Results and Recommendations of the 5th Comparison of Surface Ozone Analysers

RCC III - WMO
BUENOS AIRES – ARGENTINA
OCTOBER 2017

Submitted to the World Meteorological Organization by

C. Zellweger, M. Steinbacher and B. Buchmann

WMO World Calibration Centre WCC-Empa

Empa Dübendorf, Switzerland

G. Carbajal Benitez, M. E. Barlasina, and G. Pérez Fogwill

WMO Regional Calibration Center RCC-III

SMN Buenos Aires, Argentina

WCC-Empa Report 17/3

Acknowledgements

Activities of WCC-Empa and QA/SAC Switzerland are financially supported by MeteoSwiss and Empa.

Financial support of WMO for restauration and shipping of three ozone analysers (in-kind contribution of Empa with support from the Federal Office for the Environment) is acknowledged.

WMO supported participants from South America with travel grants.

WCC-Empa Report 17/3

Contact Information:

GAW World Calibration Centre WCC-Empa
GAW QA/SAC Switzerland
Empa / Laboratory Air Pollution - Environmental Technology
CH-8600 Dübendorf, Switzerland
mailto:gaw@empa.ch

CONTENTS

EXECUTIVE SUMMARY AND RECOMMENDATIONS

The 5th tropospheric ozone analyser inter-comparison was organized by the Regional Calibration Centre for Surface Ozone (RCC-III) in Buenos Aires. RCC-III is run by the National Weather Service of Argentina (Servicio Meteorológico Nacional - SMN). The World Calibration Centre for Surface Ozone (WCC-Empa) and the Quality Assurance / Science Activity Centre Switzerland (QA/SAC-CH) contributed to the comparison activities through teaching, operator training, provision of replacement analyzers and instrument calibrations. Recommendations and results from the previous comparison were published in a WCC-Empa Report (Zellweger et al., 2010). Next to the organizers, the speakers and RCC-III staff, eight operators from six South American countries representing nine GAW stations participated in the workshop. The aim of the comparison exercise was to ensure traceability of ozone measurements carried out within the WMO-GAW region III against the WMO ozone standard maintained by the Central Calibration Laboratory (CCL) for Surface Ozone at the National Institute for Standard (NIST). It focused on the following topics:

- Assessment of surface ozone analyzers operated at global and regional stations of the WMO-GAW region III through comparisons against NIST traceable ozone standards from RCC-III and WCC-Empa.
- Diagnostics and repair of instruments.
- Operator training in surface ozone measurement techniques, instrument maintenance and data handling.
- Review and validation of existing surface ozone data series from the WMO-GAW region III.

The following people contributed to the workshop:

Dr. Paula Etala	SMN, Head of Research, Development and Capacity Training.
MSc. Gerardo Carbajal Benítez	SMN, Head of RCC-III
Chem. Eng. María Elena Barlasina	SMN, Co-Head of RCC-III
Mr. Ricardo Sánchez	SMN, RCC-III Operator
Mr. Germán Pérez Fogwill	SMN, RCC-III Operator
Mrs. Rocio Magalí Garcia	SMN, logistics
Dr. Christoph Zellweger	Empa Dübendorf, WCC-Empa
Dr. Martin Steinbacher	Empa Dübendorf, QA/SAC Switzerland

A list of all participants is given in the Appendix.

This report summarises recommendations with regard to the operation of RCC-III and the performance of the tested ozone instruments.

The report is distributed to RCC-III, SMN, the participants of the workshop and the World Meteorological Organization in Geneva. The report will be posted on the internet (www.empa.ch/web/s503/wcc-empa).

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.

RCC-III facilities

RCC-III is located at the Buenos Aires Main Observatory (34.58987°S, 58.48302°W). The location as well as the basic infrastructure (laboratory space, internet access etc.) at the site serves well for the operation of the calibration centre.

RCC-III is equipped with one ozone calibrator (TEI 49C-PS) and a very small stock of spare parts. The equipment has reached the end of its expected lifetime, and renewal of the instrumentation is needed.

Recommendation 1 (*, critical, 2018)**
The current equipment, while still functioning, needs replacement in the immediate future. It is recommended that at least one but preferably two ozone calibrators are purchased. Furthermore, supporting infrastructure such as zero air supplies and data acquisition systems is needed. The current equipment will not allow a successful operation of RCC-III in future.

Recommendation 2 (, important, 2020)**
Regional calibration centres should be equipped with the highest level standards, which in case of surface ozone is a NIST Standard Reference Photometer (SRP). In the longer term, RCC-III should purchase a NIST SRP.

RCC-III operation

The RCC-III regularly organises comparison campaigns for surface ozone instruments. The interval (of recently 7 years) however is relatively long between campaigns. During the rest of the time RCC-III calibrates instruments mainly for the Argentine GAW stations. The current operation does not include station visits and on-site calibrations outside Argentina. It was noted during the current workshop that the current operational concept has advantages, which are:

- Personal contact and networking of station staff during comparison campaigns strengthens cooperation within WMO GAW region III.
- Coordinated training activities are a good way to share and improve knowledge of station staff.

However, it also became clear that the concept has shortcomings and disadvantages, which are as follows:

- Stations outside Argentina often cannot afford to send instruments and/or station staff to the training workshops due to shortage of economic resources.
- Import/export procedures are complicated in South America, particularly in Argentina. For example, the ozone instrument of the Chacaltaya GAW station and the WCC-Empa reference instrument were not released in time by customs, despite the fact that they were already for several weeks in Argentina. This results in very long turn over times and data loss of several months at stations in the respective countries.
- Workshops are still dependent on external support and funding by WMO because a lack of financial resources.

Due to the above findings, several recommendations for the future operation of RCC-III are proposed by WCC-Empa:

Recommendation 3 (*, critical, ongoing)**
RCC-III should consider doing also on-site instrument calibration and operator training. This should not be limited to Argentina but cover the whole WMO GAW region III.

Recommendation 4 (*, critical, ongoing)**
External calibrations are only possible if an ozone calibrator which can be used as a travelling standard is available. SMN is strongly encouraged to purchase an additional ozone calibrator for this purpose.

Recommendation 5 (*, critical, ongoing)**
The operation of a regional calibration centre needs support and funding from the host institute. The current support from SMN is limited to activities within Argentina and no support of other countries within WMO GAW region III is possible. Funds are needed to supporting stations which cannot cover costs related to the calibration of their instruments.

Recommendation 6 (*, critical, ongoing)**
A dedicated budget to support the operation of the RCC-III and the instrumentation (reference and travelling standards with zero air supplies, spare parts) is needed.

Recommendation 7 (*, critical, ongoing)**
In case shipment of an instrument to/from the RCC-III is needed, turn over times need to be much shorter. Import/export needs to be done within a maximum of one or two weeks. SMN is encouraged to seek for solutions to optimise this process.

Data submission and review of available data series

It was already recognised after the last comparison workshop in 2010 that data submission of ozone data to the World Data Centres (WDCs) is sparse. At that time, only data of Ushuaia has been submitted. In the meantime, the situation improved for Argentine GAW stations, and also data of the Chilean GAW station El Tololo is now available. However, other data is still unavailable from WDCs. Moreover, metadata including instrumentation, traceability, observation procedures are insufficiently documented in the GAW Station Information System GAWSIS (https://gawsis.meteoswiss.ch). In addition to the data series residing at the WDCs, a few time series were made available for the Tropospheric Ozone Assessment Report (TOAR) (Schultz et al., 2017). Most of these however are from city networks (Santiago de Chile and Sao Paulo, and a few others from Brazil), and are only accessible as summaries with daily or coarser time resolution from the TOAR data base. The TOAR activity identified South America (among others) as a region with major gaps in surface ozone observations (Schultz et al., 2017).

Recommendation 8 (*, important, ongoing)**
Data submission is an obligation of all GAW stations. It is recommended to submit data to the corresponding data centres at least in yearly intervals, with a maximum submission delay of one year according to the GAW implementation plan. One hourly data must be submitted for all parameters.

Recommendation 9 (*, important, ongoing)**
GAWSIS needs to be continuously updated for all stations. It was noticed that the available information was partly outdated.

Ozone data was accessed from the World Data Centre for Greenhouse Gases (WDCGG) for El Tololo (1995-2015) and San Julian Aero (1997-2002), and from the World Data Centre for Reactive Gases for the GAW stations Ushuaia (1994-2016), La Quiaca (1996-2016) and Marambio (2011-2016). This data was reviewed, and summary plots and a short description of the findings are presented in the Appendix.

Table 1 shows an overview of GAW stations measuring surface ozone in WMO GAW region III, representation of these stations in the current workshop and data availability.

Table 1. Surface ozone measurement sites within WMO/GAW region III (GAW Stations only)

Station	*GAW ID*	*Participation in current workshop*	*Analyser available at workshop*	*Station registered in GAWSIS*	*O_3 series registered in GAWSIS*	*Data at WDC*
Arembepe	ABP	N	N	Y	Y	N[1]
Chacaltaya	CHC	Y	Y	Y	N	N
El Tololo	TLL	Y	Y[2]	Y	Y	Y
La Quiaca	LQO	Y	Y	Y	Y	Y
Natal	NAT	N	N	Y	N	N
Paramaribo	PMO	Y	N	Y	Y	N
Pilar	PIL	Y	Y[3]	Y	Y	Y
Manaus	MAO	Y	N	Y	Y	N
Salto Grande	SAG	Y	Y	Y	N	N
Marambio	MBI	Y	Y[3]	Y	Y	Y
San Julián Aero	SJA	Y	Y	Y	N	Y
San Lorenzo	SNL	N	N	Y	Y	Y
Ushuaia	USH	Y	Y	Y	Y	Y

[1] Measurements of surface ozone discontinued since about 2003.
[2] Station audit at TLL by WCC-Empa at TLL after the workshop, including on-site ozone comparison.
[3] Only instrument that will be at station in future was available (instruments donated by Empa).

Instrument calibration and comparison

An overview of instruments available during the workshop is shown in Table 2. Not all calibrations could be completed during the workshop itself, since the WCC-Empa reference, the CHC analyser and all three analysers donated by Empa were stuck at the customs in Buenos Aires. All comparisons were completed by RCC-III staff (Germán Pérez Fogwill and Ricardo Sánchez) between December 2017 and January 2018.

Table 2. Instruments calibrated during and after the workshop

Station	*Instrument*	*Remarks*
RCC-III	TEI 49C-PS #56084-306	Reference of RCC-III
USH	TEI 49C #56546-318	
USH	TEI 49C #3301027171	Instrument donated by Empa 2017
LQO	TEI 49C #72419-371	Instrument donated by Empa 2010
SAG	TEI 49C #72419-371	Instrument donated by Empa 2010
CHC	TEI 49i #CM11200038	
MBI	TEI 49C #4275008924	Instrument donated by Empa 2017
PIL	TEI 49C #4275008924	Instrument donated by Empa 2017

The above instruments were compared against the reference instruments of RCC-III (comparisons made during the workshop) and WCC-Empa (comparisons after the workshop). The WCC-Empa ref-

erence instrument has traceability to a Standard Reference Photometer (SRP), which is shown in the Appendix. Comparisons made with the RCC-III reference instrument were also corrected for the (small) bias found during the comparison with the WCC-Empa reference after the workshop. The internal ozone generator of the transfer standards was used for generation of a randomised sequence of ozone levels. The results of the comparisons are summarised below with respect to the WMO GAW Data Quality Objectives (DQOs) (WMO, 2013). The data was acquired by the WCC-Empa data acquisition system, and no further corrections were applied.

Results of the comparisons

Regional Calibration Centre (RCC-III)

The comparison of the RCC-III reference instrument was made against the WCC-Empa reference after the workshop. The pressure sensor was not adjusted for the comparison (reference: 1011.3 hPa, OC: 1008.7). The results are shown in the Equations and Figure below with respect to the WMO/GAW DQO of 1 ppb. Individual measurement results can be found in the Appendix.

Thermo Scientific 49C-PS #032610195956084 (RCC-III) (BKG -0.5 ppb, COEF 1.015):

Unbiased O_3 mole fraction (ppb): X_{O3} (ppb) = ([OC] - 0.05 ppb) / 0.9947 (1a)

Standard uncertainty (ppb): u_{O3} (ppb) = sqrt (0.31 ppb^2 + 2.57e-05 * X_{O3}^2) (1b)

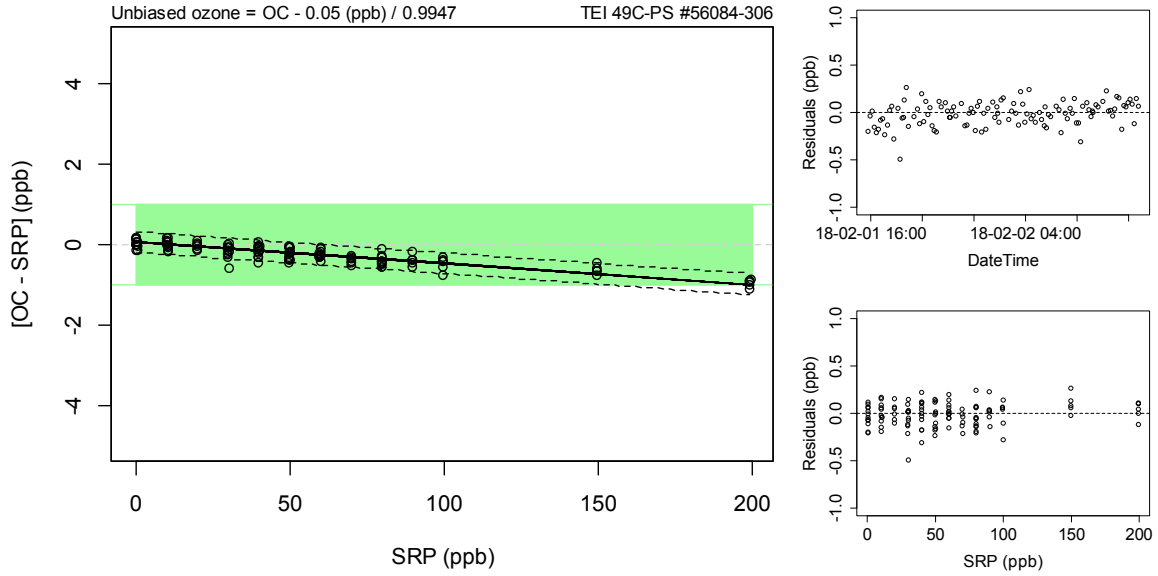

Figure 1. *Left: Bias of the RCC-III ozone calibrator with respect to the SRP as a function of mole fraction. Each point represents the average of the last 5 one-minute values at a given level. The green area corresponds to the relevant mole fraction range, while the DQOs are indicated with green lines. 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).*

The results confirm the comparisons made with this instrument during the WCC-Empa audit in 2016 (Zellweger et al., 2016b) and fully comply with the WMO GAW DQOs. Nevertheless the observed bias was compensated for the analysis of the comparisons between the RCC-III reference and station analysers that were made during the workshop.

The instrument was found to be in a good working condition, and no further action is required. However, replacement by a new calibrator is strongly encouraged, since the instrument has reached the end of its expected lifetime.

Ushuaia (USH)

Two comparisons were made with the USH analyser. The initial comparison was made against the reference of RCC-III during the workshop and another comparison against the WCC-Empa reference after the workshop. The pressure sensor was adjusted for the comparison (reference: 1007.1 hPa, OA: 997.1). Since no change of the calibration settings were made, only the final comparison against the WCC-Empa reference is shown in the Equations and Figure below with respect to the WMO/GAW DQO of 1 ppb. Individual measurement results can be found in the Appendix.

Thermo Scientific 49C #58546-318 (USH) (BKG 0.0 ppb, COEF 1.012):

Unbiased O_3 mole fraction (ppb): X_{O3} (ppb) = ([OA] + 0.22 ppb) / 1.0039 (2a)

Standard uncertainty (ppb): u_{O3} (ppb) = sqrt (0.29 ppb^2 + 2.52e-05 * X_{O3}^2) (2b)

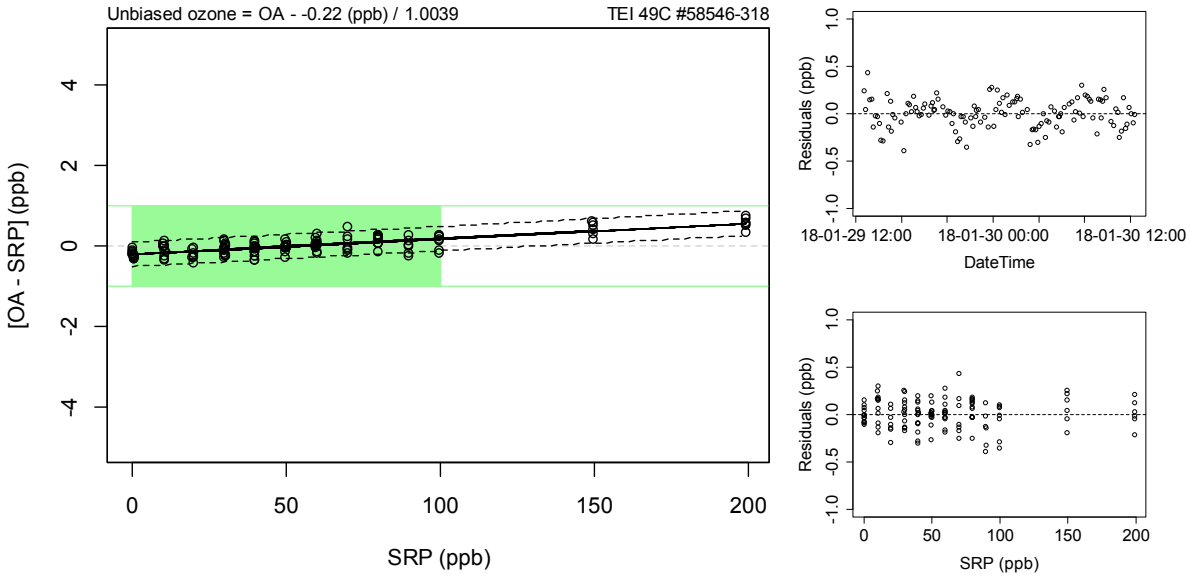

Figure 2. *Left: Bias of the USH ozone analyser with respect to the SRP as a function of mole fraction. Each point represents the average of the last 5 one-minute values at a given level. The green area corresponds to the relevant mole fraction range, while the DQOs are indicated with green lines. The 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).*

The results confirm the comparisons made with this instrument during the WCC-Empa audit in 2016 (Zellweger et al., 2016b) and fully comply with the WMO GAW DQOs. The instrument was found to be in a good working condition, and no further action is required.

La Quiaca (LQO)

Two comparisons were made with the LQO analyser. The initial comparison was made against the reference of RCC-III during the workshop and another comparison with adjusted calibration settings against the WCC-Empa reference after the workshop. The pressure sensor was not adjusted (reference: 1006.1 hPa, OA: 1006.3). The results are shown in the Equations and Figure below with respect to the WMO/GAW DQO of 1 ppb. Individual measurement results can be found in the Appendix.

Thermo Scientific 49C #61161-330 (LQO, initial comparison) (BKG 0.1 ppb, COEF 1.013):

Unbiased O_3 mole fraction (ppb): X_{O3} (ppb) = ([OA] + 0.63 ppb) / 0.9747 (3a)

Standard uncertainty (ppb): u_{O3} (ppb) = sqrt (0.30 ppb^2 + 2.71e-05 * X_{O3}^2) (3b)

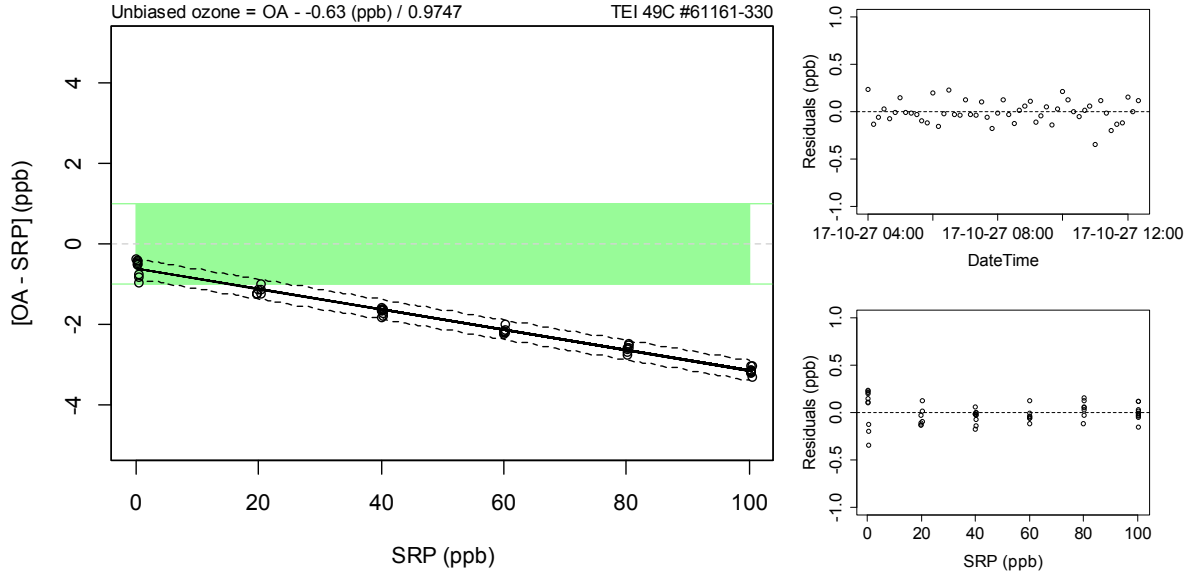

Figure 3. *Left: Bias of the LQO ozone analyser (initial comparison) with respect to the SRP as a function of mole fraction. Each point represents the average of the last 5 one-minute values at a given level. The green area corresponds to the relevant mole fraction range, while the DQOs are indicated with green lines. 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).*

The LQO instrument was measuring low during the first comparison. It was also noted that the instrument was drifting at beginning, and the corresponding data was not used for the comparison. A second comparison, with adjusted calibration settings, showed good results.

