellweger et al., 2007) remains still valid and need to be implemented. Furthermore, due to the above shown disagreement of the CO data, it is recommended to withdraw the ASK CO data for 2013 from WDCGG.

Recommendation 6 (*, critical, immediately)**

The following recommendations were made after the audit in 2007 by WCC-Empa. These recommendations have not been implemented and remain still valid:

- 1) Completely discard the period from 2001-07-27 thru 2003-02-02;*
- 2) Flag the data of 2004-09-22, 2004-09-23, and 2005-05-05 as invalid;*
- 3) Correct the data prior to 2003-02-06 by multiplication with 1.06;*
- 4) Re-submit the data (hourly, daily, monthly, yearly aggregates) to WDCGG.*

Recommendation 7 (*, critical, immediately)**

Withdraw CO data of 2013 from WDCGG if no plausible correction based on analysis of meta data is possible.










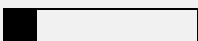
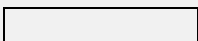




Conclusions

The Global GAW station Assekrem is situated in a strategically important location for the GAW programme, which makes the available data a very significant contribution to GAW.

Access to the site and collaboration with external partners remains difficult due to the political situation. Furthermore, funding issues remain a problem for the sustainable operation of the measurements, and the CO instrument needs to be replaced.

Nevertheless the continuation of the Assekrem measurement series is highly recommended and important for GAW.

Summary Ranking of the Assekrem GAW Station

System Audit Aspect	Adequacy [#]	Comment
Access	 (3)	Currently not possible for international collaborators
Facilities		
Laboratory and office space	 (3)	Basic facilities only.
Internet access	 (0)	No internet access.
Air Conditioning	 (0)	Not available
Power supply	 (4)	Solar power / batteries.
General Management and Operation		
Organisation	 (3)	Well organised but funding issues
Competence of staff	 (3)	Ongoing technical and scientific training of staff needed
Air Inlet System	 (4)	Basic but adequate system
Instrumentation		
Ozone	 (4)	Adequate instrumentation
Carbon monoxide	 (1)	Calibration and performance issues., replacement needed
Standards		
Ozone	 (0)	No standard available
CO	 (3)	Working standards available, no local supplier
Data Management		
Data acquisition	 (4)	Adequate system
Data processing	 (3)	More QA/QC needed before submission
Data submission	 (3)	Data partly submitted, some of the data needs to be withdrawn

[#]0: inadequate thru 5: adequate.

Dübendorf, January 2016



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APPENDIX

Table 1. Results of the comparison of the ASK ozone analyser (OA) TEI 49C #56109-306 against the WCC-Empa ozone reference SRP#15..

Run#	SRP#15 (ppb)	sdSRP#15 (ppb)	OA (ppb)	sdOA (ppb)	OA-SRP#15 (ppb)	OA- SRP#15 (%)
1	-0.07	0.23	-1.22	0.09	-1.15	NA
2	116.16	0.19	116.14	0.11	-0.02	-0.01
3	185.21	0.43	186.11	0.35	0.90	0.48
4	76.93	0.19	76.73	0.18	-0.20	-0.26
5	133.65	0.15	133.94	0.19	0.30	0.22
6	151.30	0.15	151.58	0.13	0.27	0.18
7	19.34	0.37	18.17	0.16	-1.17	-6.03
8	57.33	0.23	56.92	0.16	-0.41	-0.72
9	168.31	0.26	168.77	0.09	0.46	0.28
10	37.77	0.11	36.94	0.18	-0.83	-2.20
11	96.64	0.23	96.21	0.14	-0.43	-0.44
12	0.00	0.24	-1.19	0.16	-1.19	NA
13	0.10	0.28	-1.28	0.25	-1.38	NA
14	19.16	0.24	18.41	0.12	-0.75	-3.92
15	115.82	0.31	115.66	0.13	-0.16	-0.14
16	168.74	0.30	169.13	0.23	0.38	0.23
17	96.21	0.31	96.18	0.21	-0.04	-0.04
18	133.36	0.27	133.71	0.09	0.35	0.26
19	37.76	0.19	36.81	0.11	-0.95	-2.51
20	184.32	0.34	185.12	0.15	0.80	0.43
21	57.34	0.17	56.76	0.15	-0.58	-1.00
22	150.90	0.15	151.32	0.24	0.42	0.28
23	77.01	0.20	76.56	0.19	-0.45	-0.58
24	-0.19	0.17	-1.20	0.21	-1.01	NA
25	-0.13	0.28	-1.27	0.10	-1.14	NA
26	19.14	0.19	18.15	0.17	-0.98	-5.14
27	133.94	0.24	134.13	0.12	0.19	0.14
28	37.82	0.20	36.80	0.15	-1.02	-2.71
29	168.08	0.31	168.58	0.20	0.50	0.30
30	115.26	0.21	115.02	0.17	-0.24	-0.21
31	96.14	0.16	95.92	0.10	-0.22	-0.23
32	57.43	0.20	56.73	0.09	-0.69	-1.21
33	184.32	0.21	184.93	0.19	0.61	0.33
34	150.97	0.38	151.08	0.10	0.11	0.07
35	76.89	0.16	76.52	0.15	-0.37	-0.48
36	-0.05	0.29	-1.10	0.18	-1.05	NA