Thermo Scientific 49C #61161-330 (LQO, final comparison) (BKG -1.4 ppb, COEF 1.018):

Unbiased O_3 mole fraction (ppb): X_{O3} (ppb) = ([OA] + 0.03 ppb) / 1.0011 (3c)

Standard uncertainty (ppb): u_{O3} (ppb) = sqrt (0.29 ppb^2 + 2.52e-05 * X_{O3}^2) (3d)

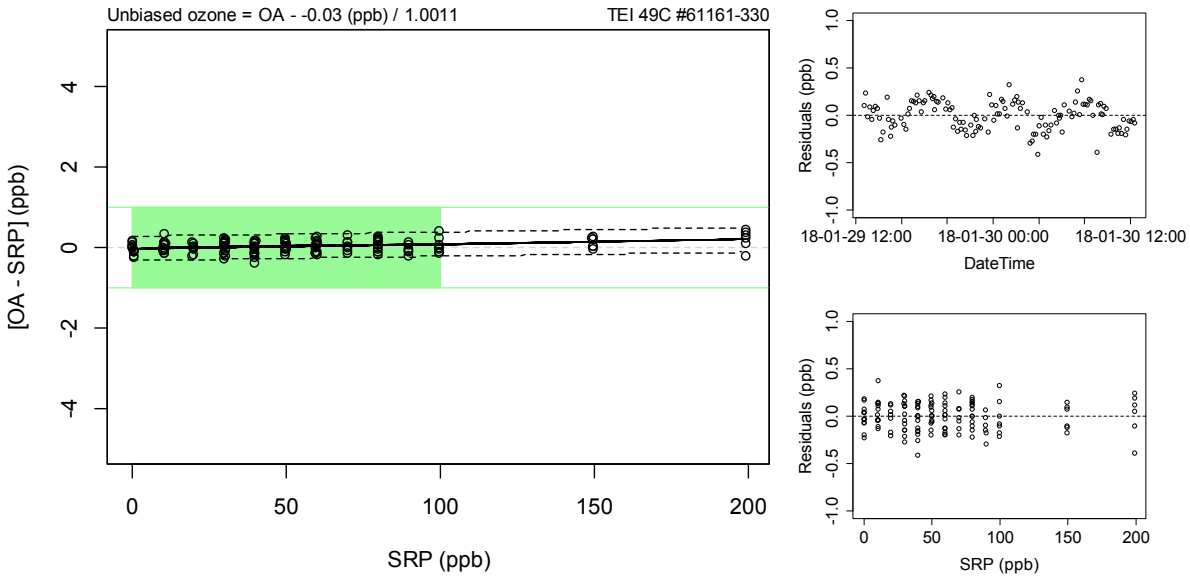

Figure 4. *Same as above, after adjustment of the calibration settings.*

The environmental conditions at LQO are harsh (dust, wide temperature range), which requires shorter service and cleaning intervals. The instrument is near the end of its expected lifetime, and replacement is recommended.

> **Recommendation 10 (***, important, 2019)**
> *Replacement of the LQO ozone analyser by a new or a refurbished instrument is recommended, preferably with an overlap of the measurements of both the existing and the new instrument.*

Salto Grande (SAG)

The ozone instrument of SAG was brought to the comparison workshop and was available during that time. It was donated to Uruguay by WCC-Empa after the comparison workshop in 2010. Unfortunately, it never has been used until 2014, when it was running for 4 months. Then, water entered the instrument. It was completely disassembled and cleaned, but again has never been used since then. Two comparisons against the reference of RCC-III were made. The pressure sensor was adjusted (reference: 1008.3 hPa, OA: 1008.9) and the calibration settings were changed. The Equations and Figures below show the observed bias with respect to the WMO/GAW DQO of 1 ppb. Individual measurement results can be found in the Appendix.

Thermo Scientific 49C #72419-371 (SAG, initial settings) (BKG 0.1 ppb, COEF 1.009):

Unbiased O_3 mole fraction (ppb): X_{O3} (ppb) = ([OA] + 0.08 ppb) / 0.9753 (4a)

Standard uncertainty (ppb): u_{O3} (ppb) = sqrt (0.30 ppb^2 + 2.69e-05 * X_{O3}^2) (4b)

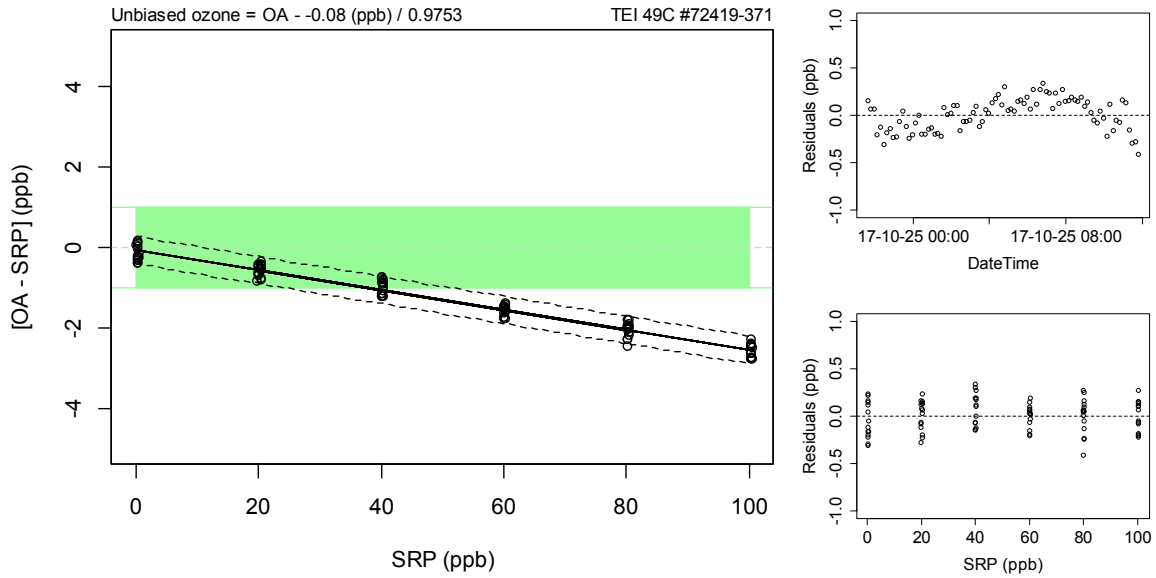

Figure 5. *Left: Bias of the SAG ozone analyser (initial settings) with respect to the SRP as a function of mole fraction. Each point represents the average of the last 5 one-minute values at a given level. The green area corresponds to the relevant mole fraction range, while the DQOs are indicated with green lines. 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).*

Thermo Scientific 49C #72419-371 (SAG, final settings) (BKG 0.1 ppb, COEF 1.023):

Unbiased O_3 mole fraction (ppb): X_{O3} (ppb) = ([OA] + 0.63 ppb) / 0.9990 (4c)

Standard uncertainty (ppb): u_{O3} (ppb) = sqrt (0.31 ppb^2 + 2.79e-05 * X_{O3}^2) (4d)

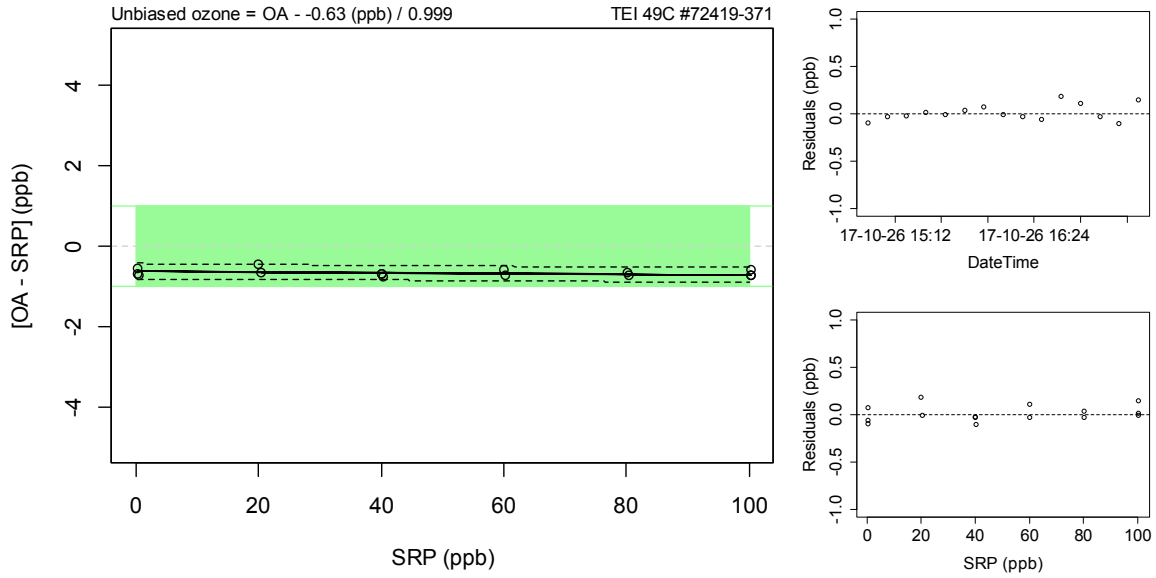

Figure 6. *Same as above for the final calibration settings.*

The instrument was found to be in working condition. However, the stability seems relatively poor, and long conditioning times were needed. The instrument was measuring low and the calibration settings were adjusted after the first comparison. Replacement of the analyser is recommended.

Recommendation 11 (*, critical, immediately)**
The instrument needs to be deployed at the SAG GAW station. If difficulties in the operation occur, RCC-III should be contacted immediately.

Recommendation 12 (*, important, as soon as possible)**
While the instrument was found to be still in working condition, potential damage from flooding in 2014 cannot be excluded. It is highly recommended to replace the analyser.

Chacaltaya (CHC)

The CHC instrument has not arrived in time for the workshop due to issues related to customs. Comparisons were made under remote supervision of WCC-Empa by RCC-III staff in December 2017 (initial comparison against the WCC-Empa reference), and in January 2018 after adjustments of the calibration settings. The pressure sensor was not adjusted (reference: 1005.5 hPa, OA: 997.9). The Equations and Figures below show the observed bias with respect to the WMO/GAW DQO of 1 ppb. Individual measurement results can be found in the Appendix.

Thermo Scientific 49i #CM11200038 (CHC, initial settings) (BKG 0.1 ppb, COEF 1.040):

Unbiased O_3 mole fraction (ppb): X_{O3} (ppb) = ([OA] + 0.69 ppb) / 1.0373 (5a)

Standard uncertainty (ppb): u_{O3} (ppb) = sqrt (0.26 ppb^2 + 2.36e-05 * X_{O3}^2) (5b)

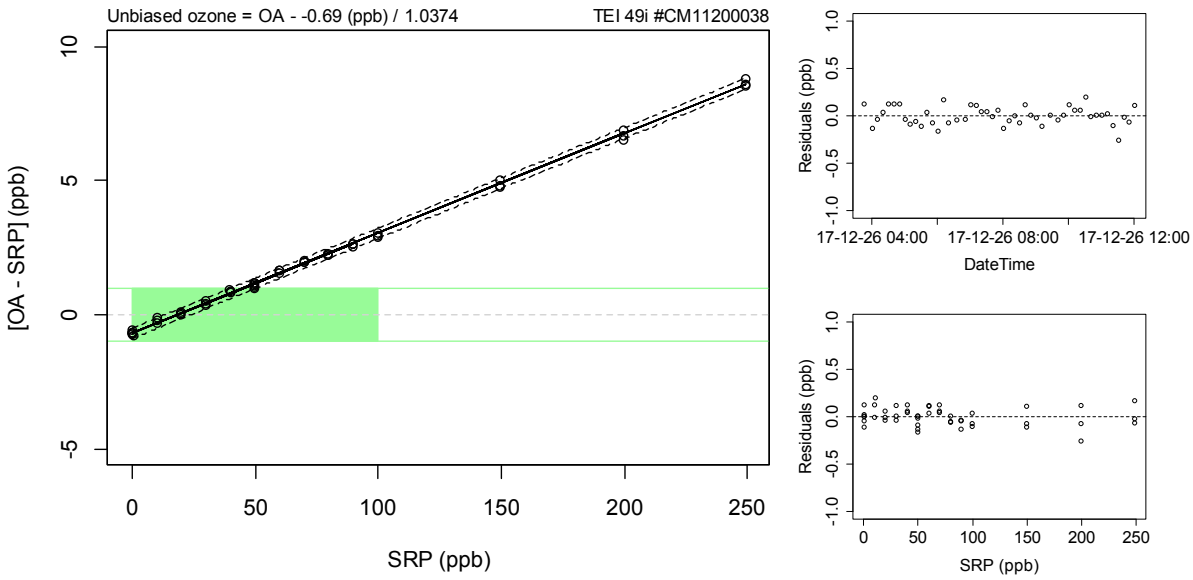

Figure 7. *Left: Bias of the CHC ozone analyser (initial settings) with respect to the SRP as a function of mole fraction. Each point represents the average of the last 5 one-minute values at a given level. The green area corresponds to the relevant mole fraction range, while the DQOs are indicated with green lines. 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).*

The CHC instrument was found to be in a good working condition, but the initial calibration settings were too high. This was corrected after the first comparison run, and agreement with the WCC-Empa reference was very good afterwards.

Thermo Scientific 49i #CM11200038 (CHC, final settings) (BKG -0.3 ppb, COEF 1.006):

Unbiased O_3 mole fraction (ppb): X_{O3} (ppb) = ([OA] + 0.04 ppb) / 0.9971 (5c)

Standard uncertainty (ppb): u_{O3} (ppb) = sqrt (0.28 ppb^2 + 2.55e-05 * X_{O3}^2) (5d)

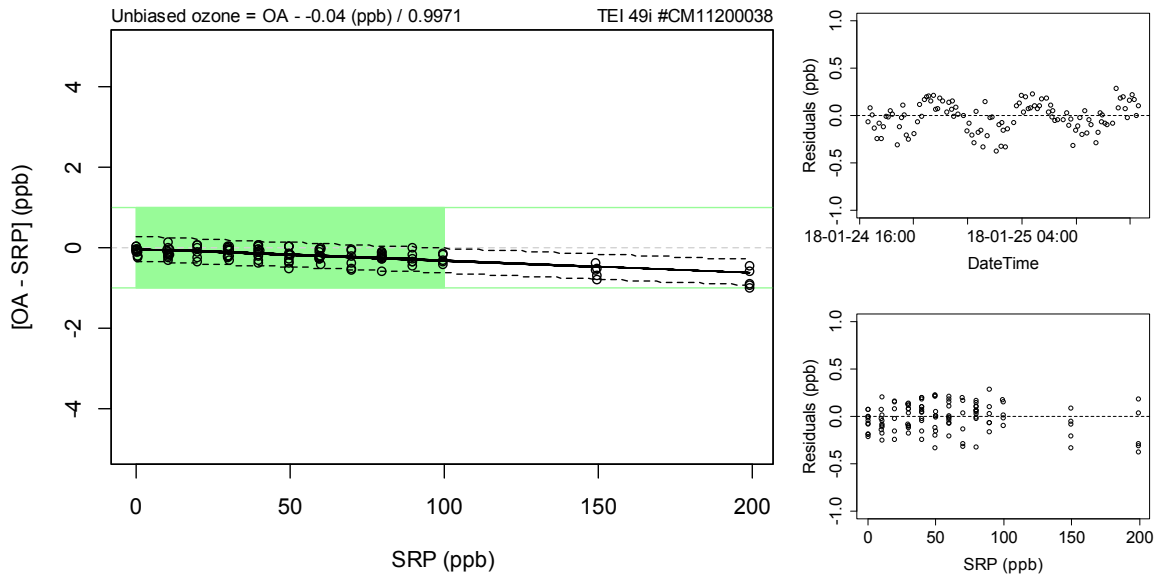

Figure 8. *Same as above for the final calibration settings.*

One potentially critical issue is the fact that the instrument will be used at very high altitude. It is recommended that the pressure sensor will also be checked once the instrument is re-installed at CHC.

Marambio (MBI) – new instrument provided by WCC-Empa

The instrumentation which currently is in operation at MBI was unavailable for the workshop. It was shipped but has not arrived at RCC-III until the end of the comparison period. Since the existing instruments are old Thermo Scientific 49 models, it was decided to use one of the three instruments provided by Empa for future measurements at MBI. This instrument was also compared against the WCC-Empa reference after the workshop. The pressure sensor was not adjusted for the comparison (reference: 1019.9 hPa, OA: 1016.7). The Equations and Figures below show the observed bias with respect to the WMO/GAW DQO of 1 ppb. Individual measurement results can be found in the Appendix.

Thermo Scientific 49C #0427508924 (MBI) (BKG -0.6 ppb, COEF 1.007):

Unbiased O_3 mole fraction (ppb): X_{O3} (ppb) = ([OA] - 0.09 ppb) / 1.0024 (6a)

Standard uncertainty (ppb): u_{O3} (ppb) = sqrt (0.28 ppb^2 + 2.52e-05 * X_{O3}^2) (6b)

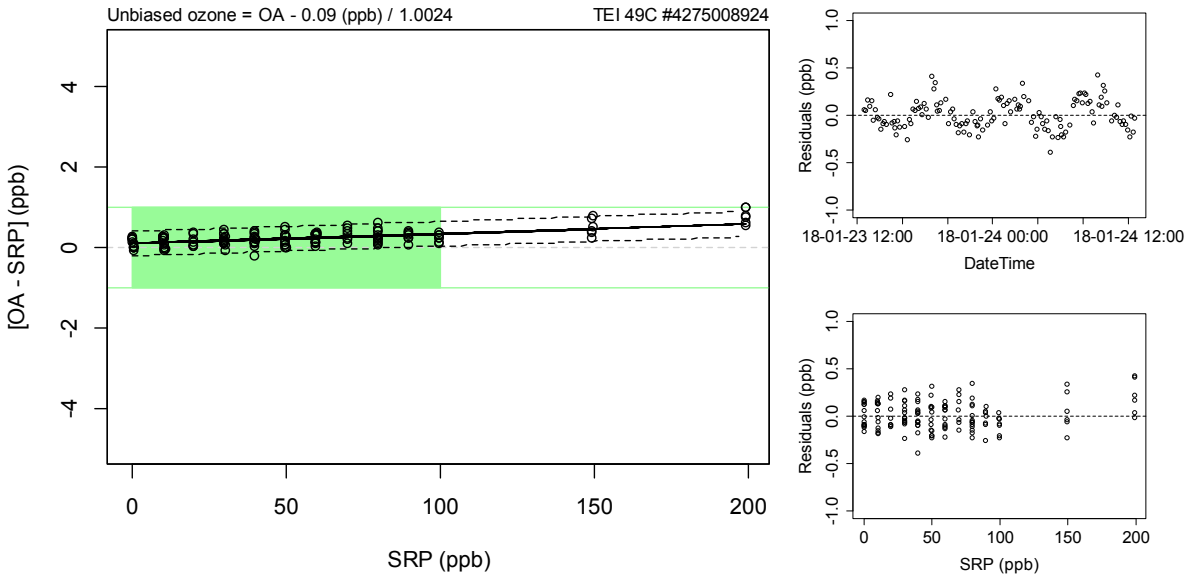

Figure 9. *Left: Bias of the future MBI ozone analyser with respect to the SRP as a function of mole fraction. Each point represents the average of the last 5 one-minute values at a given level. The green area corresponds to the relevant mole fraction range, while the DQOs are indicated with green lines. 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).*

The results of this instrument fully comply with the WMO GAW DQOs. The instrument was found in a good working condition, and no further action is required.

Pilar (PIL) – new instrument provided by WCC-Empa

The second instrument donated by Empa will be used at the GAW station PIL. The existing instrument at PIL is no longer functioning and was decommissioned in September 2013. Measurements will resume once the new instrument is installed. This instrument was also compared against the WCC-Empa reference after the workshop. The pressure sensor was not adjusted for the comparison (it has not been checked by RCC-III staff). The Equations and Figures below show the observed bias with respect to the WMO/GAW DQO of 1 ppb. Individual measurement results can be found in the Appendix.

Thermo Scientific 49C #0427508925 (PIL) (BKG 0.3 ppb, COEF 1.026):

Unbiased O_3 mole fraction (ppb): X_{O3} (ppb) = ([OA] + 0.49 ppb) / 1.0118 (7a)

Standard uncertainty (ppb): u_{O3} (ppb) = sqrt (0.28 ppb^2 + 2.47e-05 * X_{O3}^2) (7b)

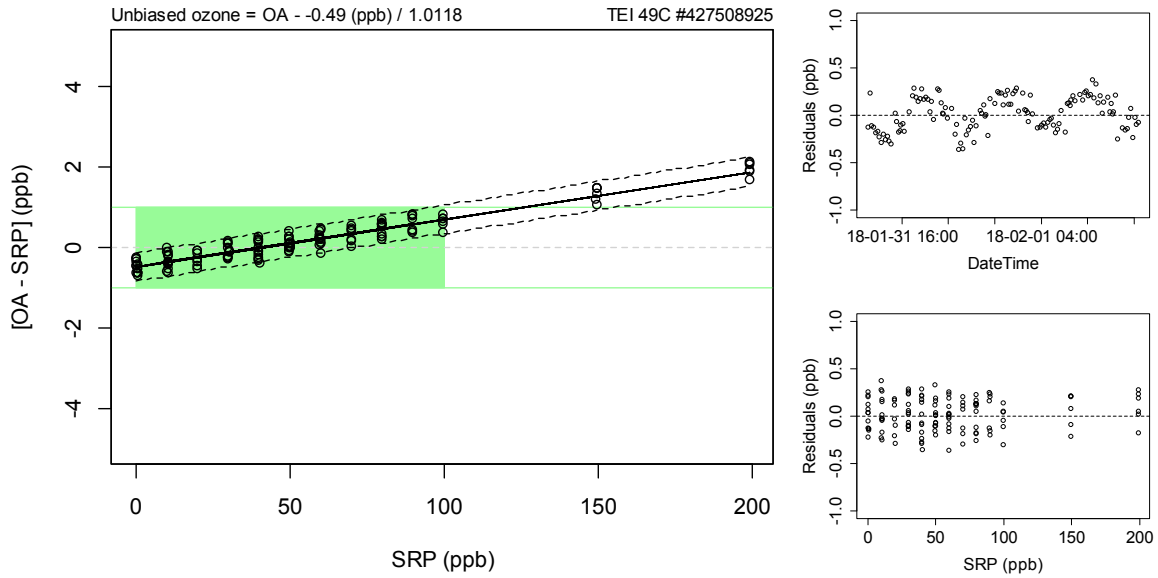

Figure 10. *Left: Bias of the future PIL ozone analyser with respect to the SRP as a function of mole fraction. Each point represents the average of the last 5 one-minute values at a given level. The green area corresponds to the relevant mole fraction range, while the DQOs are indicated with green lines. 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).*

The results of this instrument comply with the WMO GAW DQOs in the relevant mole fraction range. The instrument was found in a good working condition, and no further action is required.

Ushuaia – new instrument provided by WCC-Empa

The third instrument donated by Empa will be used at the GAW station USH. Measurements will be done in parallel with the existing analyser. Since USH has an ozone record of more than 20 years, continuation of measurements without data gaps is of high importance. This can be guaranteed with deployment of two instruments at the station. The new instrument was also compared against the WCC-Empa reference after the workshop. The pressure sensor was not adjusted for the comparison (it has not been checked by RCC-III staff). The Equations and Figures below show the observed bias with respect to the WMO/GAW DQO of 1 ppb. Individual measurement results can be found in the Appendix.

Thermo Scientific 49C #0330102717 (USH) (BKG 0.0 ppb, COEF 1.024):

Unbiased O_3 mole fraction (ppb): X_{O3} (ppb) = ([OA] + 0.13 ppb) / 1.0122 (8a)

Standard uncertainty (ppb): u_{O3} (ppb) = sqrt (0.28 ppb^2 + 2.47e-05 * X_{O3}^2) (8b)

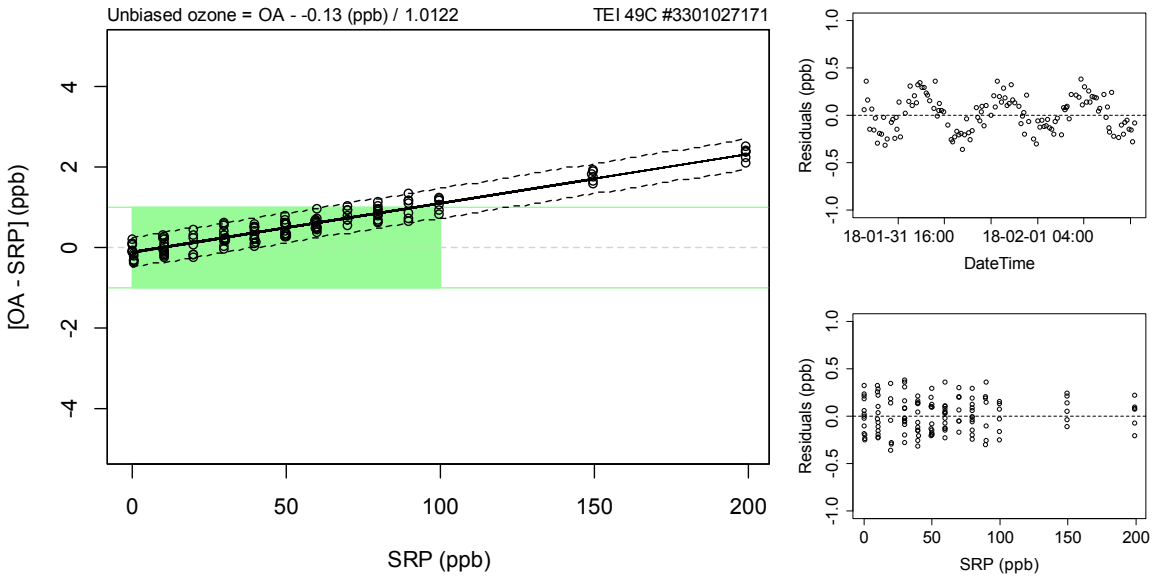

Figure 11. *Left: Bias of the new backup USH ozone analyser with respect to the SRP as a function of mole fraction. Each point represents the average of the last 5 one-minute values at a given level. The green area corresponds to the relevant mole fraction range, while the DQOs are indicated with green lines. 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).*

The results of this instrument almost comply with the WMO GAW DQOs in the relevant mole fraction range of the station, and only exceed at mole fractions close to 100 ppb and above. However, the instrument was also compared at Empa before shipment, and results were within the DQOs then. Therefore, calibration settings should not be changed at the moment. The instrument was found in a good working condition, and no further action is required.

Paramaribo (PMO)

The ozone instrument of PMO was not available during the comparison exercise due to the fact that that no funding for the shipment of the analyser was available. However, the PMO station operator participated in the workshop, and remote diagnostics of the instrument was made with assistance from QA/SAC Switzerland and WCC-Empa. It was recognized that the instrument was not running properly since many years due to malfunction of the internal pump and potentially other issues. The measurements at PMO were established in collaboration with the Royal Netherlands Meteorological Institute (KNMI); however, only very limited support could be provided by KNMI until now. The instrument could be at least partly fixed after the workshop by the station operator, but a full instrument service and calibration is needed.

Recommendation 13 (*, important, ongoing)**
The partnership between PMO and KNMI should be intensified. KNMI is encouraged to collaborate more closely with the PMO station staff with regard to operator training and the scientific use of the data.

Recommendation 14 (*, critical, as soon as possible)**
The PMO instrument needs to be serviced and calibrated against a reference instrument. Support of KNMI would be highly valuable.

Manaus (MAO) and other Brazilian GAW stations

The ozone instruments of MAO and other stations were also not available during the comparison exercise. The MAO instrument however seems to be in a good operational condition. Calibration against a reference instrument is needed. WCC-Empa recommended contacting CETESB (Companhia Ambiental do Estado de São Paulo) who operates a NIST SRP for ozone calibrations within the measurement network of São Paulo.

Recommendation 15 (*, important, ongoing)**
It is highly recommended that ozone measurements made within GAW in Brazil are linked to the reference instrument available at CETESB. Collaboration between different partners remains important.

El Tololo (TLL)

The instrument of TLL was not available during the workshop but a full station audit including ozone comparisons were made by WCC-Empa after the workshop at the GAW station El Tololo. All findings of the audit will be summarised in the corresponding WCC-Empa audit report, but for completeness, the results of the ozone comparison are also presented here:

Thermo Scientific 49C #72417-371 (TLL) (BKG -1.1 ppb, COEF 1.010):

Unbiased O_3 mole fraction (ppb): X_{O3} (ppb) = ([OA] - 0.39 ppb) / 1.0038 (8a)

Standard uncertainty (ppb): u_{O3} (ppb) = sqrt (0.28 ppb^2 + 2.53e-05 * X_{O3}^2) (8b)

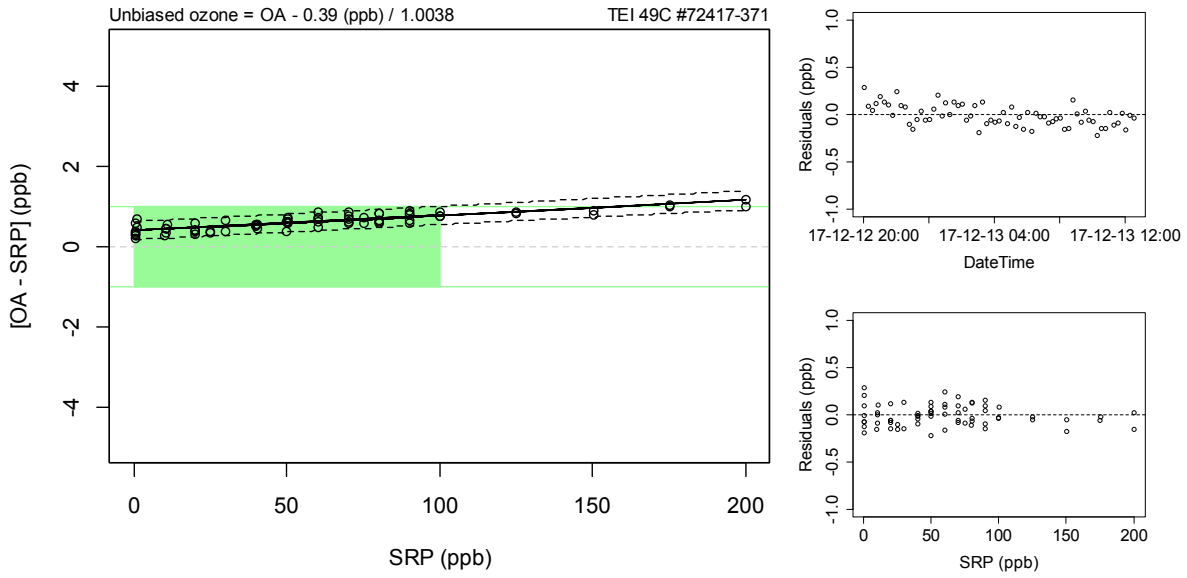

Figure 12. *Left: Bias of the TLL ozone analyser with respect to the SRP as a function of mole fraction. Each point represents the average of the last 5 one-minute values at a given level. The green area corresponds to the relevant mole fraction range, while the DQOs are indicated with green lines. The 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).*

The results of the TLL instrument comply with the WMO GAW DQOs in the relevant mole fraction range. The Thermo Scientific 49C instrument was found in a good working condition, and no further action is required. However, the older Thermo Scientific 49 analyser showed lower readings and has not passed the A/B ozone check. This analyser needs to be decommissioned.

Comparison results Compared to Other Stations

This section compares the results of the current workshop to station audits made by WCC-Empa. The method used to relate the results to other audits was developed and described by Zellweger et al. (2016a) for CO_2 and CH_4, but is also applicable to other compounds. Basically, the bias at the centre of the relevant mole fraction range is plotted against the slope of the linear regression analysis of the performance audit. For surface ozone the mole fraction range of 0 -100 ppb was chosen, since this covers most of the natural ozone variation in the troposphere. This results in well-defined bias/slope combinations which are acceptable for meeting the WMO/GAW compatibility goals in a certain mole fraction range. Figure 13 shows the bias vs. the slope of the O_3 performance audits made by WCC-Empa as well as the current results obtained during and after the workshop. The grey dots show all comparison results made during WCC-Empa audits for the main station analysers but excludes cases with known instrumental problems. If an adjustment was made during an audit, only the final comparison is shown. The results of the RCC-III comparisons are shown as coloured dots in Figure 13. It can be seen that only the three instruments which needed adjustment were initally clearly ouside the DQOs. All other instruments as well as the the adjusted analysers are meeting the DQOs except for the new backup analyser of USH, which is just slightly outside the DQO. However, the settings of this instrument were not changed, since a calibration made at WCC-Empa showed good agreement before shipping to Argentina. The instrument will currently only be used as a backup analyser at USH, and an assessment will be made during the next performace audit at USH by WCC-Empa.

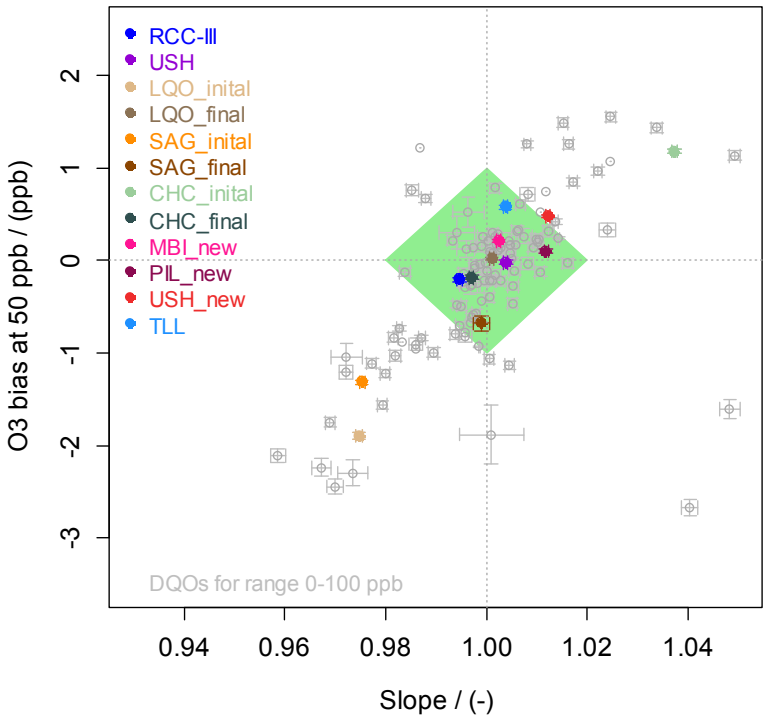

Figure 13. *O_3 bias in the centre of the relevant mole fraction range vs. the slope of the performance audits made by WCC-Empa. The grey dots correspond to past performance audits by WCC-Empa at various stations, while the coloured dots shows the results obtained during the RCC-III workshop. The green area corresponds to the WMO/GAW DQO for surface ozone.*

CONCLUSIONS

Regional calibration centres are an important element of the quality management framework of the WMO/GAW programme. They do support the goals of the WMO/GAW implementation plan (WMO, 2017), and especially training activities provided by these centres are highly important. The current activities of SMN supporting this regional infrastructure are therefore appreciated and should be continued. However, the current workshop also showed the potential to further optimise the operation of RCC-III.

The number of submitted ozone time series as well as the quality of the assessed data improved since the last RCC-III workshop in 2010. This clearly demonstrates that RCC-III activities, in collaboration with external partners, have a positive impact on data availability and quality. Furthermore, regional networking between different countries, institutes, station operators and scientists is of utmost importance for successful implementation of WMO/GAW goals. RCC-III contributes significantly, and activities could be further fostered and potentially expanded to other parameters such as greenhouse or reactive gases.

The table below summarises the findings related to RCC-III obtained from the current workshop. Results of the individual stations are discussed in the executive summary above. In general, they span a wide range of adequacy: from stations with multi-decadal records of high quality (e.g. USH, TLL) to stations without successful implementation of ozone measurements (e.g. SAG, PMO).

Aspect	Adequacy[#]	Comment
RCC-III Facilities		
Laboratory and office space	(5)	Enough space to host campaigns
Internet access	(5)	Sufficient bandwidth
Air Conditioning	(4)	Adequate system
Power supply	(4)	Mostly reliable, few power cuts
RCC-III Management and Operation		
Organisation	(3)	Difficult custom procedures
Competence of staff	(3)	Skilled staff, further training needed
Comparison activities	(2)	Only few comparisons; travelling to stations with on-site training and calibratons encouraged
RCC-III Instrumentation		
Ozone reference	(3)	Adequate but reaching end of lifetime
Backup/travelling reference	(0)	Not available
Zero air system	(1)	Only one pump; new system needed

[#]0: inadequate thru 5: adequate.

Dübendorf, May 2018

Dr. C. Zellweger	Dr. M. Steinbacher	Dr. B. Buchmann
WCC-Empa	QA/SAC Switzerland	Head of Department

APPENDIX

List of Participants

Paula ETALA SMN, Buenos Aires petala@smn.gov.ar

Christoph ZELLWEGER Empa, Suiza Christoph.Zellweger@empa.ch

Martin STEINBACHER Empa, Suiza Martin.Steinbacher@empa.ch

Gerardo CARBAJAL BENÍTEZ RCC III Buenos Aires gcarbajal@smn.gov.ar

Luis Gerardo VALLE El Tololo, Chile lvalle@dgac.gob.cl

Fernando VELARDE APAZA Chacaltaya, BOLIVIA fvelarde@chacaltaya.edu.bo

Fabricio Ávila Chacaltaya, BOLIVIA fabricio.avila@chacaltaya.edu.bo

Sergio ARIZCORRECTA El Salto, URUGUAY s.arizcorreta@meteorologia.gub.uy

Luciana VARANDA RIZZO Manaus, BRASIL luvarizzo@gmail.com

Mohamed Firozali AMIERALI Paramaribo, SURINAM Feroz22@hotmail.com

Gonzalo GAMBARTE Ushuaia, Argentina ggambarte@smn.gov.ar

Hernan SALUTTO Pilar, Argentina hsalutto@smn.gov.ar

Maria Elena BARLASINA RCC III Buenos Aires barlasina@smn.gov.ar

Ricardo SÁNCHEZ RCC III Buenos Aires rsanchez@smn.gov.ar

Jonathan Ezequiel FERRARA RCC III Buenos Aires jferrara@smn.gov.ar

Germán PÉREZ FOGWILL RCC III Buenos Aires gfogwill@smn.gov.ar

Gustavo COPES RCC III Buenos Aires gcopes@smn.gov.ar

Francisco SOSA RCC III Buenos Aires fsosa@smn.gov.ar

Federico GIMENEZ RCC III Buenos Aires fgimenez@smn.gov.ar

Juan Daniel AGÜERO RCC III Buenos Aires jdaguero@smn.gov.ar

Figure 14. *Participants of the workshop.*

Data Review

The following figures show summary plots of data accessed on 11 April 2018 from WDCGG and WDCRG. The plots below show time series of hourly data, frequency distribution, as well as diurnal and seasonal variations for valid data. Data that has been flagged invalid was considered for the data review.

Data from La Quiaca, Pilar and Marambio were reprocessed after the workshop and resubmitted to WDCRG in December 2017. His was needed as during the data review, some episodes with incorrect data were identified and the flagging criteria were found to be inappropriate leading to systematic biases in the valid data.

San Julian (SJA)

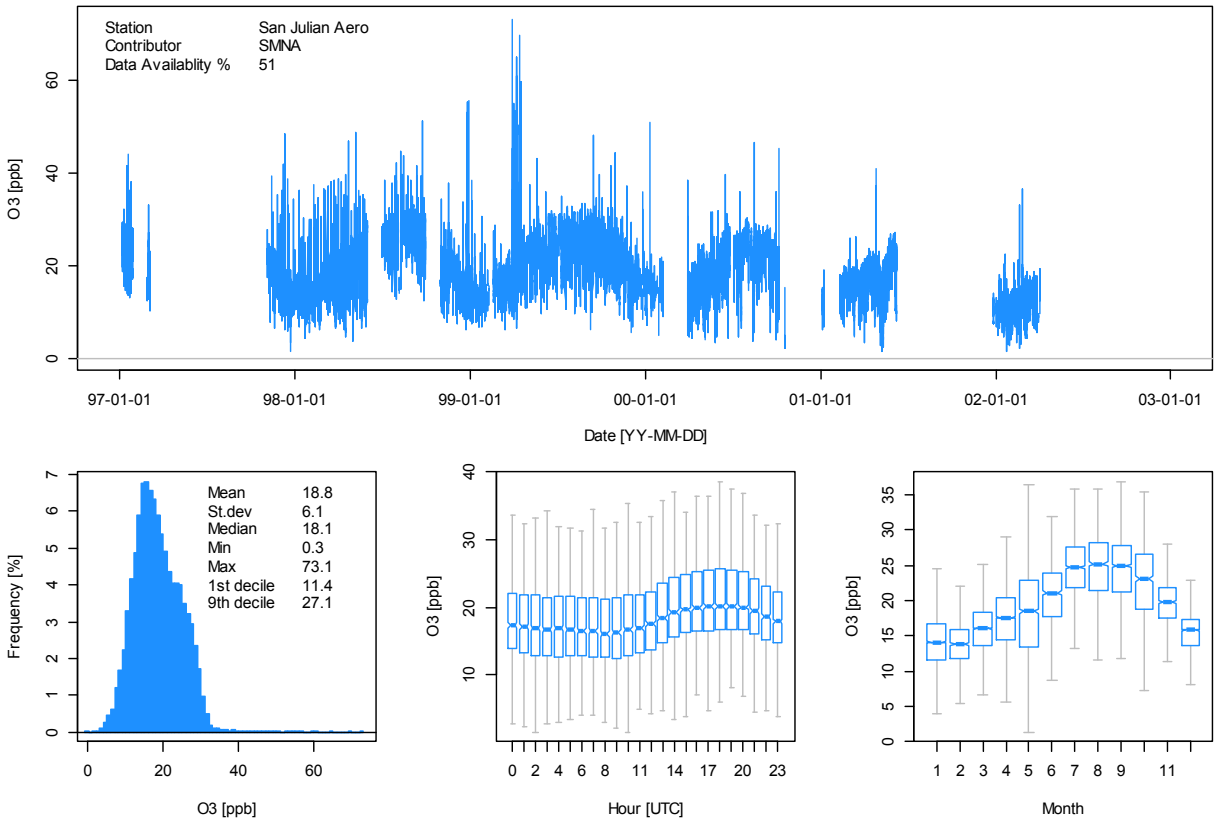

Figure 15. *SJA O_3 data accessed from WDCGG. Top: Time series. Bottom: Left: Frequency distribution; Middle: Diurnal variation Right: Seasonal variation; the horizontal blue line denotes to the median, the blue boxes show the inter-quartile range, and the whiskers are ±1.5 times the inter-quartile range.*

The main findings of the SJA data review can be summarised as follows:

- Data looks fully plausible with regard to diurnal and seasonal variation
- Data availability is relatively poor.
- There is likely a downward trend in the time series which potentially could be due to decreasing instrument sensitivity.
- Absolute mole fractions should therefore be looked at with caution.