Table 2. Results of the comparison of the ASK ozone analyser (OA) TEI 49C ##3255000001334 against the WCC-Empa ozone reference SRP#15..

Run#	SRP#15 (ppb)	sdSRP#15 (ppb)	OA (ppb)	sdOA (ppb)	OA-SRP#15 (ppb)	OA- SRP#15 (%)
1	0.00	0.32	-0.13	0.09	-0.13	NA
2	95.66	0.16	95.82	0.10	0.15	0.16
3	149.79	0.27	150.17	0.20	0.38	0.25
4	18.77	0.30	18.75	0.09	-0.02	-0.13
5	56.68	0.32	56.62	0.06	-0.06	-0.11
6	76.13	0.21	76.18	0.10	0.04	0.06
7	182.54	0.38	183.14	0.13	0.60	0.33
8	114.27	0.33	114.17	0.11	-0.09	-0.08
9	166.74	0.26	166.85	0.10	0.11	0.06
10	36.89	0.22	36.91	0.15	0.02	0.06
11	132.08	0.18	132.21	0.13	0.12	0.09
12	-0.18	0.28	-0.10	0.05	0.08	NA
13	-0.07	0.25	-0.09	0.09	-0.03	NA
14	150.35	0.25	150.49	0.14	0.14	0.10
15	166.50	0.44	167.04	0.36	0.54	0.33
16	76.24	0.14	76.24	0.09	0.00	0.00
17	95.20	0.29	95.32	0.05	0.12	0.12
18	113.86	0.18	114.05	0.11	0.19	0.17
19	131.90	0.25	132.30	0.11	0.40	0.30
20	56.27	0.24	56.41	0.14	0.14	0.25
21	182.00	0.22	182.72	0.08	0.71	0.39
22	36.83	0.27	36.92	0.11	0.09	0.26
23	18.58	0.22	18.83	0.14	0.25	1.37
24	0.08	0.15	-0.01	0.12	-0.09	NA
25	0.10	0.45	0.01	0.14	-0.09	NA
26	56.43	0.25	56.71	0.17	0.29	0.51
27	132.46	0.27	132.80	0.15	0.34	0.26
28	182.45	0.30	182.76	0.07	0.31	0.17
29	149.47	0.36	149.63	0.09	0.16	0.10
30	18.80	0.26	18.84	0.11	0.04	0.21
31	76.12	0.22	76.17	0.10	0.05	0.07
32	37.37	0.27	37.10	0.11	-0.27	-0.72
33	95.39	0.17	95.36	0.11	-0.03	-0.03
34	113.77	0.34	114.06	0.07	0.30	0.26
35	166.69	0.17	166.76	0.12	0.08	0.05
36	0.12	0.23	-0.03	0.13	-0.15	NA

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Ozone Audit Executive Summary

0.1 Station Name: Assekrem
 0.2 GAW ID: ASK
 0.3 Coordinates/Elevation: 23.26667°N 5.63333°E (864 m a.s.l.)
 Parameter: Surface Ozone