El Tololo (TLL)

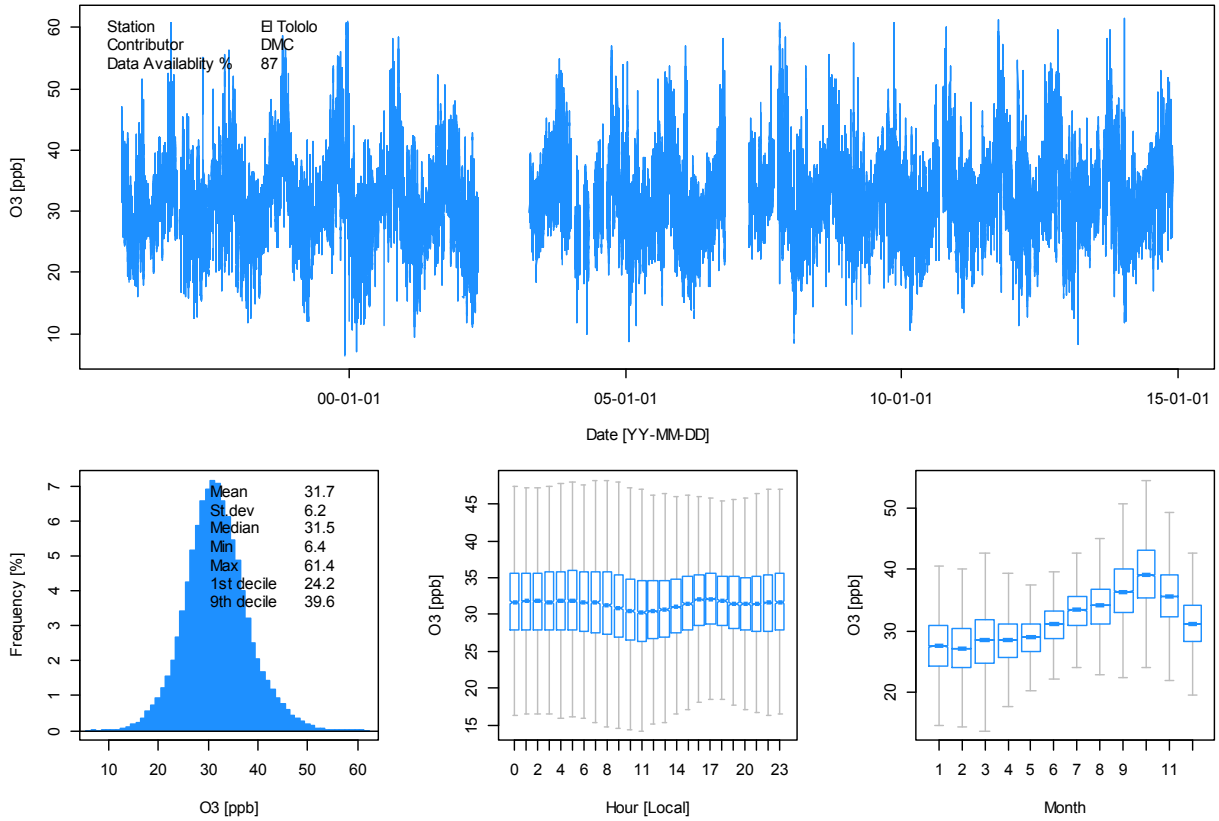

Figure 16. *TLL O_3 data accessed from WDCGG for the Thermo Environmental TEI49 instrument. Top: Time series. Bottom: Left: Frequency distribution; Middle: Diurnal variation Right: Seasonal variation; the horizontal blue line denotes to the median, the blue boxes show the inter-quartile range, and the whiskers are ±1.5 times the inter-quartile range.*

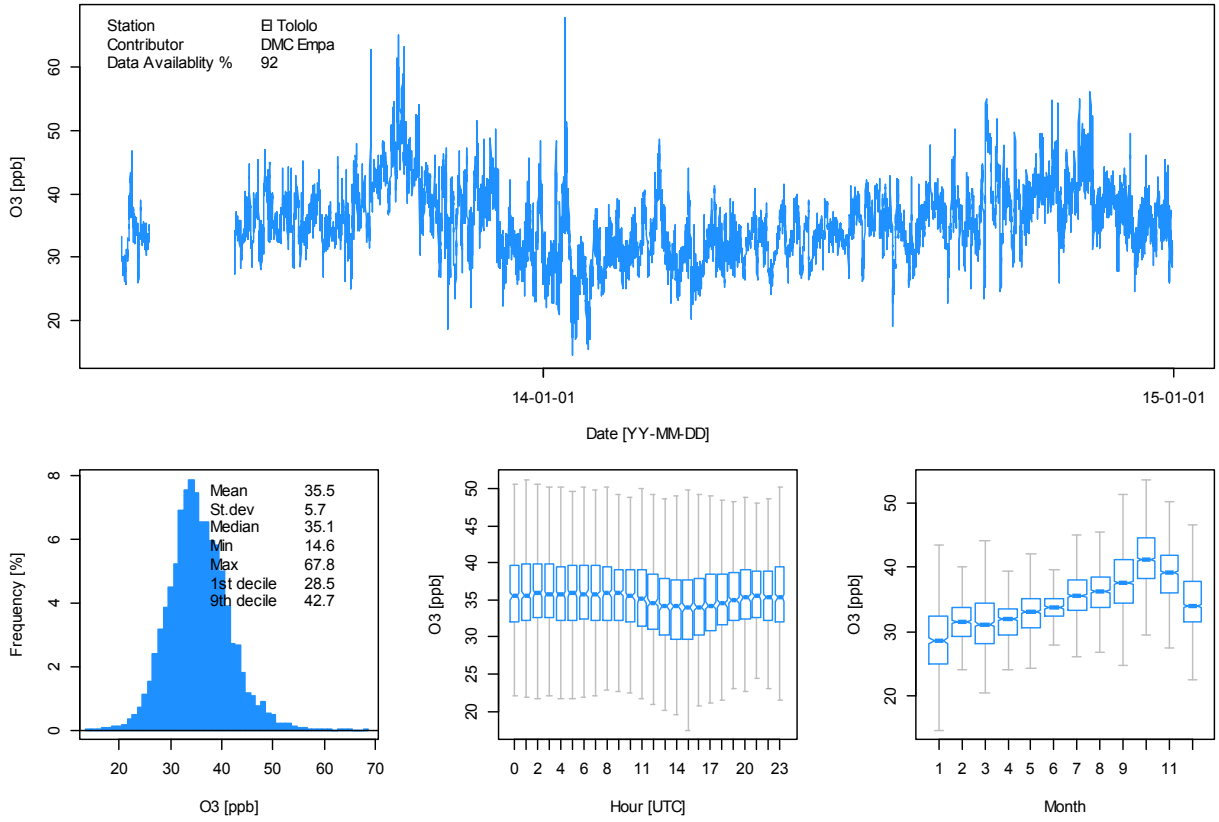

Figure 17. *Same as above for the Thermo Environmental TEI49C instrument.*

The main findings of the TLL data review can be summarised as follows:

- Data looks fully plausible with regard to all aspects (mole fraction range, diurnal and seasonal variation).
- A comprehensive analysis of the TLL data was recently published (Anet et al., 2017).

Ushuaia (USH)

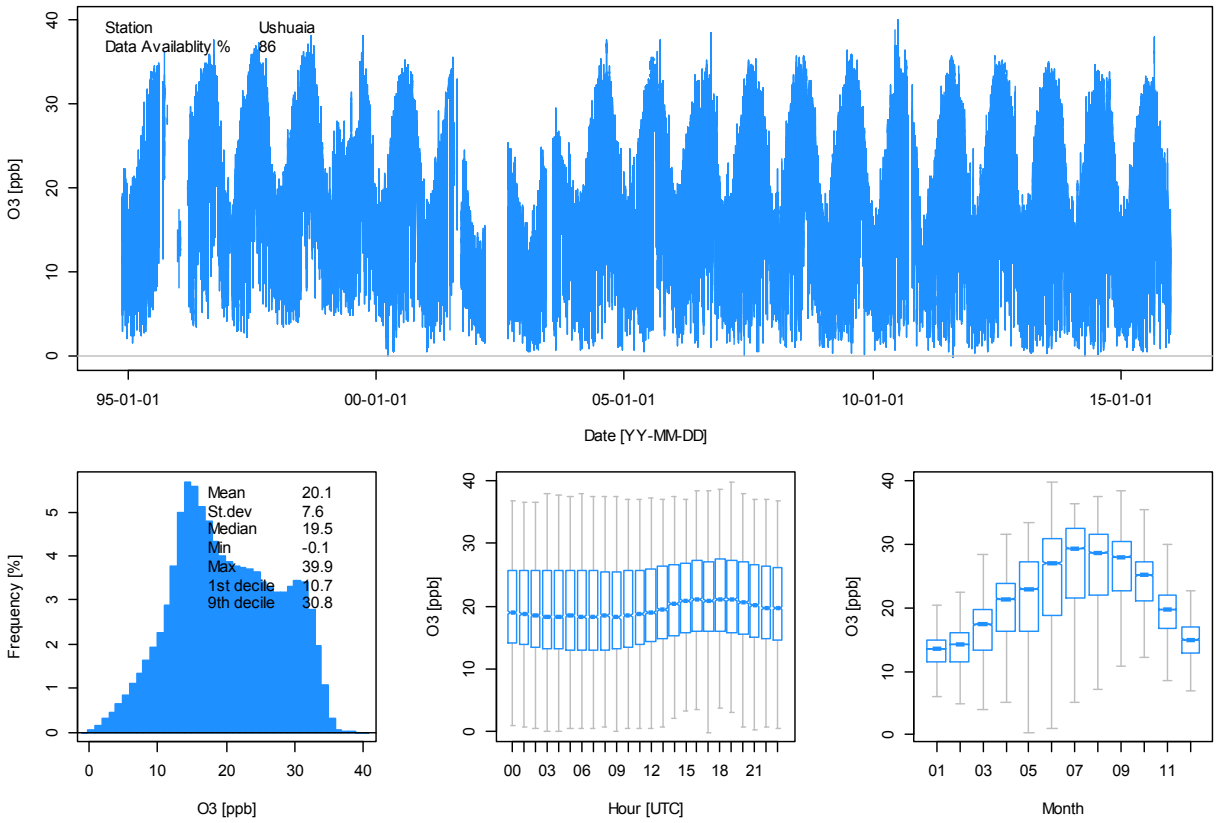

Figure 18. *USH O_3 data accessed from WDCRG. Top: Time series. Bottom: Left: Frequency distribution; Middle: Diurnal variation Right: Seasonal variation; the horizontal blue line denotes to the median, the blue boxes show the inter-quartile range, and the whiskers are ±1.5 times the inter-quartile range.*

The main findings of the USH data review can be summarised as follows:

- Data looks generally plausible with regard to all aspects (mole fraction range, diurnal and seasonal variation).
- However, mole fractions are low for the most of the years 2001 – 2003, with significantly lower data availability during this period.
- Most likely part of the data of this period is invalid. During this time the USH station encountered a problem with the ozone inlet system, which was recognised during a WCC-Empa audit at USH in 2003 (Zellweger et al., 2003).
- Data between 2001 and 2003 needs to be revised.
- A further feature of the whole time series is the absence of very low ozone values before 2000, while such values are relatively frequent afterwards.

La Quiaca (LQO)

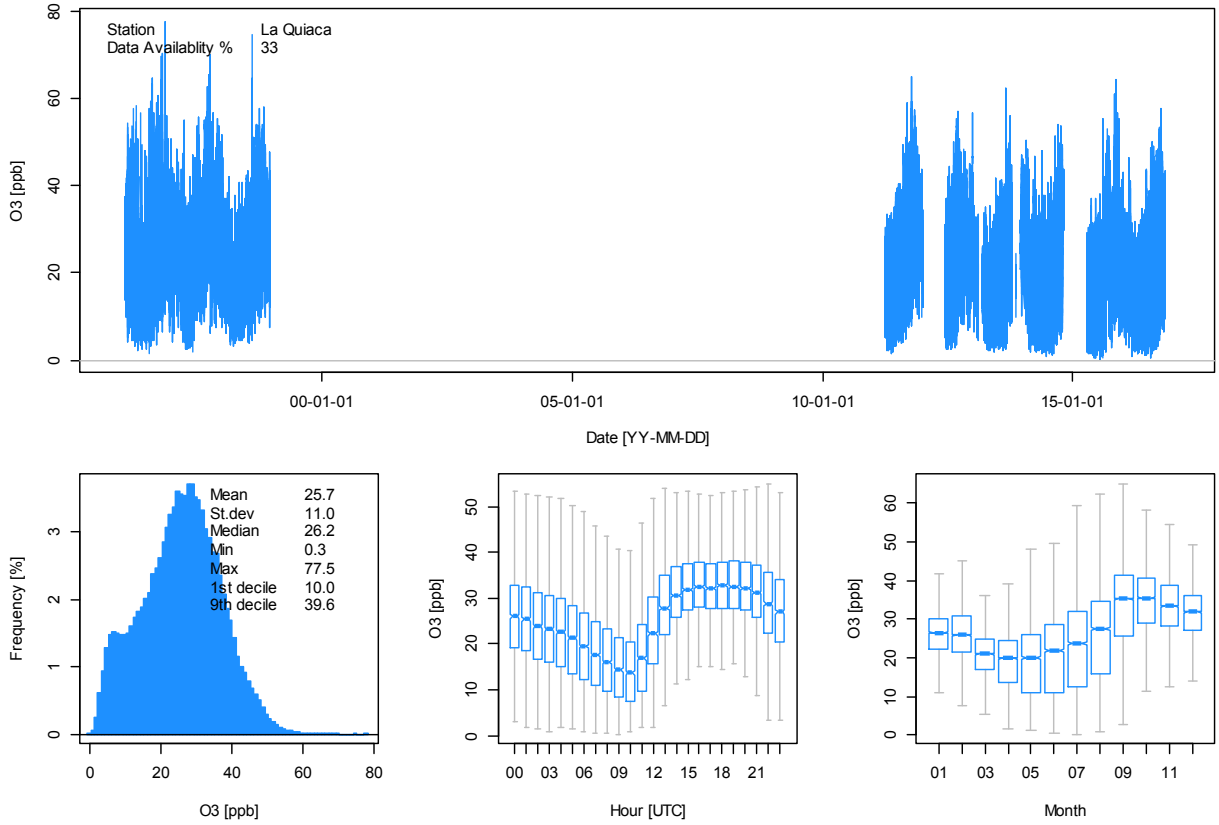

Figure 19. *LQO O_3 data accessed from EBAS. Top: Time series. Bottom: Left: Frequency distribution; Middle: Diurnal variation Right: Seasonal variation; the horizontal blue line denotes to the median, the blue boxes show the inter-quartile range, and the whiskers are ±1.5 times the inter-quartile range.*

The main findings of the LQO data review can be summarised as follows:

- Data looks generally plausible with regard to all aspects (mole fraction range, diurnal and seasonal variation).
- Long data gap of more than a decade due to failure of the analyser. Restart of measurements after instrument replacement in 2011 (analyser provided by Empa).

Marambio (MBI)

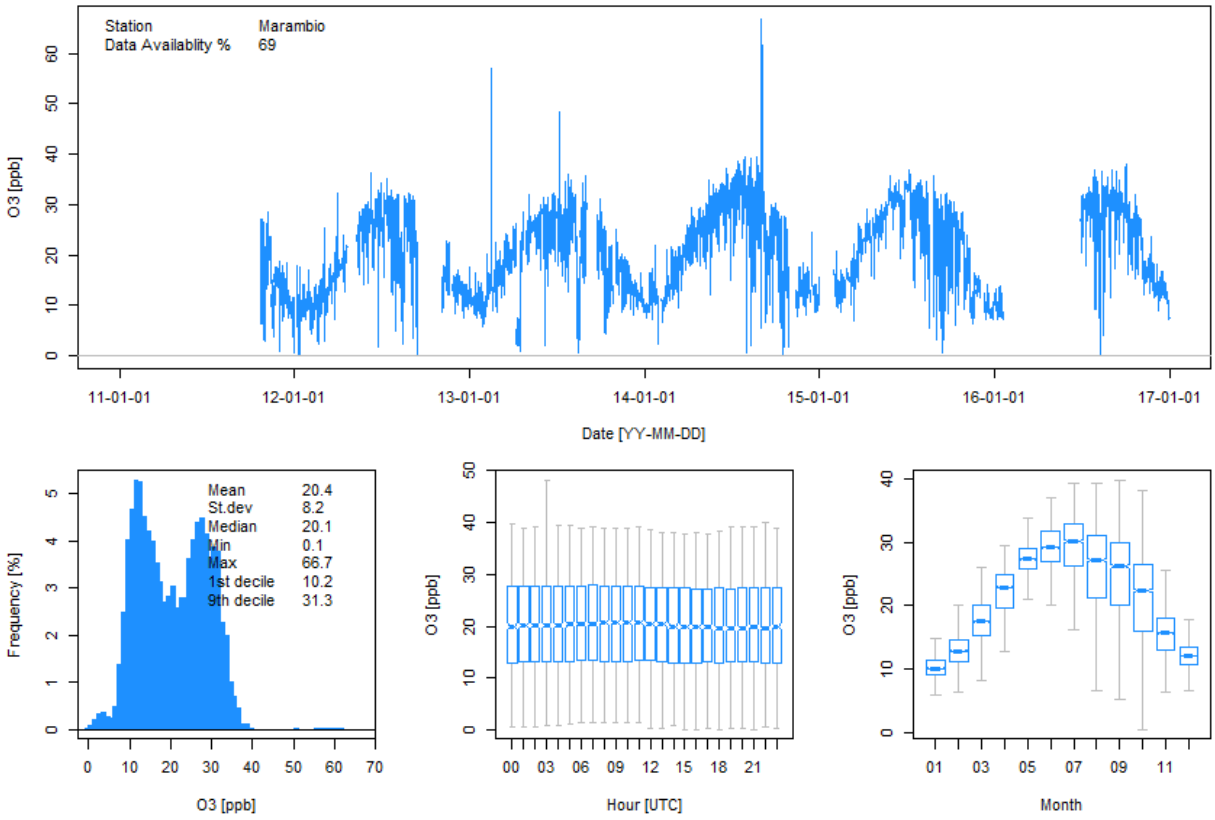

Figure 20. *MBI O_3 data accessed from WDCRG. Top: Time series. Bottom: Left: Frequency distribution; Middle: Diurnal variation Right: Seasonal variation; the horizontal blue line denotes to the median, the blue boxes show the inter-quartile range, and the whiskers are ±1.5 times the inter-quartile range.*

The main findings of the MBI data review can be summarised as follows:

- Data looks generally plausible with regard to all aspects (mole fraction range, diurnal and seasonal variation).
- A few spikes potentially look suspicious and need further attention, especially a longer period of low values in April 2013.

Pilar (PIL)

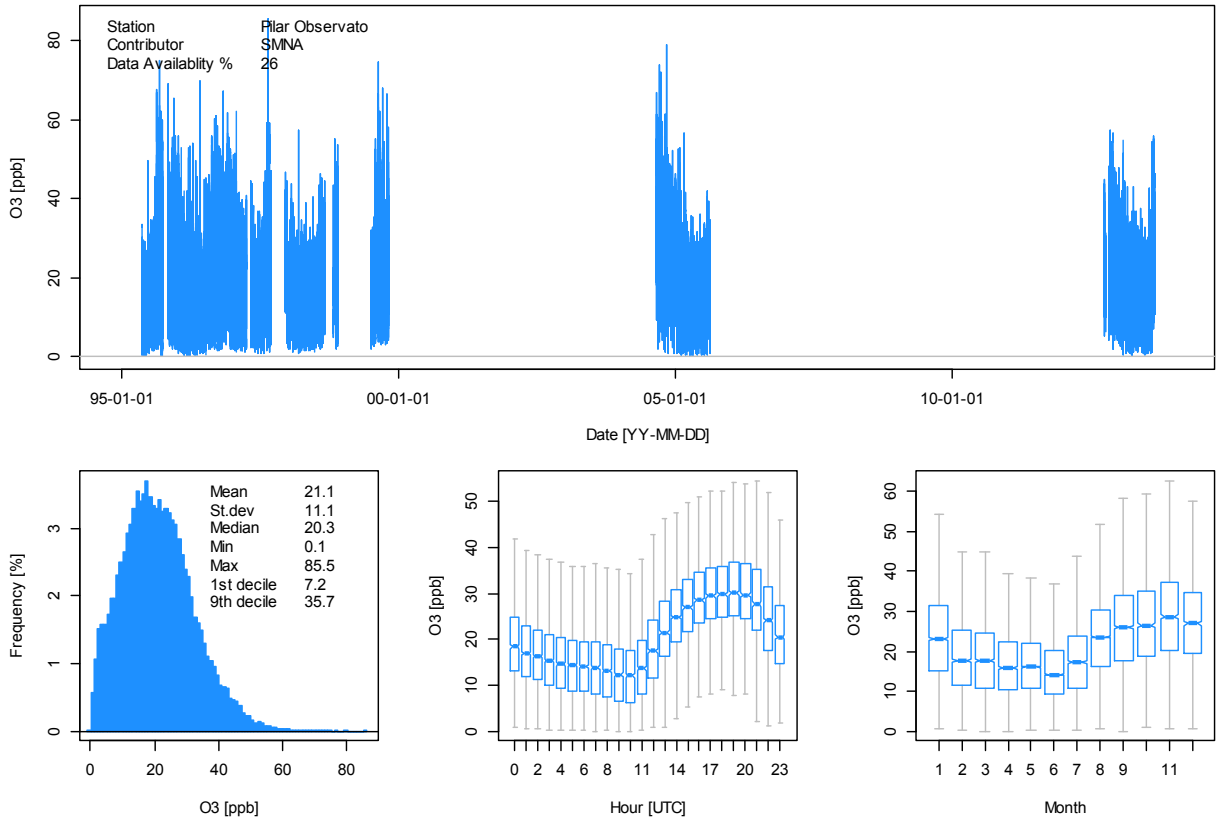

Figure 21. *PIL O_3 data accessed from WDCGG. Top: Time series. Bottom: Left: Frequency distribution; Middle: Diurnal variation Right: Seasonal variation; the horizontal blue line denotes to the median, the blue boxes show the inter-quartile range, and the whiskers are ±1.5 times the inter-quartile range.*

The main findings of the PIL data review can be summarised as follows:

- Data looks plausible with regard to mole fraction range, diurnal and seasonal variation. The station is located in close to settlements, which explains the frequent occurrence of low ozone mole fractions.
- Large data gaps due to malfunction of the instrument.
- Measurements will resume in 2018 with an instrument donated by Empa.
- Station coordinates are likely wrong in GAWSIS. Needs to be checked.

San Lorenzo (SNL)

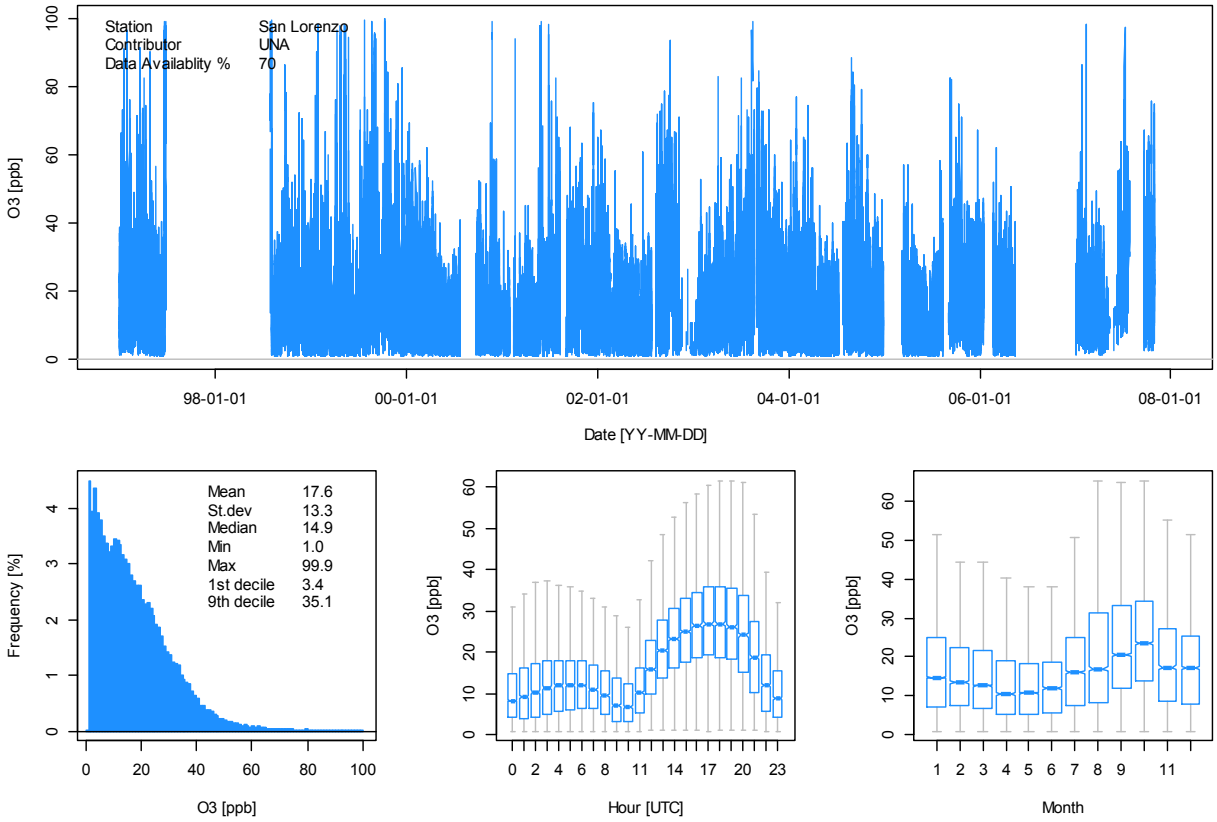

Figure 22. *SNL O_3 data accessed from WDCGG. Top: Time series. Bottom: Left: Frequency distribution; Middle: Diurnal variation Right: Seasonal variation; the horizontal blue line denotes to the median, the blue boxes show the inter-quartile range, and the whiskers are ±1.5 times the inter-quartile range.*

The main findings of the SNL data review can be summarised as follows:

- Data looks mostly plausible with regard to diurnal and seasonal variation. The station is located in an urban environment, which explains the frequent occurrence of low ozone mole fractions.
- Data seems to be cut at 100 ppb.
- Towards the end of the time series, low mole fractions are less frequent, which might be an artefact.
- The time series available at WDCGG ends in 2007 because no data acquisition system was available since then.
- The station contact of SNL has been contacted by SMN regarding the comparison workshop. No response was received.
- Data series are likely to be discontinued.

Surface Ozone Comparisons

All comparisons were done at the laboratory of RCC-III and included comparisons of the traveling standard with the Standard Reference Photometer at Empa before and after the comparison workshop. Details of the WCC-Empa reference are given further below. The RCC-III laboratory was not air conditioned but it is expected that this has no influence on the comparison results.

Table 3 shows calibration settings and pressure sensor deviations for the instruments that were calibrated.

Table 3. Calibration settings of the instruments

Station	*Instrument*	*COEF*	*BKG*	*Deviation of pressure sensor (%)*	*Pass A/B check*
RCC-III	TEI 49C-PS #56084-306	1.015	-0.5	-0.3	Y
USH	TEI 49C #56546-318	1.012	0.0	-1.0*	Y
LQO	TEI 49C #61161-330	1.013[a] 1.018[b]	0.1[a] -1.4[b]	0.0	Y
SAG	TEI 49C #72419-371	1.009[a] 1.023[b]	0.1[a] 0.1[b]	-1.9*	Y
CHC	TEI 49i #CM11200038	1.040[a] 1.006[b]	0.1[a] -0.3[b]	-0.8	Y
MBI[#]	TEI 49C #4275008924	1.007	-0.6	-0.3	Y
PIL[#]	TEI 49C #4275008925	1.026	0.3	NA	Y
USH[#]	TEI 49C #3301027171	1.024	0.0	NA	Y
TLL	TEI 49C #72417-371	1.010	-1.1	+0.2	Y

* Initial comparison, adjustment was made to reference pressure.
[a] Initial calibration settings
[b] Final calibration settings
[#] Instrument donated by Empa, installed at the station after the workshop

Results

Each ozone level was applied for 10 minutes, and the last 5 one-minute averages were aggregated. These aggregates were used in the assessment of the comparison. All results are valid for the calibration factors as given in Table 3 above. The readings of the travelling standard (TS) were compensated for bias with respect to the Standard Reference Photometer (SRP) prior to the evaluation of the ozone analyser (OA) values.
The results of the assessments are shown in the following Tables (individual measurement points) and further presented in the Executive Summary.

Table 4. Ten-minute aggregates computed from the last 5 of a total of 10 one-minute values for the comparison of the RCC-III ozone calibrator (OC) with the WCC-Empa travelling standard (TS).

Date - Time	Run #	Level (ppb)	TS (ppb)	OC (ppb)	sdTS (ppb)	sdOC (ppb)	OC-TS (ppb)	OC-TS (%)
2018-02-01 15:45	1	0	0.29	0.11	0.10	0.17	-0.18	NA
2018-02-01 15:55	1	90	90.05	89.27	0.08	0.32	-0.78	-0.9
2018-02-01 16:05	1	30	30.05	29.83	0.06	0.28	-0.22	-0.7
2018-02-01 16:15	1	60	60.02	59.37	0.15	0.06	-0.65	-1.1
2018-02-01 16:25	1	70	70.08	69.30	0.09	0.14	-0.78	-1.1
2018-02-01 16:35	1	40	40.02	39.53	0.09	0.30	-0.49	-1.2
2018-02-01 16:45	1	10	10.32	10.17	0.28	0.32	-0.15	-1.5
2018-02-01 16:55	1	20	20.06	19.84	0.08	0.14	-0.22	-1.1
2018-02-01 17:05	1	50	49.93	49.29	0.16	0.15	-0.64	-1.3
2018-02-01 17:15	1	80	80.05	79.26	0.18	0.27	-0.79	-1.0
2018-02-01 17:25	2	0	0.35	0.38	0.16	0.22	0.03	8.6
2018-02-01 17:35	2	40	39.88	39.63	0.07	0.33	-0.25	-0.6
2018-02-01 17:45	2	100	99.88	98.78	0.13	0.18	-1.10	-1.1
2018-02-01 18:05	2	200	199.95	198.32	0.10	0.14	-1.63	-0.8
2018-02-01 18:15	2	30	30.20	29.47	0.18	0.37	-0.73	-2.4
2018-02-01 18:25	2	80	79.89	79.18	0.11	0.28	-0.71	-0.9
2018-02-01 18:30	2	60	59.92	59.38	0.12	0.16	-0.54	-0.9
2018-02-01 18:35	2	50	50.04	49.77	0.17	0.31	-0.27	-0.5
2018-02-01 18:45	2	150	149.90	148.92	0.13	0.42	-0.98	-0.7
2018-02-01 18:55	2	10	10.38	10.16	0.13	0.19	-0.22	-2.1
2018-02-01 19:20	3	0	0.27	0.24	0.10	0.17	-0.03	NA
2018-02-01 19:35	3	90	90.04	89.34	0.04	0.17	-0.70	-0.8
2018-02-01 19:45	3	30	29.90	29.55	0.09	0.22	-0.35	-1.2
2018-02-01 19:55	3	60	59.99	59.70	0.10	0.13	-0.29	-0.5
2018-02-01 20:05	3	70	70.05	69.38	0.12	0.12	-0.67	-1.0
2018-02-01 20:15	3	40	40.09	39.89	0.07	0.28	-0.20	-0.5
2018-02-01 20:25	3	10	9.97	9.88	0.23	0.06	-0.09	-0.9
2018-02-01 20:35	3	20	19.97	19.87	0.13	0.05	-0.10	-0.5
2018-02-01 20:45	3	50	49.83	49.29	0.13	0.24	-0.54	-1.1
2018-02-01 20:55	3	80	80.09	79.24	0.13	0.25	-0.85	-1.1
2018-02-01 21:05	4	0	0.31	0.13	0.08	0.21	-0.18	NA
2018-02-01 21:15	4	40	39.86	39.66	0.11	0.18	-0.20	-0.5
2018-02-01 21:25	4	100	99.83	99.07	0.13	0.31	-0.76	-0.8
2018-02-01 21:45	4	200	200.01	198.44	0.22	0.45	-1.57	-0.8
2018-02-01 21:55	4	30	30.23	30.01	0.09	0.20	-0.22	-0.7
2018-02-01 22:05	4	80	79.93	79.22	0.20	0.02	-0.71	-0.9
2018-02-01 22:10	4	60	59.89	59.35	0.20	0.24	-0.54	-0.9
2018-02-01 22:15	4	50	50.05	49.67	0.07	0.18	-0.38	-0.8
2018-02-01 22:25	4	150	149.90	148.71	0.19	0.25	-1.19	-0.8
2018-02-01 22:35	4	10	10.65	10.54	0.40	0.38	-0.11	-1.0
2018-02-01 23:00	5	0	0.28	0.39	0.14	0.26	0.11	NA
2018-02-01 23:15	5	90	90.11	89.23	0.10	0.22	-0.88	-1.0
2018-02-01 23:25	5	30	29.92	29.55	0.10	0.14	-0.37	-1.2
2018-02-01 23:35	5	60	59.93	59.44	0.08	0.34	-0.49	-0.8
2018-02-01 23:45	5	70	70.03	69.50	0.09	0.20	-0.53	-0.8
2018-02-01 23:55	5	40	40.11	39.80	0.11	0.12	-0.31	-0.8

Date - Time	Run #	Level (ppb)	TS (ppb)	OC (ppb)	sdTS (ppb)	sdOC (ppb)	OC-TS (ppb)	OC-TS (%)
2018-02-02 00:05	5	10	10.29	10.03	0.18	0.19	-0.26	-2.5
2018-02-02 00:15	5	20	19.95	19.86	0.07	0.17	-0.09	-0.5
2018-02-02 00:25	5	50	49.78	49.50	0.18	0.29	-0.28	-0.6
2018-02-02 00:35	5	80	80.04	79.18	0.09	0.18	-0.86	-1.1
2018-02-02 00:45	6	0	0.25	0.26	0.04	0.10	0.01	NA
2018-02-02 00:55	6	40	39.86	39.36	0.08	0.18	-0.50	-1.3
2018-02-02 01:05	6	100	99.84	99.05	0.17	0.38	-0.79	-0.8
2018-02-02 01:25	6	200	200.04	198.47	0.16	0.27	-1.57	-0.8
2018-02-02 01:35	6	30	30.09	29.80	0.12	0.28	-0.29	-1.0
2018-02-02 01:45	6	80	79.96	79.36	0.11	0.14	-0.60	-0.8
2018-02-02 01:50	6	60	59.92	59.42	0.19	0.37	-0.50	-0.8
2018-02-02 01:55	6	50	50.01	49.50	0.12	0.57	-0.51	-1.0
2018-02-02 02:05	6	150	149.91	148.80	0.14	0.39	-1.11	-0.7
2018-02-02 02:15	6	10	10.33	10.42	0.20	0.11	0.09	0.9
2018-02-02 02:40	7	0	0.25	0.19	0.10	0.27	-0.06	NA
2018-02-02 02:55	7	90	90.06	89.33	0.13	0.41	-0.73	-0.8
2018-02-02 03:05	7	30	29.84	29.70	0.07	0.26	-0.14	-0.5
2018-02-02 03:15	7	60	60.01	59.52	0.17	0.14	-0.49	-0.8
2018-02-02 03:25	7	70	70.03	69.33	0.05	0.19	-0.70	-1.0
2018-02-02 03:35	7	40	40.07	39.97	0.13	0.30	-0.10	-0.2
2018-02-02 03:45	7	10	10.13	10.15	0.11	0.05	0.02	0.2
2018-02-02 03:55	7	20	19.82	19.57	0.13	0.24	-0.25	-1.3
2018-02-02 04:05	7	50	49.84	49.42	0.18	0.30	-0.42	-0.8
2018-02-02 04:15	7	80	80.01	79.60	0.04	0.24	-0.41	-0.5
2018-02-02 04:25	8	0	0.23	0.18	0.10	0.50	-0.05	NA
2018-02-02 04:35	8	40	39.85	39.50	0.06	0.10	-0.35	-0.9
2018-02-02 04:45	8	100	99.88	98.95	0.08	0.26	-0.93	-0.9
2018-02-02 05:05	8	200	199.96	198.29	0.14	0.31	-1.67	-0.8
2018-02-02 05:15	8	30	30.18	29.87	0.13	0.20	-0.31	-1.0
2018-02-02 05:25	8	80	80.03	79.23	0.14	0.17	-0.80	-1.0
2018-02-02 05:30	8	60	59.90	59.47	0.19	0.24	-0.43	-0.7
2018-02-02 05:35	8	50	50.04	49.47	0.10	0.11	-0.57	-1.1
2018-02-02 05:45	8	150	150.08	148.81	0.18	0.44	-1.27	-0.8
2018-02-02 05:55	8	10	10.69	10.57	0.22	0.36	-0.12	-1.1
2018-02-02 06:20	9	0	0.31	0.39	0.08	0.24	0.08	NA
2018-02-02 06:35	9	90	90.02	89.31	0.10	0.23	-0.71	-0.8
2018-02-02 06:45	9	30	29.87	29.42	0.10	0.15	-0.45	-1.5
2018-02-02 06:55	9	60	59.98	59.63	0.11	0.12	-0.35	-0.6
2018-02-02 07:05	9	70	70.00	69.42	0.06	0.21	-0.58	-0.8
2018-02-02 07:15	9	40	40.06	39.67	0.12	0.27	-0.39	-1.0
2018-02-02 07:25	9	10	10.18	10.16	0.11	0.19	-0.02	-0.2
2018-02-02 07:35	9	20	19.92	19.76	0.09	0.14	-0.16	-0.8
2018-02-02 07:45	9	50	49.80	49.54	0.12	0.26	-0.26	-0.5
2018-02-02 07:55	9	80	79.97	79.21	0.10	0.37	-0.76	-1.0
2018-02-02 08:05	10	0	0.35	0.26	0.07	0.26	-0.09	NA
2018-02-02 08:15	10	40	39.92	39.29	0.12	0.48	-0.63	-1.6
2018-02-02 08:25	10	100	99.78	99.02	0.10	0.29	-0.76	-0.8
2018-02-02 08:45	10	200	199.93	198.36	0.26	0.51	-1.57	-0.8

Date - Time	Run #	Level (ppb)	TS (ppb)	OC (ppb)	sdTS (ppb)	sdOC (ppb)	OC-TS (ppb)	OC-TS (%)
2018-02-02 08:55	10	30	30.17	29.96	0.11	0.20	-0.21	-0.7
2018-02-02 09:05	10	80	80.04	79.33	0.13	0.21	-0.71	-0.9
2018-02-02 09:10	10	60	59.94	59.47	0.16	0.31	-0.47	-0.8
2018-02-02 09:15	10	50	50.03	49.62	0.11	0.11	-0.41	-0.8
2018-02-02 09:25	10	150	149.99	148.82	0.21	0.19	-1.17	-0.8
2018-02-02 09:35	10	10	10.37	10.36	0.23	0.18	-0.01	-0.1
2018-02-02 10:00	11	0	0.23	0.36	0.11	0.23	0.13	56.5
2018-02-02 10:15	11	90	90.04	89.53	0.07	0.11	-0.51	-0.6
2018-02-02 10:25	11	30	29.86	29.64	0.12	0.18	-0.22	-0.7
2018-02-02 10:35	11	60	60.00	59.53	0.09	0.32	-0.47	-0.8
2018-02-02 10:45	11	70	70.09	69.48	0.07	0.27	-0.61	-0.9
2018-02-02 10:55	11	40	39.97	39.69	0.12	0.27	-0.28	-0.7
2018-02-02 11:05	11	10	10.21	10.31	0.03	0.07	0.10	1.0
2018-02-02 11:15	11	20	19.75	19.75	0.04	0.15	0.00	0.0
2018-02-02 11:25	11	50	49.85	49.26	0.18	0.16	-0.59	-1.2
2018-02-02 11:35	11	80	80.05	79.47	0.13	0.12	-0.58	-0.7
2018-02-02 11:45	12	0	0.27	0.34	0.16	0.09	0.07	25.9
2018-02-02 11:55	12	40	39.82	39.61	0.07	0.23	-0.21	-0.5
2018-02-02 12:05	12	100	99.92	99.24	0.11	0.24	-0.68	-0.7
2018-02-02 12:15	12	60	59.97	59.57	0.07	0.22	-0.40	-0.7
2018-02-02 12:25	12	200	199.95	198.17	0.33	0.52	-1.78	-0.9
2018-02-02 12:35	12	30	30.22	30.13	0.10	0.37	-0.09	-0.3
2018-02-02 12:45	12	80	80.04	79.45	0.13	0.20	-0.59	-0.7

Table 5. Ten-minute aggregates computed from the last 5 of a total of 10 one-minute values for the comparison of the USH ozone analyser (OA) with the WCC-Empa travelling standard (TS).