1.1	Date of Audit:	2015-12-10
1.2	Auditor:	Christoph Zellweger
1.3	Station staff involved in audit:	Mohamed Mimouni
1.4	Ozone Reference [SRP]:	NIST SRP#15
1.5	Ozone Transfer Standard [TS]	
1.5.1	Model and serial number:	NA
1.5.2	Range of calibration:	NA
1.5.3	Mean calibration (ppb):	NA
1.6	Ozone Analyser [OA]	
1.6.1	Model:	TEI 49C #56109-306
1.6.2	Range of calibration:	0 – 185 ppb
1.6.3	Coefficients at start of audit	BKG = +0.0; COEF = 1.015
1.6.4	Calibration at start of audit (ppb):	[OA] = (0.9986±0.0002) * [SRP] - (0.86±0.02)
1.6.5	Unbiased ozone mixing ratio (ppb) at start of audit:	$X_{O_3} \text{ (ppb)} = 0.9901 * [OA] + 1.17$
1.6.6	Expanded uncertainty (k=2)remaining after compensation of calibration bias (ppb):	$U_{O_3} \text{ (ppb)} = \text{sqrt} (0.85 \text{ ppb}^2 + 7.3\text{e-}05 * X_{O_3}^2)$
1.6.7	Coefficients after audit	NA
1.6.8	Calibration after audit (ppb):	NA
1.6.9	Unbiased ozone mixing ratio (ppb) after audit:	NA
1.6.10	Standard uncertainty remaining after compensation of calibration bias (ppb):	NA
1.7	Comments:	NA
1.8	Reference:	WCC-Empa Report 15/3

[OA]: Instrument readings; [SRP]: SRP readings; X_{O_3} : mixing ratios on SRP scale

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Ozone Audit Executive Summary

0.4 Station Name: Assekrem
 0.5 GAW ID: ASK
 0.6 Coordinates/Elevation: 23.26667°N 5.63333°E (864 m a.s.l.)
 Parameter: Surface Ozone

1.3	Date of Audit:	2015-07-21
1.4	Auditor:	Christoph Zellweger
1.9	Station staff involved in audit:	Mohamed Mimouni
1.10	Ozone Reference [SRP]:	NIST SRP#15
1.11	Ozone Transfer Standard [TS]	
1.11.1	Model and serial number:	NA
1.11.2	Range of calibration:	NA
1.11.3	Mean calibration (ppb):	NA
1.12	Ozone Analyser [OA]	
1.12.1	Model:	TEI 49C # 32550000001334
1.12.2	Range of calibration:	0 – 182 ppb
1.12.3	Coefficients at start of audit	BKG = -0.3; COEF = 1.012
1.12.4	Calibration at start of audit (ppb):	[OA] = (0.9986±0.0002) * [SRP] - (0.86±0.02)
1.12.5	Unbiased ozone mixing ratio (ppb) at start of audit:	0.9976 * [OA] + 0.07
1.12.6	Expanded uncertainty (k=2)remaining after compensation of calibration bias (ppb):	$U_{O_3} \text{ (ppb)} = \text{sqrt} (0.88 \text{ ppb}^2 + 7.2\text{e-}05 * X_{O_3}^2)$
1.12.7	Coefficients after audit	NA
1.12.8	Calibration after audit (ppb):	NA
1.12.9	Unbiased ozone mixing ratio (ppb) after audit:	NA
1.12.10	Standard uncertainty remaining after compensation of calibration bias (ppb):	NA
1.13	Comments:	NA
1.14	Reference:	WCC-Empa Report 15/3

[OA]: Instrument readings; [SRP]: SRP readings; X_{O3}: mixing ratios on SRP scale

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LIST OF ABBREVIATIONS

ASK	Assekrem GAW Station
BKG	Background
COEF	Coefficient
CRDS	Cavity Ring-Down Spectroscopy
DQO	Data Quality Objective
GAW	Global Atmosphere Watch
GAWSIS	GAW Station Information System
GMD	Global Monitoring Division
ONM	Kenya Meteorological Department
NA	Not Applicable
NOAA	National Oceanic and Atmospheric Administration
NDIR	Non-Dispersive Infrared
SOP	Standard Operating Procedure
TS	Traveling Standard
WCC-Empa	World Calibration Centre Empa
WDCGG	World Data Centre for Greenhouse Gases
WMO	World Meteorological Organization