Date - Time	Run #	Level (ppb)	TS (ppb)	OA (ppb)	sdTS (ppb)	sdOA (ppb)	OA-TS (ppb)	OA-TS (%)
2018-01-29 12:43	1	30	29.90	29.91	0.10	0.22	0.01	0.0
2018-01-29 12:53	1	60	59.98	59.81	0.06	0.18	-0.17	-0.3
2018-01-29 13:03	1	70	70.01	70.24	0.08	0.17	0.23	0.3
2018-01-29 13:13	1	40	40.00	39.92	0.08	0.22	-0.08	-0.2
2018-01-29 13:23	1	10	10.42	10.32	0.15	0.19	-0.10	-1.0
2018-01-29 13:33	1	20	19.88	19.50	0.10	0.16	-0.38	-1.9
2018-01-29 13:43	1	50	49.80	49.56	0.14	0.26	-0.24	-0.5
2018-01-29 13:53	1	80	80.05	79.82	0.06	0.11	-0.23	-0.3
2018-01-29 14:03	2	0	0.35	-0.01	0.14	0.20	-0.36	NA
2018-01-29 14:13	2	40	39.96	39.46	0.17	0.10	-0.50	-1.3
2018-01-29 14:23	2	100	99.86	99.39	0.14	0.30	-0.47	-0.5
2018-01-29 14:43	2	200	199.92	200.01	0.14	0.10	0.09	0.0
2018-01-29 14:53	2	30	30.15	29.77	0.09	0.15	-0.38	-1.3
2018-01-29 15:03	2	80	79.97	79.90	0.17	0.14	-0.07	-0.1
2018-01-29 15:08	2	60	60.00	59.61	0.09	0.14	-0.39	-0.6
2018-01-29 15:13	2	50	50.08	49.85	0.05	0.24	-0.23	-0.5
2018-01-29 15:23	2	150	149.91	149.71	0.24	0.26	-0.20	-0.1
2018-01-29 15:58	3	0	0.36	0.02	0.12	0.12	-0.34	NA

Date - Time	Run #	Level (ppb)	TS (ppb)	OA (ppb)	sdTS (ppb)	sdOA (ppb)	OA-TS (ppb)	OA-TS (%)
2018-01-29 16:13	3	90	90.00	89.41	0.10	0.14	-0.59	-0.7
2018-01-29 16:23	3	30	29.90	29.67	0.07	0.08	-0.23	-0.8
2018-01-29 16:33	3	60	59.99	59.88	0.11	0.14	-0.11	-0.2
2018-01-29 16:43	3	70	69.98	69.87	0.16	0.16	-0.11	-0.2
2018-01-29 16:53	3	40	40.13	39.93	0.14	0.36	-0.20	-0.5
2018-01-29 17:03	3	10	10.43	10.36	0.17	0.18	-0.07	-0.7
2018-01-29 17:13	3	20	19.72	19.55	0.15	0.28	-0.17	-0.9
2018-01-29 17:23	3	50	49.80	49.60	0.21	0.21	-0.20	-0.4
2018-01-29 17:33	3	80	80.02	79.80	0.11	0.20	-0.22	-0.3
2018-01-29 17:43	4	0	0.27	0.01	0.05	0.07	-0.26	NA
2018-01-29 17:53	4	40	39.94	39.77	0.03	0.16	-0.17	-0.4
2018-01-29 18:03	4	100	99.87	99.79	0.09	0.15	-0.08	-0.1
2018-01-29 18:23	4	200	199.82	199.68	0.19	0.09	-0.14	-0.1
2018-01-29 18:33	4	30	30.28	30.13	0.19	0.28	-0.15	-0.5
2018-01-29 18:43	4	80	80.00	79.92	0.09	0.32	-0.08	-0.1
2018-01-29 18:48	4	60	59.86	59.69	0.16	0.27	-0.17	-0.3
2018-01-29 18:53	4	50	50.03	49.85	0.12	0.22	-0.18	-0.4
2018-01-29 19:03	4	150	149.90	149.96	0.11	0.21	0.06	0.0
2018-01-29 19:13	4	10	10.69	10.60	0.29	0.37	-0.09	-0.8
2018-01-29 19:38	5	0	0.17	-0.01	0.04	0.24	-0.18	NA
2018-01-29 19:53	5	90	90.00	89.79	0.06	0.18	-0.21	-0.2
2018-01-29 20:03	5	30	29.71	29.50	0.15	0.32	-0.21	-0.7
2018-01-29 20:13	5	60	59.96	59.76	0.16	0.15	-0.20	-0.3
2018-01-29 20:23	5	70	70.03	69.72	0.11	0.09	-0.31	-0.4
2018-01-29 20:33	5	40	40.05	39.82	0.10	0.12	-0.23	-0.6
2018-01-29 20:43	5	10	10.53	10.09	0.12	0.27	-0.44	-4.2
2018-01-29 20:53	5	20	19.87	19.34	0.14	0.20	-0.53	-2.7
2018-01-29 21:03	5	50	49.84	49.36	0.15	0.11	-0.48	-1.0
2018-01-29 21:13	5	80	80.03	79.80	0.08	0.15	-0.23	-0.3
2018-01-29 21:23	6	0	0.40	0.12	0.07	0.20	-0.28	NA
2018-01-29 21:33	6	40	39.86	39.55	0.08	0.15	-0.31	-0.8
2018-01-29 21:43	6	100	99.85	99.31	0.11	0.08	-0.54	-0.5
2018-01-29 22:03	6	200	199.88	199.72	0.25	0.22	-0.16	-0.1
2018-01-29 22:13	6	30	30.30	29.93	0.30	0.37	-0.37	-1.2
2018-01-29 22:23	6	80	79.98	79.86	0.12	0.23	-0.12	-0.2
2018-01-29 22:28	6	60	59.84	59.60	0.25	0.27	-0.24	-0.4
2018-01-29 22:33	6	50	50.02	49.84	0.07	0.20	-0.18	-0.4
2018-01-29 22:43	6	150	149.88	149.77	0.18	0.27	-0.11	-0.1
2018-01-29 22:53	6	10	10.68	10.35	0.33	0.50	-0.33	-3.1
2018-01-29 23:18	7	0	0.32	0.02	0.09	0.19	-0.30	NA
2018-01-29 23:33	7	90	90.00	89.67	0.14	0.18	-0.33	-0.4
2018-01-29 23:43	7	30	29.78	29.80	0.06	0.16	0.02	0.1
2018-01-29 23:53	7	60	60.03	60.09	0.08	0.17	0.06	0.1
2018-01-30 00:03	7	70	70.02	69.69	0.16	0.23	-0.33	-0.5
2018-01-30 00:13	7	40	40.06	39.88	0.08	0.15	-0.18	-0.4
2018-01-30 00:23	7	10	9.96	9.97	0.25	0.22	0.01	0.1
2018-01-30 00:33	7	20	19.95	19.82	0.15	0.03	-0.13	-0.7
2018-01-30 00:43	7	50	49.82	49.61	0.21	0.28	-0.21	-0.4

Date - Time	Run #	Level (ppb)	TS (ppb)	OA (ppb)	sdTS (ppb)	sdOA (ppb)	OA-TS (ppb)	OA-TS (%)
2018-01-30 00:53	7	80	79.95	79.92	0.07	0.15	-0.03	0.0
2018-01-30 01:03	8	0	0.17	-0.09	0.15	0.19	-0.26	NA
2018-01-30 01:13	8	40	39.96	39.94	0.15	0.17	-0.02	-0.1
2018-01-30 01:23	8	100	99.85	99.75	0.09	0.27	-0.10	-0.1
2018-01-30 01:43	8	200	199.86	199.86	0.18	0.27	0.00	0.0
2018-01-30 01:53	8	30	30.20	30.10	0.20	0.24	-0.10	-0.3
2018-01-30 02:03	8	80	80.00	79.97	0.10	0.28	-0.03	0.0
2018-01-30 02:08	8	60	59.85	59.82	0.19	0.29	-0.03	-0.1
2018-01-30 02:13	8	50	50.01	49.76	0.09	0.20	-0.25	-0.5
2018-01-30 02:23	8	150	149.89	149.89	0.18	0.15	0.00	0.0
2018-01-30 02:33	8	10	10.72	10.49	0.34	0.43	-0.23	-2.1
2018-01-30 02:58	9	0	0.25	0.05	0.10	0.20	-0.20	NA
2018-01-30 03:13	9	90	90.01	89.49	0.12	0.19	-0.52	-0.6
2018-01-30 03:23	9	30	29.98	29.58	0.19	0.28	-0.40	-1.3
2018-01-30 03:33	9	60	60.00	59.63	0.10	0.09	-0.37	-0.6
2018-01-30 03:43	9	70	70.02	69.64	0.09	0.21	-0.38	-0.5
2018-01-30 03:53	9	40	40.01	39.48	0.14	0.09	-0.53	-1.3
2018-01-30 04:03	9	10	10.49	10.11	0.27	0.35	-0.38	-3.6
2018-01-30 04:13	9	20	19.76	19.41	0.10	0.11	-0.35	-1.8
2018-01-30 04:23	9	50	49.80	49.58	0.19	0.22	-0.22	-0.4
2018-01-30 04:33	9	80	80.04	79.59	0.06	0.18	-0.45	-0.6
2018-01-30 04:43	10	0	0.40	0.07	0.12	0.18	-0.33	NA
2018-01-30 04:53	10	40	39.93	39.62	0.12	0.06	-0.31	-0.8
2018-01-30 05:03	10	100	99.85	99.74	0.11	0.17	-0.11	-0.1
2018-01-30 05:23	10	200	199.81	199.72	0.21	0.31	-0.09	0.0
2018-01-30 05:33	10	30	30.25	29.88	0.19	0.13	-0.37	-1.2
2018-01-30 05:43	10	80	79.96	79.73	0.11	0.14	-0.23	-0.3
2018-01-30 05:48	10	60	59.86	59.62	0.15	0.20	-0.24	-0.4
2018-01-30 05:53	10	50	50.07	49.84	0.12	0.18	-0.23	-0.5
2018-01-30 06:03	10	150	149.92	149.57	0.15	0.31	-0.35	-0.2
2018-01-30 06:13	10	10	10.53	10.35	0.28	0.22	-0.18	-1.7
2018-01-30 06:38	11	0	0.19	0.04	0.10	0.14	-0.15	NA
2018-01-30 06:53	11	90	89.96	89.90	0.10	0.17	-0.06	-0.1
2018-01-30 07:03	11	30	29.87	29.57	0.19	0.13	-0.30	-1.0
2018-01-30 07:13	11	60	60.01	59.82	0.10	0.13	-0.19	-0.3
2018-01-30 07:23	11	70	70.01	69.98	0.10	0.10	-0.03	0.0
2018-01-30 07:33	11	40	40.07	39.85	0.10	0.12	-0.22	-0.5
2018-01-30 07:43	11	10	10.33	10.38	0.15	0.20	0.05	0.5
2018-01-30 07:53	11	20	19.98	19.71	0.12	0.18	-0.27	-1.4
2018-01-30 08:03	11	50	49.81	49.79	0.18	0.29	-0.02	0.0
2018-01-30 08:13	11	80	80.00	79.99	0.03	0.13	-0.01	0.0
2018-01-30 08:23	12	0	0.14	0.04	0.10	0.09	-0.10	NA
2018-01-30 08:33	12	40	39.88	39.78	0.12	0.30	-0.10	-0.3
2018-01-30 08:43	12	100	99.83	99.60	0.12	0.17	-0.23	-0.2
2018-01-30 09:03	12	200	199.87	199.54	0.11	0.23	-0.33	-0.2
2018-01-30 09:13	12	30	30.16	30.08	0.08	0.07	-0.08	-0.3
2018-01-30 09:23	12	80	79.98	79.94	0.08	0.07	-0.04	-0.1
2018-01-30 09:28	12	60	59.89	59.63	0.16	0.27	-0.26	-0.4

Date - Time	Run #	Level (ppb)	TS (ppb)	OA (ppb)	sdTS (ppb)	sdOA (ppb)	OA-TS (ppb)	OA-TS (%)
2018-01-30 09:33	12	50	50.08	50.00	0.10	0.13	-0.08	-0.2
2018-01-30 09:43	12	150	149.82	149.92	0.11	0.22	0.10	0.1
2018-01-30 09:53	12	10	10.55	10.48	0.16	0.25	-0.07	-0.7
2018-01-30 10:18	13	0	0.45	0.12	0.07	0.21	-0.33	NA
2018-01-30 10:33	13	90	89.98	89.66	0.11	0.12	-0.32	-0.4
2018-01-30 10:43	13	30	29.94	29.76	0.15	0.24	-0.18	-0.6
2018-01-30 10:53	13	60	59.94	59.74	0.11	0.30	-0.20	-0.3
2018-01-30 11:03	13	70	70.02	69.57	0.06	0.14	-0.45	-0.6
2018-01-30 11:13	13	40	39.96	39.55	0.09	0.12	-0.41	-1.0
2018-01-30 11:23	13	10	10.20	10.12	0.05	0.15	-0.08	-0.8
2018-01-30 11:33	13	20	19.66	19.26	0.16	0.26	-0.40	-2.0
2018-01-30 11:43	13	50	49.79	49.46	0.20	0.17	-0.33	-0.7
2018-01-30 11:53	13	80	80.02	79.89	0.08	0.20	-0.13	-0.2
2018-01-30 12:03	14	0	0.42	0.16	0.12	0.18	-0.26	NA
2018-01-30 12:13	14	40	39.95	39.63	0.09	0.11	-0.32	-0.8
2018-01-30 12:23	14	100	99.80	99.61	0.18	0.23	-0.19	-0.2

Table 6. Ten-minute aggregates computed from the last 5 of a total of 10 one-minute values for the comparison of the LQO ozone analyser (OA) (initial settings) with the WCC-Empa travelling standard (TS).

Date - Time	Run #	Level (ppb)	TS (ppb)	OA (ppb)	sdTS (ppb)	sdOA (ppb)	OA-TS (ppb)	OA-TS (%)
2017-10-27 04:00	1	0	0.11	-0.29	0.14	0.11	-0.40	NA
2017-10-27 04:10	1	20	19.76	18.50	0.09	0.21	-1.26	-6.4
2017-10-27 04:20	1	60	60.02	57.81	0.12	0.16	-2.21	-3.7
2017-10-27 04:30	1	80	80.22	77.59	0.12	0.20	-2.63	-3.3
2017-10-27 04:40	1	40	40.21	38.49	0.12	0.14	-1.72	-4.3
2017-10-27 04:50	1	100	100.36	97.18	0.08	0.08	-3.18	-3.2
2017-10-27 05:00	2	0	0.30	-0.19	0.18	0.16	-0.49	NA
2017-10-27 05:10	2	60	60.18	58.02	0.05	0.13	-2.16	-3.6
2017-10-27 05:20	2	40	40.04	38.39	0.06	0.10	-1.65	-4.1
2017-10-27 05:30	2	100	100.32	97.12	0.10	0.32	-3.20	-3.2
2017-10-27 05:40	2	20	20.41	19.17	0.20	0.28	-1.24	-6.1
2017-10-27 05:50	2	80	80.08	77.30	0.18	0.34	-2.78	-3.5
2017-10-27 06:00	3	0	0.26	-0.19	0.09	0.06	-0.45	NA
2017-10-27 06:10	3	100	100.43	97.11	0.05	0.12	-3.32	-3.3
2017-10-27 06:20	3	40	40.08	38.41	0.11	0.08	-1.67	-4.2
2017-10-27 06:30	4	0	0.24	-0.17	0.40	0.19	-0.41	NA
2017-10-27 06:40	4	20	19.92	18.76	0.12	0.09	-1.16	-5.8
2017-10-27 06:50	4	60	60.05	57.86	0.09	0.14	-2.19	-3.6
2017-10-27 07:00	4	80	80.29	77.75	0.02	0.14	-2.54	-3.2
2017-10-27 07:10	4	40	40.30	38.62	0.14	0.14	-1.68	-4.2
2017-10-27 07:20	4	100	100.36	97.16	0.11	0.10	-3.20	-3.2
2017-10-27 07:30	5	0	0.26	-0.28	0.14	0.20	-0.54	NA
2017-10-27 07:40	5	60	60.21	58.00	0.10	0.05	-2.21	-3.7
2017-10-27 07:50	5	40	40.07	38.24	0.08	0.17	-1.83	-4.6

Date - Time	Run #	Level (ppb)	TS (ppb)	OA (ppb)	sdTS (ppb)	sdOA (ppb)	OA-TS (ppb)	OA-TS (%)
2017-10-27 08:00	5	100	100.33	97.15	0.09	0.17	-3.18	-3.2
2017-10-27 08:10	5	20	20.39	19.36	0.10	0.23	-1.03	-5.1
2017-10-27 08:20	5	80	80.13	77.44	0.12	0.13	-2.69	-3.4
2017-10-27 08:30	6	0	0.39	-0.38	0.30	0.15	-0.77	NA
2017-10-27 08:40	6	100	100.39	97.24	0.06	0.09	-3.15	-3.1
2017-10-27 08:50	6	40	40.07	38.48	0.09	0.26	-1.59	-4.0
2017-10-27 09:00	7	0	0.29	-0.24	0.26	0.14	-0.53	NA
2017-10-27 09:10	7	20	19.82	18.58	0.10	0.06	-1.24	-6.3
2017-10-27 09:20	7	60	60.07	57.88	0.11	0.18	-2.19	-3.6
2017-10-27 09:30	7	80	80.30	77.69	0.07	0.17	-2.61	-3.3
2017-10-27 09:40	7	40	40.28	38.48	0.10	0.10	-1.80	-4.5
2017-10-27 09:50	7	100	100.40	97.26	0.10	0.10	-3.14	-3.1
2017-10-27 10:00	8	0	0.16	-0.27	0.17	0.13	-0.43	NA
2017-10-27 10:10	8	60	60.20	58.17	0.06	0.17	-2.03	-3.4
2017-10-27 10:20	8	40	40.08	38.44	0.03	0.12	-1.64	-4.1
2017-10-27 10:30	8	100	100.33	97.10	0.12	0.25	-3.23	-3.2
2017-10-27 10:40	8	20	20.43	19.29	0.20	0.25	-1.14	-5.6
2017-10-27 10:50	8	80	80.13	77.53	0.20	0.26	-2.60	-3.2
2017-10-27 11:00	9	0	0.44	-0.55	0.23	0.24	-0.99	NA
2017-10-27 11:10	9	100	100.41	97.36	0.08	0.10	-3.05	-3.0
2017-10-27 11:20	9	40	40.03	38.37	0.03	0.06	-1.66	-4.1
2017-10-27 11:30	10	0	0.40	-0.44	0.17	0.18	-0.84	NA
2017-10-27 11:40	10	20	19.71	18.45	0.19	0.20	-1.26	-6.4
2017-10-27 11:50	10	60	60.07	57.80	0.05	0.10	-2.27	-3.8
2017-10-27 12:00	10	80	80.30	77.79	0.14	0.17	-2.51	-3.1
2017-10-27 12:10	10	40	40.29	38.65	0.12	0.38	-1.64	-4.1
2017-10-27 12:20	10	100	100.38	97.33	0.06	0.06	-3.05	-3.0

Table 7. Ten-minute aggregates computed from the last 5 of a total of 10 one-minute values for the comparison of the LQO ozone analyser (OA) (final settings) with the WCC-Empa travelling standard (TS).

Date - Time	Run #	Level (ppb)	TS (ppb)	OA (ppb)	sdTS (ppb)	sdOA (ppb)	OA-TS (ppb)	OA-TS (%)
2018-01-29 12:43	1	30	29.90	29.87	0.10	0.12	-0.03	-0.1
2018-01-29 12:53	1	60	59.98	60.01	0.06	0.10	0.03	0.1
2018-01-29 13:03	1	70	70.01	69.78	0.08	0.05	-0.23	-0.3
2018-01-29 13:13	1	40	40.00	39.93	0.08	0.19	-0.07	-0.2
2018-01-29 13:23	1	10	10.42	10.28	0.15	0.29	-0.14	-1.3
2018-01-29 13:33	1	20	19.88	19.82	0.10	0.12	-0.06	-0.3
2018-01-29 13:43	1	50	49.80	49.72	0.14	0.16	-0.08	-0.2
2018-01-29 13:53	1	80	80.05	79.88	0.06	0.14	-0.17	-0.2
2018-01-29 14:03	2	0	0.35	0.25	0.14	0.13	-0.10	NA
2018-01-29 14:13	2	40	39.96	39.55	0.17	0.22	-0.41	-1.0
2018-01-29 14:23	2	100	99.86	99.40	0.14	0.21	-0.46	-0.5
2018-01-29 14:43	2	200	199.92	199.62	0.14	0.13	-0.30	-0.2
2018-01-29 14:53	2	30	30.15	29.97	0.09	0.27	-0.18	-0.6

Date - Time	Run #	Level (ppb)	TS (ppb)	OA (ppb)	sdTS (ppb)	sdOA (ppb)	OA-TS (ppb)	OA-TS (%)
2018-01-29 15:03	2	80	79.97	79.51	0.17	0.11	-0.46	-0.6
2018-01-29 15:08	2	60	60.00	59.68	0.09	0.16	-0.32	-0.5
2018-01-29 15:13	2	50	50.08	49.84	0.05	0.24	-0.24	-0.5
2018-01-29 15:23	2	150	149.91	149.42	0.24	0.30	-0.49	-0.3
2018-01-29 15:58	3	0	0.36	0.26	0.12	0.16	-0.10	NA
2018-01-29 16:13	3	90	90.00	89.64	0.10	0.09	-0.36	-0.4
2018-01-29 16:23	3	30	29.90	29.62	0.07	0.07	-0.28	-0.9
2018-01-29 16:33	3	60	59.99	59.81	0.11	0.08	-0.18	-0.3
2018-01-29 16:43	3	70	69.98	69.84	0.16	0.15	-0.14	-0.2
2018-01-29 16:53	3	40	40.13	40.13	0.14	0.26	0.00	0.0
2018-01-29 17:03	3	10	10.43	10.48	0.17	0.18	0.05	0.5
2018-01-29 17:13	3	20	19.72	19.74	0.15	0.27	0.02	0.1
2018-01-29 17:23	3	50	49.80	49.84	0.21	0.21	0.04	0.1
2018-01-29 17:33	3	80	80.02	79.94	0.11	0.19	-0.08	-0.1
2018-01-29 17:43	4	0	0.27	0.24	0.05	0.10	-0.03	NA
2018-01-29 17:53	4	40	39.94	39.91	0.03	0.14	-0.03	-0.1
2018-01-29 18:03	4	100	99.87	99.74	0.09	0.16	-0.13	-0.1
2018-01-29 18:23	4	200	199.82	199.57	0.19	0.23	-0.25	-0.1
2018-01-29 18:33	4	30	30.28	30.37	0.19	0.28	0.09	0.3
2018-01-29 18:43	4	80	80.00	79.94	0.09	0.34	-0.06	-0.1
2018-01-29 18:48	4	60	59.86	59.86	0.16	0.31	0.00	0.0
2018-01-29 18:53	4	50	50.03	49.91	0.12	0.13	-0.12	-0.2
2018-01-29 19:03	4	150	149.90	149.65	0.11	0.26	-0.25	-0.2
2018-01-29 19:13	4	10	10.69	10.74	0.29	0.37	0.05	0.5
2018-01-29 19:38	5	0	0.17	0.29	0.04	0.11	0.12	NA
2018-01-29 19:53	5	90	90.00	89.80	0.06	0.07	-0.20	-0.2
2018-01-29 20:03	5	30	29.71	29.70	0.15	0.24	-0.01	0.0
2018-01-29 20:13	5	60	59.96	59.82	0.16	0.19	-0.14	-0.2
2018-01-29 20:23	5	70	70.03	69.89	0.11	0.23	-0.14	-0.2
2018-01-29 20:33	5	40	40.05	39.77	0.10	0.16	-0.28	-0.7
2018-01-29 20:43	5	10	10.53	10.40	0.12	0.46	-0.13	-1.2
2018-01-29 20:53	5	20	19.87	19.59	0.14	0.20	-0.28	-1.4
2018-01-29 21:03	5	50	49.84	49.60	0.15	0.07	-0.24	-0.5
2018-01-29 21:13	5	80	80.03	79.64	0.08	0.20	-0.39	-0.5
2018-01-29 21:23	6	0	0.40	0.26	0.07	0.33	-0.14	NA
2018-01-29 21:33	6	40	39.86	39.55	0.08	0.18	-0.31	-0.8
2018-01-29 21:43	6	100	99.85	99.36	0.11	0.15	-0.49	-0.5
2018-01-29 22:03	6	200	199.88	199.29	0.25	0.20	-0.59	-0.3
2018-01-29 22:13	6	30	30.30	29.95	0.30	0.35	-0.35	-1.2
2018-01-29 22:23	6	80	79.98	79.74	0.12	0.24	-0.24	-0.3
2018-01-29 22:28	6	60	59.84	59.47	0.25	0.20	-0.37	-0.6
2018-01-29 22:33	6	50	50.02	49.81	0.07	0.08	-0.21	-0.4
2018-01-29 22:43	6	150	149.88	149.37	0.18	0.23	-0.51	-0.3
2018-01-29 22:53	6	10	10.68	10.46	0.33	0.27	-0.22	-2.1
2018-01-29 23:18	7	0	0.32	0.21	0.09	0.17	-0.11	NA
2018-01-29 23:33	7	90	90.00	89.57	0.14	0.19	-0.43	-0.5
2018-01-29 23:43	7	30	29.78	29.87	0.06	0.24	0.09	0.3
2018-01-29 23:53	7	60	60.03	59.95	0.08	0.12	-0.08	-0.1

Date - Time	Run #	Level (ppb)	TS (ppb)	OA (ppb)	sdTS (ppb)	sdOA (ppb)	OA-TS (ppb)	OA-TS (%)
2018-01-30 00:03	7	70	70.02	69.76	0.16	0.12	-0.26	-0.4
2018-01-30 00:13	7	40	40.06	40.01	0.08	0.09	-0.05	-0.1
2018-01-30 00:23	7	10	9.96	9.89	0.25	0.23	-0.07	-0.7
2018-01-30 00:33	7	20	19.95	19.85	0.15	0.21	-0.10	-0.5
2018-01-30 00:43	7	50	49.82	49.81	0.21	0.12	-0.01	0.0
2018-01-30 00:53	7	80	79.95	79.86	0.07	0.18	-0.09	-0.1
2018-01-30 01:03	8	0	0.17	0.17	0.15	0.16	0.00	NA
2018-01-30 01:13	8	40	39.96	39.80	0.15	0.16	-0.16	-0.4
2018-01-30 01:23	8	100	99.85	99.89	0.09	0.09	0.04	0.0
2018-01-30 01:43	8	200	199.86	199.48	0.18	0.09	-0.38	-0.2
2018-01-30 01:53	8	30	30.20	30.23	0.20	0.23	0.03	0.1
2018-01-30 02:03	8	80	80.00	79.96	0.10	0.21	-0.04	0.0
2018-01-30 02:08	8	60	59.85	59.52	0.19	0.21	-0.33	-0.6
2018-01-30 02:13	8	50	50.01	49.97	0.09	0.16	-0.04	-0.1
2018-01-30 02:23	8	150	149.89	149.58	0.18	0.23	-0.31	-0.2
2018-01-30 02:33	8	10	10.72	10.76	0.34	0.37	0.04	0.4
2018-01-30 02:58	9	0	0.25	0.22	0.10	0.12	-0.03	NA
2018-01-30 03:13	9	90	90.01	89.45	0.12	0.21	-0.56	-0.6
2018-01-30 03:23	9	30	29.98	29.58	0.19	0.22	-0.40	-1.3
2018-01-30 03:33	9	60	60.00	59.60	0.10	0.19	-0.40	-0.7
2018-01-30 03:43	9	70	70.02	69.60	0.09	0.21	-0.42	-0.6
2018-01-30 03:53	9	40	40.01	39.44	0.14	0.10	-0.57	-1.4
2018-01-30 04:03	9	10	10.49	10.29	0.27	0.25	-0.20	-1.9
2018-01-30 04:13	9	20	19.76	19.63	0.10	0.20	-0.13	-0.7
2018-01-30 04:23	9	50	49.80	49.43	0.19	0.23	-0.37	-0.7
2018-01-30 04:33	9	80	80.04	79.70	0.06	0.10	-0.34	-0.4
2018-01-30 04:43	10	0	0.40	0.10	0.12	0.20	-0.30	NA
2018-01-30 04:53	10	40	39.93	39.62	0.12	0.14	-0.31	-0.8
2018-01-30 05:03	10	100	99.85	99.47	0.11	0.21	-0.38	-0.4
2018-01-30 05:23	10	200	199.81	199.38	0.21	0.17	-0.43	-0.2
2018-01-30 05:33	10	30	30.25	30.04	0.19	0.20	-0.21	-0.7
2018-01-30 05:43	10	80	79.96	79.72	0.11	0.33	-0.24	-0.3
2018-01-30 05:48	10	60	59.86	59.63	0.15	0.21	-0.23	-0.4
2018-01-30 05:53	10	50	50.07	49.89	0.12	0.14	-0.18	-0.4
2018-01-30 06:03	10	150	149.92	149.35	0.15	0.19	-0.57	-0.4
2018-01-30 06:13	10	10	10.53	10.55	0.28	0.20	0.02	0.2
2018-01-30 06:38	11	0	0.19	0.16	0.10	0.19	-0.03	NA
2018-01-30 06:53	11	90	89.96	89.69	0.10	0.17	-0.27	-0.3
2018-01-30 07:03	11	30	29.87	29.77	0.19	0.09	-0.10	-0.3
2018-01-30 07:13	11	60	60.01	59.95	0.10	0.08	-0.06	-0.1
2018-01-30 07:23	11	70	70.01	70.05	0.10	0.19	0.04	0.1
2018-01-30 07:33	11	40	40.07	39.92	0.10	0.14	-0.15	-0.4
2018-01-30 07:43	11	10	10.33	10.61	0.15	0.26	0.28	2.7
2018-01-30 07:53	11	20	19.98	19.99	0.12	0.08	0.01	0.1
2018-01-30 08:03	11	50	49.81	49.75	0.18	0.32	-0.06	-0.1
2018-01-30 08:13	11	80	80.00	79.88	0.03	0.23	-0.12	-0.2
2018-01-30 08:23	12	0	0.14	0.24	0.10	0.15	0.10	NA
2018-01-30 08:33	12	40	39.88	39.88	0.12	0.18	0.00	0.0

Date - Time	Run #	Level (ppb)	TS (ppb)	OA (ppb)	sdTS (ppb)	sdOA (ppb)	OA-TS (ppb)	OA-TS (%)
2018-01-30 08:43	12	100	99.83	99.55	0.12	0.27	-0.28	-0.3
2018-01-30 09:03	12	200	199.87	198.99	0.11	0.15	-0.88	-0.4
2018-01-30 09:13	12	30	30.16	30.14	0.08	0.20	-0.02	-0.1
2018-01-30 09:23	12	80	79.98	79.87	0.08	0.12	-0.11	-0.1
2018-01-30 09:28	12	60	59.89	59.71	0.16	0.29	-0.18	-0.3
2018-01-30 09:33	12	50	50.08	49.91	0.10	0.18	-0.17	-0.3
2018-01-30 09:43	12	150	149.82	149.53	0.11	0.15	-0.29	-0.2
2018-01-30 09:53	12	10	10.55	10.54	0.16	0.16	-0.01	-0.1
2018-01-30 10:18	13	0	0.45	0.19	0.07	0.15	-0.26	NA
2018-01-30 10:33	13	90	89.98	89.57	0.11	0.18	-0.41	-0.5
2018-01-30 10:43	13	30	29.94	29.66	0.15	0.16	-0.28	-0.9
2018-01-30 10:53	13	60	59.94	59.55	0.11	0.21	-0.39	-0.7
2018-01-30 11:03	13	70	70.02	69.67	0.06	0.09	-0.35	-0.5
2018-01-30 11:13	13	40	39.96	39.61	0.09	0.10	-0.35	-0.9
2018-01-30 11:23	13	10	10.20	10.06	0.05	0.10	-0.14	-1.4
2018-01-30 11:33	13	20	19.66	19.34	0.16	0.32	-0.32	-1.6
2018-01-30 11:43	13	50	49.79	49.47	0.20	0.35	-0.32	-0.6
2018-01-30 11:53	13	80	80.02	79.72	0.08	0.18	-0.30	-0.4
2018-01-30 12:03	14	0	0.42	0.28	0.12	0.07	-0.14	NA
2018-01-30 12:13	14	40	39.95	39.75	0.09	0.15	-0.20	-0.5
2018-01-30 12:23	14	100	99.80	99.44	0.18	0.18	-0.36	-0.4

Table 8. Ten-minute aggregates computed from the last 5 of a total of 10 one-minute values for the comparison of the SAG ozone analyser (OA) (initial settings) with the WCC-Empa travelling standard (TS).

Date - Time	Run #	Level (ppb)	TS (ppb)	OA (ppb)	sdTS (ppb)	sdOA (ppb)	OA-TS (ppb)	OA-TS (%)
2017-10-24 21:38	1	20	20.31	19.88	0.20	0.21	-0.43	-2.1
2017-10-24 21:48	1	80	80.06	78.07	0.16	0.19	-1.99	-2.5
2017-10-24 21:58	1	60	60.20	58.70	0.09	0.14	-1.50	-2.5
2017-10-24 22:08	1	100	100.39	97.62	0.07	0.26	-2.77	-2.8
2017-10-24 22:18	1	40	40.21	39.01	0.11	0.22	-1.20	-3.0
2017-10-24 22:28	1	0	0.18	-0.21	0.23	0.11	-0.39	NA
2017-10-24 22:38	2	100	100.37	97.62	0.09	0.19	-2.75	-2.7
2017-10-24 22:48	2	40	40.05	38.84	0.07	0.06	-1.21	-3.0
2017-10-24 22:58	2	80	80.26	77.96	0.09	0.07	-2.30	-2.9
2017-10-24 23:08	2	20	20.29	19.48	0.14	0.26	-0.81	-4.0
2017-10-24 23:18	2	60	60.06	58.43	0.07	0.19	-1.63	-2.7
2017-10-24 23:28	2	0	0.18	0.14	0.16	0.11	-0.04	NA
2017-10-24 23:38	3	20	19.92	19.23	0.11	0.14	-0.69	-3.5
2017-10-24 23:48	3	80	80.14	77.84	0.08	0.09	-2.30	-2.9
2017-10-24 23:58	3	60	60.20	58.42	0.07	0.07	-1.78	-3.0
2017-10-25 00:08	3	100	100.37	97.72	0.08	0.22	-2.65	-2.6
2017-10-25 00:18	3	40	40.28	39.20	0.05	0.14	-1.08	-2.7
2017-10-25 00:28	3	0	0.23	-0.06	0.24	0.10	-0.29	NA
2017-10-25 00:38	4	100	100.37	97.61	0.14	0.08	-2.76	-2.7

Date - Time	Run #	Level (ppb)	TS (ppb)	OA (ppb)	sdTS (ppb)	sdOA (ppb)	OA-TS (ppb)	OA-TS (%)
2017-10-25 00:48	4	40	40.00	38.79	0.03	0.13	-1.21	-3.0
2017-10-25 00:58	4	80	80.28	78.08	0.05	0.17	-2.20	-2.7
2017-10-25 01:08	4	20	20.38	19.60	0.14	0.23	-0.78	-3.8
2017-10-25 01:18	4	60	60.07	58.31	0.09	0.22	-1.76	-2.9
2017-10-25 01:28	4	0	0.28	-0.03	0.23	0.07	-0.31	NA
2017-10-25 01:38	5	20	19.95	19.45	0.17	0.16	-0.50	-2.5
2017-10-25 01:48	5	80	80.07	78.02	0.09	0.24	-2.05	-2.6
2017-10-25 01:58	5	60	60.23	58.68	0.08	0.11	-1.55	-2.6
2017-10-25 02:08	5	100	100.36	97.90	0.08	0.18	-2.46	-2.5
2017-10-25 02:18	5	40	40.22	39.24	0.07	0.14	-0.98	-2.4
2017-10-25 02:28	5	0	0.28	0.02	0.08	0.17	-0.26	NA
2017-10-25 02:38	6	100	100.38	97.75	0.08	0.08	-2.63	-2.6
2017-10-25 02:48	6	40	40.02	38.89	0.08	0.13	-1.13	-2.8
2017-10-25 02:58	6	80	80.26	78.15	0.08	0.11	-2.11	-2.6
2017-10-25 03:08	6	20	20.32	19.77	0.16	0.19	-0.55	-2.7
2017-10-25 03:18	6	60	60.07	58.59	0.13	0.25	-1.48	-2.5
2017-10-25 03:28	6	0	0.29	0.09	0.28	0.10	-0.20	NA
2017-10-25 03:38	7	20	19.91	19.26	0.11	0.07	-0.65	-3.3
2017-10-25 03:48	7	80	80.09	78.08	0.08	0.12	-2.01	-2.5
2017-10-25 03:58	7	60	60.24	58.69	0.10	0.18	-1.55	-2.6
2017-10-25 04:08	7	100	100.40	97.97	0.05	0.09	-2.43	-2.4
2017-10-25 04:18	7	40	40.27	39.37	0.14	0.19	-0.90	-2.2
2017-10-25 04:28	7	0	0.23	0.36	0.13	0.17	0.13	NA
2017-10-25 04:38	8	100	100.38	97.93	0.08	0.10	-2.45	-2.4
2017-10-25 04:48	8	40	40.00	39.23	0.09	0.14	-0.77	-1.9
2017-10-25 04:58	8	80	80.26	78.25	0.06	0.10	-2.01	-2.5
2017-10-25 05:08	8	20	20.36	19.84	0.25	0.25	-0.52	-2.6
2017-10-25 05:18	8	60	60.07	58.55	0.12	0.17	-1.52	-2.5
2017-10-25 05:28	8	0	0.13	0.19	0.23	0.14	0.06	NA
2017-10-25 05:38	9	20	19.85	19.44	0.11	0.14	-0.41	-2.1
2017-10-25 05:48	9	80	80.12	78.18	0.09	0.21	-1.94	-2.4
2017-10-25 05:58	9	60	60.24	58.86	0.14	0.18	-1.38	-2.3
2017-10-25 06:08	9	100	100.41	97.91	0.06	0.09	-2.50	-2.5
2017-10-25 06:18	9	40	40.22	39.42	0.09	0.09	-0.80	-2.0
2017-10-25 06:28	9	0	0.25	0.27	0.22	0.08	0.02	8.0
2017-10-25 06:38	10	100	100.37	98.08	0.07	0.22	-2.29	-2.3
2017-10-25 06:48	10	40	40.03	39.29	0.08	0.09	-0.74	-1.8
2017-10-25 06:58	10	80	80.29	78.47	0.03	0.17	-1.82	-2.3
2017-10-25 07:08	10	20	20.33	19.98	0.18	0.16	-0.35	-1.7
2017-10-25 07:18	10	60	60.06	58.57	0.11	0.07	-1.49	-2.5
2017-10-25 07:28	10	0	0.18	0.33	0.15	0.17	0.15	NA
2017-10-25 07:38	11	20	19.93	19.48	0.09	0.13	-0.45	-2.3
2017-10-25 07:48	11	80	80.08	78.29	0.04	0.11	-1.79	-2.2
2017-10-25 07:58	11	60	60.21	58.79	0.09	0.11	-1.42	-2.4
2017-10-25 08:08	11	100	100.39	97.98	0.06	0.08	-2.41	-2.4
2017-10-25 08:18	11	40	40.30	39.41	0.20	0.26	-0.89	-2.2
2017-10-25 08:28	11	0	0.16	0.23	0.17	0.17	0.07	NA
2017-10-25 08:38	12	100	100.37	97.96	0.05	0.09	-2.41	-2.4

Date - Time	Run #	Level (ppb)	TS (ppb)	OA (ppb)	sdTS (ppb)	sdOA (ppb)	OA-TS (ppb)	OA-TS (%)
2017-10-25 08:48	12	40	40.04	39.16	0.13	0.06	-0.88	-2.2
2017-10-25 08:58	12	80	80.27	78.30	0.10	0.22	-1.97	-2.5
2017-10-25 09:08	12	20	20.33	19.88	0.19	0.22	-0.45	-2.2
2017-10-25 09:18	12	60	60.02	58.49	0.18	0.11	-1.53	-2.5
2017-10-25 09:28	12	0	0.44	0.29	0.12	0.06	-0.15	NA
2017-10-25 09:38	13	20	19.93	19.28	0.11	0.24	-0.65	-3.3
2017-10-25 09:48	13	80	80.10	78.08	0.06	0.13	-2.02	-2.5
2017-10-25 09:58	13	60	60.22	58.62	0.06	0.05	-1.60	-2.7
2017-10-25 10:08	13	100	100.43	97.64	0.04	0.09	-2.79	-2.8
2017-10-25 10:18	13	40	40.32	39.35	0.10	0.19	-0.97	-2.4
2017-10-25 10:28	13	0	0.38	0.13	0.22	0.09	-0.25	NA
2017-10-25 10:38	14	100	100.38	97.76	0.07	0.17	-2.62	-2.6
2017-10-25 10:48	14	40	40.00	38.86	0.09	0.12	-1.14	-2.8
2017-10-25 10:58	14	80	80.27	78.36	0.11	0.18	-1.91	-2.4
2017-10-25 11:08	14	20	20.34	19.89	0.09	0.23	-0.45	-2.2
2017-10-25 11:18	14	60	60.01	58.28	0.17	0.25	-1.73	-2.9
2017-10-25 11:28	14	0	0.31	-0.07	0.36	0.09	-0.38	NA
2017-10-25 11:38	15	20	19.76	18.91	0.09	0.13	-0.85	-4.3
2017-10-25 11:48	15	80	80.05	77.58	0.07	0.10	-2.47	-3.1

Table 9. Ten-minute aggregates computed from the last 5 of a total of 10 one-minute values for the comparison of the SAG ozone analyser (OA) (final settings) with the WCC-Empa travelling standard (TS).

Date - Time	Run #	Level (ppb)	TS (ppb)	OA (ppb)	sdTS (ppb)	sdOA (ppb)	OA-TS (ppb)	OA-TS (%)
2017-10-26 14:58	1	0	0.42	-0.31	0.23	0.24	-0.73	NA
2017-10-26 15:08	1	60	60.15	59.42	0.07	0.16	-0.73	-1.2
2017-10-26 15:18	1	40	40.02	39.32	0.03	0.11	-0.70	-1.7
2017-10-26 15:28	1	100	100.29	99.57	0.14	0.28	-0.72	-0.7
2017-10-26 15:38	1	20	20.45	19.79	0.20	0.36	-0.66	-3.2
2017-10-26 15:48	1	80	80.08	79.40	0.16	0.26	-0.68	-0.8
2017-10-26 15:58	2	0	0.24	-0.32	0.10	0.11	-0.56	NA
2017-10-26 16:08	2	100	100.33	99.59	0.05	0.15	-0.74	-0.7
2017-10-26 16:18	2	40	40.08	39.38	0.10	0.18	-0.70	-1.7
2017-10-26 16:28	3	0	0.29	-0.40	0.19	0.18	-0.69	NA
2017-10-26 16:38	3	20	19.88	19.41	0.20	0.13	-0.47	-2.4
2017-10-26 16:48	3	60	60.03	59.45	0.06	0.26	-0.58	-1.0
2017-10-26 16:58	3	80	80.28	79.54	0.03	0.23	-0.74	-0.9
2017-10-26 17:08	3	40	40.25	39.48	0.11	0.12	-0.77	-1.9
2017-10-26 17:18	3	100	100.35	99.77	0.06	0.25	-0.58	-0.6

Table 10. Ten-minute aggregates computed from the last 5 of a total of 10 one-minute values for the comparison of the CHC ozone analyser (OA) (initial settings) with the WCC-Empa travelling standard (TS).

Date - Time	Run #	Level (ppb)	TS (ppb)	OA (ppb)	sdTS (ppb)	sdOA (ppb)	OA-TS (ppb)	OA-TS (%)
2017-12-26 03:46	1	0	0.22	-0.37	0.07	0.09	-0.59	NA
2017-12-26 04:01	1	90	90.04	92.24	0.10	0.11	2.20	2.4
2017-12-26 04:11	1	30	29.84	30.09	0.08	0.15	0.25	0.8
2017-12-26 04:21	1	60	59.98	61.33	0.09	0.14	1.35	2.3
2017-12-26 04:31	1	70	70.01	71.79	0.10	0.15	1.78	2.5
2017-12-26 04:41	1	40	39.94	40.70	0.09	0.18	0.76	1.9
2017-12-26 04:51	1	10	10.16	9.90	0.09	0.12	-0.26	-2.6
2017-12-26 05:01	1	20	19.81	19.72	0.15	0.12	-0.09	-0.5
2017-12-26 05:11	1	50	49.79	50.67	0.16	0.14	0.88	1.8
2017-12-26 05:21	1	80	80.01	81.94	0.05	0.25	1.93	2.4
2017-12-26 05:31	2	0	0.38	-0.45	0.07	0.08	-0.83	NA
2017-12-26 05:41	2	100	99.96	102.67	0.04	0.16	2.71	2.7
2017-12-26 05:51	2	200	200.07	206.08	0.18	0.25	6.01	3.0
2017-12-26 06:01	2	50	49.98	50.79	0.06	0.10	0.81	1.6
2017-12-26 06:11	2	250	249.95	257.90	0.13	0.11	7.95	3.2
2017-12-26 06:21	2	150	150.10	154.41	0.04	0.27	4.31	2.9
2017-12-26 06:36	3	0	0.31	-0.46	0.09	0.10	-0.77	NA
2017-12-26 06:51	3	90	90.00	92.30	0.10	0.19	2.30	2.6
2017-12-26 07:01	3	30	29.92	30.33	0.11	0.08	0.41	1.4
2017-12-26 07:11	3	60	60.01	61.43	0.10	0.12	1.42	2.4
2017-12-26 07:21	3	70	70.06	71.75	0.06	0.07	1.69	2.4
2017-12-26 07:31	3	40	40.05	40.73	0.11	0.15	0.68	1.7
2017-12-26 07:41	3	10	10.32	9.94	0.09	0.09	-0.38	-3.7
2017-12-26 07:51	3	20	19.87	19.87	0.18	0.25	0.00	0.0
2017-12-26 08:01	3	50	49.83	50.67	0.10	0.10	0.84	1.7
2017-12-26 08:11	3	80	80.02	81.96	0.12	0.09	1.94	2.4
2017-12-26 08:21	4	0	0.37	-0.35	0.07	0.14	-0.72	NA
2017-12-26 08:31	4	100	99.96	102.56	0.04	0.24	2.60	2.6
2017-12-26 08:41	4	200	200.06	206.26	0.10	0.24	6.20	3.1
2017-12-26 08:51	4	50	50.04	51.02	0.07	0.05	0.98	2.0
2017-12-26 09:01	4	250	249.93	257.69	0.22	0.27	7.76	3.1
2017-12-26 09:11	4	150	150.09	154.36	0.11	0.14	4.27	2.8
2017-12-26 09:26	5	0	0.27	-0.45	0.07	0.09	-0.72	NA
2017-12-26 09:41	5	90	90.02	92.31	0.09	0.14	2.29	2.5
2017-12-26 09:51	5	30	29.95	30.25	0.15	0.08	0.30	1.0
2017-12-26 10:01	5	60	59.94	61.37	0.08	0.23	1.43	2.4
2017-12-26 10:11	5	70	70.04	71.75	0.08	0.09	1.71	2.4
2017-12-26 10:21	5	40	40.03	40.73	0.04	0.12	0.70	1.7
2017-12-26 10:31	5	10	10.49	10.31	0.21	0.33	-0.18	-1.7
2017-12-26 10:41	5	20	19.94	19.88	0.07	0.09	-0.06	-0.3
2017-12-26 10:51	5	50	49.79	50.77	0.21	0.22	0.98	2.0
2017-12-26 11:01	5	80	80.00	82.00	0.02	0.14	2.00	2.5
2017-12-26 11:11	6	0	0.25	-0.46	0.13	0.09	-0.71	NA
2017-12-26 11:21	6	100	99.94	102.50	0.09	0.19	2.56	2.6
2017-12-26 11:31	6	200	200.03	205.86	0.09	0.24	5.83	2.9

Date - Time	Run #	Level (ppb)	TS (ppb)	OA (ppb)	sdTS (ppb)	sdOA (ppb)	OA-TS (ppb)	OA-TS (%)
2017-12-26 11:41	6	50	50.02	50.98	0.04	0.15	0.96	1.9
2017-12-26 11:51	6	250	249.92	257.64	0.15	0.50	7.72	3.1
2017-12-26 12:01	6	150	150.00	154.49	0.12	0.15	4.49	3.0

Table 11. Ten-minute aggregates computed from the last 5 of a total of 10 one-minute values for the comparison of the CHC ozone analyser (final settings) (OA) with the WCC-Empa travelling standard (TS).

Date - Time	Run #	Level (ppb)	TS (ppb)	OA (ppb)	sdTS (ppb)	sdOA (ppb)	OA-TS (ppb)	OA-TS (%)
2018-01-24 16:37	1	90	89.93	89.24	0.06	0.09	-0.69	-0.8
2018-01-24 16:47	1	30	30.24	30.06	0.18	0.23	-0.18	-0.6
2018-01-24 16:57	1	60	59.93	59.49	0.07	0.09	-0.44	-0.7
2018-01-24 17:07	1	70	69.98	69.34	0.11	0.05	-0.64	-0.9
2018-01-24 17:17	1	40	40.04	39.48	0.18	0.13	-0.56	-1.4
2018-01-24 17:27	1	10	10.55	10.33	0.24	0.46	-0.22	-2.1
2018-01-24 17:37	1	20	19.77	19.33	0.15	0.10	-0.44	-2.2
2018-01-24 17:47	1	50	49.79	49.29	0.23	0.21	-0.50	-1.0
2018-01-24 17:57	1	80	79.99	79.41	0.06	0.16	-0.58	-0.7
2018-01-24 18:07	2	0	0.31	0.22	0.06	0.13	-0.09	NA
2018-01-24 18:17	2	40	39.80	39.54	0.10	0.08	-0.26	-0.7
2018-01-24 18:27	2	100	99.77	99.10	0.14	0.24	-0.67	-0.7
2018-01-24 18:47	2	200	199.87	198.26	0.19	0.12	-1.61	-0.8
2018-01-24 18:57	2	30	30.05	29.67	0.07	0.13	-0.38	-1.3
2018-01-24 19:07	2	80	79.92	79.33	0.05	0.14	-0.59	-0.7
2018-01-24 19:12	2	60	59.84	59.52	0.19	0.27	-0.32	-0.5
2018-01-24 19:17	2	50	50.05	49.68	0.05	0.08	-0.37	-0.7
2018-01-24 19:27	2	150	149.88	148.68	0.17	0.21	-1.20	-0.8
2018-01-24 19:37	2	10	10.35	9.96	0.11	0.11	-0.39	-3.8
2018-01-24 20:02	3	0	0.43	0.16	0.10	0.11	-0.27	NA
2018-01-24 20:17	3	90	89.89	89.19	0.10	0.14	-0.70	-0.8
2018-01-24 20:27	3	30	29.97	29.83	0.16	0.12	-0.14	-0.5
2018-01-24 20:37	3	60	59.97	59.52	0.07	0.10	-0.45	-0.8
2018-01-24 20:47	3	70	69.97	69.64	0.04	0.08	-0.33	-0.5
2018-01-24 20:57	3	40	39.99	39.87	0.08	0.08	-0.12	-0.3
2018-01-24 21:07	3	10	10.54	10.60	0.30	0.35	0.06	0.6
2018-01-24 21:17	3	20	19.99	19.95	0.09	0.10	-0.04	-0.2
2018-01-24 21:27	3	50	49.82	49.65	0.19	0.23	-0.17	-0.3
2018-01-24 21:37	3	80	80.00	79.50	0.07	0.16	-0.50	-0.6
2018-01-24 21:47	4	0	0.18	0.17	0.11	0.06	-0.01	NA
2018-01-24 21:57	4	40	39.90	39.77	0.06	0.05	-0.13	-0.3
2018-01-24 22:07	4	100	99.79	99.26	0.10	0.14	-0.53	-0.5
2018-01-24 22:27	4	200	199.80	198.53	0.25	0.15	-1.27	-0.6
2018-01-24 22:37	4	30	30.16	30.04	0.06	0.18	-0.12	-0.4
2018-01-24 22:47	4	80	80.00	79.50	0.05	0.16	-0.50	-0.6
2018-01-24 22:52	4	60	59.82	59.53	0.17	0.31	-0.29	-0.5
2018-01-24 22:57	4	50	49.97	49.58	0.12	0.14	-0.39	-0.8

Date - Time	Run #	Level (ppb)	TS (ppb)	OA (ppb)	sdTS (ppb)	sdOA (ppb)	OA-TS (ppb)	OA-TS (%)
2018-01-24 23:07	4	150	149.86	148.96	0.11	0.16	-0.90	-0.6
2018-01-24 23:17	4	10	10.77	10.65	0.40	0.35	-0.12	-1.1
2018-01-24 23:42	5	0	0.20	0.13	0.10	0.09	-0.07	NA
2018-01-24 23:57	5	90	89.99	89.20	0.11	0.23	-0.79	-0.9
2018-01-25 00:07	5	30	29.82	29.48	0.10	0.10	-0.34	-1.1
2018-01-25 00:17	5	60	59.96	59.31	0.14	0.16	-0.65	-1.1
2018-01-25 00:27	5	70	70.04	69.24	0.04	0.12	-0.80	-1.1
2018-01-25 00:37	5	40	39.97	39.69	0.09	0.10	-0.28	-0.7
2018-01-25 00:47	5	10	10.52	10.20	0.26	0.36	-0.32	-3.0
2018-01-25 00:57	5	20	19.96	19.61	0.04	0.14	-0.35	-1.8
2018-01-25 01:07	5	50	49.81	49.10	0.12	0.15	-0.71	-1.4
2018-01-25 01:17	5	80	79.95	79.53	0.14	0.07	-0.42	-0.5
2018-01-25 01:27	6	0	0.34	0.05	0.10	0.06	-0.29	NA
2018-01-25 01:37	6	40	39.83	39.49	0.07	0.11	-0.34	-0.9
2018-01-25 01:47	6	100	99.77	99.07	0.15	0.30	-0.70	-0.7
2018-01-25 02:07	6	200	199.77	198.09	0.21	0.22	-1.68	-0.8
2018-01-25 02:17	6	30	30.21	29.85	0.15	0.16	-0.36	-1.2
2018-01-25 02:27	6	80	79.95	79.06	0.10	0.10	-0.89	-1.1
2018-01-25 02:32	6	60	59.86	59.35	0.22	0.18	-0.51	-0.9
2018-01-25 02:37	6	50	49.90	49.37	0.10	0.15	-0.53	-1.1
2018-01-25 02:47	6	150	149.90	148.57	0.10	0.12	-1.33	-0.9
2018-01-25 02:57	6	10	10.29	10.01	0.09	0.09	-0.28	-2.7
2018-01-25 03:22	7	0	0.31	0.17	0.09	0.12	-0.14	NA
2018-01-25 03:37	7	90	89.97	89.45	0.07	0.11	-0.52	-0.6
2018-01-25 03:47	7	30	29.80	29.68	0.06	0.07	-0.12	-0.4
2018-01-25 03:57	7	60	59.97	59.74	0.08	0.18	-0.23	-0.4
2018-01-25 04:07	7	70	70.04	69.58	0.05	0.06	-0.46	-0.7
2018-01-25 04:17	7	40	40.03	39.91	0.13	0.19	-0.12	-0.3
2018-01-25 04:27	7	10	10.29	10.22	0.19	0.13	-0.07	-0.7
2018-01-25 04:37	7	20	19.80	19.69	0.12	0.16	-0.11	-0.6
2018-01-25 04:47	7	50	49.81	49.66	0.14	0.30	-0.15	-0.3
2018-01-25 04:57	7	80	80.01	79.55	0.09	0.12	-0.46	-0.6
2018-01-25 05:07	8	0	0.17	0.17	0.15	0.12	0.00	NA
2018-01-25 05:17	8	40	39.93	39.72	0.11	0.16	-0.21	-0.5
2018-01-25 05:27	8	100	99.75	99.25	0.17	0.09	-0.50	-0.5
2018-01-25 05:47	8	200	199.80	198.68	0.21	0.22	-1.12	-0.6
2018-01-25 05:57	8	30	30.23	30.01	0.20	0.07	-0.22	-0.7
2018-01-25 06:07	8	80	79.96	79.51	0.11	0.21	-0.45	-0.6
2018-01-25 06:12	8	60	59.91	59.46	0.19	0.23	-0.45	-0.8
2018-01-25 06:17	8	50	49.99	49.66	0.08	0.11	-0.33	-0.7
2018-01-25 06:27	8	150	149.91	148.86	0.17	0.24	-1.05	-0.7
2018-01-25 06:37	8	10	10.34	10.16	0.05	0.06	-0.18	-1.7
2018-01-25 07:02	9	0	0.23	0.11	0.08	0.10	-0.12	NA
2018-01-25 07:17	9	90	89.94	89.34	0.10	0.14	-0.60	-0.7
2018-01-25 07:27	9	30	29.91	29.55	0.15	0.09	-0.36	-1.2
2018-01-25 07:37	9	60	59.94	59.46	0.16	0.09	-0.48	-0.8
2018-01-25 07:47	9	70	70.05	69.23	0.11	0.18	-0.82	-1.2
2018-01-25 07:57	9	40	39.95	39.47	0.07	0.08	-0.48	-1.2

Date - Time	Run #	Level (ppb)	TS (ppb)	OA (ppb)	sdTS (ppb)	sdOA (ppb)	OA-TS (ppb)	OA-TS (%)
2018-01-25 08:07	9	10	10.38	10.13	0.20	0.14	-0.25	-2.4
2018-01-25 08:17	9	20	19.83	19.61	0.14	0.15	-0.22	-1.1
2018-01-25 08:27	9	50	49.89	49.31	0.10	0.18	-0.58	-1.2
2018-01-25 08:37	9	80	79.91	79.40	0.15	0.17	-0.51	-0.6
2018-01-25 08:47	10	0	0.36	0.11	0.12	0.09	-0.25	NA
2018-01-25 08:57	10	40	39.93	39.56	0.18	0.10	-0.37	-0.9
2018-01-25 09:07	10	100	99.83	99.04	0.13	0.08	-0.79	-0.8
2018-01-25 09:27	10	200	199.81	198.22	0.28	0.31	-1.59	-0.8
2018-01-25 09:37	10	30	30.21	29.78	0.10	0.20	-0.43	-1.4
2018-01-25 09:47	10	80	79.93	79.40	0.08	0.08	-0.53	-0.7
2018-01-25 09:52	10	60	59.87	59.36	0.22	0.22	-0.51	-0.9
2018-01-25 09:57	10	50	50.02	49.65	0.10	0.22	-0.37	-0.7
2018-01-25 10:07	10	150	149.71	148.64	0.24	0.18	-1.07	-0.7
2018-01-25 10:17	10	10	10.71	10.47	0.36	0.33	-0.24	-2.2
2018-01-25 10:42	11	0	0.22	0.06	0.08	0.15	-0.16	NA
2018-01-25 10:57	11	90	89.90	89.56	0.08	0.19	-0.34	-0.4
2018-01-25 11:07	11	30	29.96	29.78	0.10	0.18	-0.18	-0.6
2018-01-25 11:17	11	60	59.98	59.72	0.09	0.07	-0.26	-0.4
2018-01-25 11:27	11	70	69.94	69.63	0.06	0.11	-0.31	-0.4
2018-01-25 11:37	11	40	40.07	39.83	0.09	0.14	-0.24	-0.6
2018-01-25 11:47	11	10	10.20	10.04	0.09	0.12	-0.16	-1.6
2018-01-25 11:57	11	20	19.84	19.81	0.06	0.08	-0.03	-0.2
2018-01-25 12:07	11	50	49.83	49.67	0.17	0.28	-0.16	-0.3
2018-01-25 12:17	11	80	79.99	79.59	0.05	0.13	-0.40	-0.5
2018-01-25 12:27	12	0	0.16	0.08	0.08	0.10	-0.08	NA
2018-01-25 12:37	12	40	39.92	39.71	0.11	0.04	-0.21	-0.5

Table 12. Ten-minute aggregates computed from the last 5 of a total of 10 one-minute values for the comparison of the MBI ozone analyser (OA) with the WCC-Empa travelling standard (TS).

Date - Time	Run #	Level (ppb)	TS (ppb)	OA (ppb)	sdTS (ppb)	sdOA (ppb)	OA-TS (ppb)	OA-TS (%)
2018-01-23 12:36	1	0	0.28	0.39	0.12	0.08	0.11	NA
2018-01-23 12:46	1	90	89.98	90.01	0.09	0.15	0.03	0.0
2018-01-23 12:56	1	30	29.91	30.10	0.12	0.13	0.19	0.6
2018-01-23 13:06	1	60	59.88	59.98	0.12	0.08	0.10	0.2
2018-01-23 13:16	1	70	69.96	70.11	0.08	0.17	0.15	0.2
2018-01-23 13:26	1	40	39.99	39.96	0.16	0.06	-0.03	-0.1
2018-01-23 13:36	1	10	10.22	10.32	0.10	0.09	0.10	1.0
2018-01-23 13:46	1	20	19.95	19.97	0.09	0.10	0.02	0.1
2018-01-23 13:56	1	50	49.76	49.74	0.20	0.19	-0.02	0.0
2018-01-23 14:06	1	80	80.00	79.85	0.04	0.11	-0.15	-0.2
2018-01-23 14:16	2	0	0.37	0.33	0.10	0.07	-0.04	NA
2018-01-23 14:26	2	40	39.91	39.86	0.06	0.13	-0.05	-0.1
2018-01-23 14:36	2	100	99.82	99.71	0.09	0.15	-0.11	-0.1
2018-01-23 14:56	2	200	199.83	199.95	0.25	0.35	0.12	0.1
2018-01-23 15:06	2	30	30.14	30.09	0.14	0.21	-0.05	-0.2

Date - Time	Run #	Level (ppb)	TS (ppb)	OA (ppb)	sdTS (ppb)	sdOA (ppb)	OA-TS (ppb)	OA-TS (%)
2018-01-23 15:16	2	80	79.92	79.85	0.14	0.18	-0.07	-0.1
2018-01-23 15:21	2	60	59.83	59.70	0.22	0.26	-0.13	-0.2
2018-01-23 15:26	2	50	49.98	49.79	0.07	0.12	-0.19	-0.4
2018-01-23 15:36	2	150	149.83	149.71	0.08	0.25	-0.12	-0.1
2018-01-23 15:46	2	10	10.69	10.61	0.38	0.38	-0.08	-0.7
2018-01-23 16:11	3	0	0.40	0.34	0.10	0.09	-0.06	NA
2018-01-23 16:26	3	90	89.98	89.70	0.07	0.23	-0.28	-0.3
2018-01-23 16:36	3	30	29.91	29.89	0.13	0.24	-0.02	-0.1
2018-01-23 16:46	3	60	59.93	59.84	0.06	0.19	-0.09	-0.2
2018-01-23 16:56	3	70	69.92	69.99	0.10	0.05	0.07	0.1
2018-01-23 17:06	3	40	39.99	40.06	0.06	0.12	0.07	0.2
2018-01-23 17:16	3	10	10.09	10.28	0.14	0.13	0.19	1.9
2018-01-23 17:26	3	20	19.78	19.89	0.07	0.05	0.11	0.6
2018-01-23 17:36	3	50	49.77	49.87	0.17	0.22	0.10	0.2
2018-01-23 17:46	3	80	79.97	79.96	0.07	0.14	-0.01	0.0
2018-01-23 17:56	4	0	0.12	0.29	0.09	0.06	0.17	NA
2018-01-23 18:06	4	40	39.88	39.97	0.17	0.20	0.09	0.2
2018-01-23 18:16	4	100	99.77	99.72	0.19	0.31	-0.05	-0.1
2018-01-23 18:36	4	200	199.96	200.27	0.16	0.30	0.31	0.2
2018-01-23 18:46	4	30	30.08	30.38	0.19	0.14	0.30	1.0
2018-01-23 18:56	4	80	79.91	80.25	0.22	0.23	0.34	0.4
2018-01-23 19:01	4	60	59.85	59.96	0.19	0.22	0.11	0.2
2018-01-23 19:06	4	50	50.02	50.08	0.10	0.20	0.06	0.1
2018-01-23 19:16	4	150	149.88	149.86	0.14	0.11	-0.02	0.0
2018-01-23 19:26	4	10	10.62	10.80	0.32	0.34	0.18	1.7
2018-01-23 19:51	5	0	0.15	0.37	0.13	0.07	0.22	NA
2018-01-23 20:06	5	90	89.93	89.83	0.03	0.09	-0.10	-0.1
2018-01-23 20:16	5	30	29.89	29.95	0.10	0.12	0.06	0.2
2018-01-23 20:26	5	60	60.01	60.08	0.14	0.05	0.07	0.1
2018-01-23 20:36	5	70	69.99	69.95	0.09	0.13	-0.04	-0.1
2018-01-23 20:46	5	40	39.96	39.89	0.05	0.08	-0.07	-0.2
2018-01-23 20:56	5	10	10.38	10.25	0.17	0.18	-0.13	-1.3
2018-01-23 21:06	5	20	19.86	19.79	0.10	0.13	-0.07	-0.4
2018-01-23 21:16	5	50	49.86	49.79	0.20	0.16	-0.07	-0.1
2018-01-23 21:26	5	80	79.93	79.75	0.04	0.14	-0.18	-0.2
2018-01-23 21:36	6	0	0.38	0.35	0.12	0.07	-0.03	NA
2018-01-23 21:46	6	40	39.91	39.87	0.12	0.11	-0.04	-0.1
2018-01-23 21:56	6	100	99.79	99.56	0.15	0.26	-0.23	-0.2
2018-01-23 22:16	6	200	199.93	199.86	0.30	0.45	-0.07	0.0
2018-01-23 22:26	6	30	30.13	30.09	0.18	0.18	-0.04	-0.1
2018-01-23 22:36	6	80	79.95	79.83	0.10	0.15	-0.12	-0.2
2018-01-23 22:41	6	60	59.83	59.74	0.23	0.20	-0.09	-0.2
2018-01-23 22:46	6	50	50.05	49.83	0.11	0.12	-0.22	-0.4
2018-01-23 22:56	6	150	149.87	149.77	0.24	0.37	-0.10	-0.1
2018-01-23 23:06	6	10	10.59	10.48	0.31	0.28	-0.11	-1.0
2018-01-23 23:31	7	0	0.42	0.36	0.07	0.05	-0.06	NA
2018-01-23 23:46	7	90	89.92	89.94	0.11	0.18	0.02	0.0
2018-01-23 23:56	7	30	29.97	29.94	0.10	0.11	-0.03	-0.1

Date - Time	Run #	Level (ppb)	TS (ppb)	OA (ppb)	sdTS (ppb)	sdOA (ppb)	OA-TS (ppb)	OA-TS (%)
2018-01-24 00:06	7	60	59.92	59.89	0.17	0.07	-0.03	-0.1
2018-01-24 00:16	7	70	70.01	70.29	0.10	0.14	0.28	0.4
2018-01-24 00:26	7	40	39.99	40.19	0.09	0.13	0.20	0.5
2018-01-24 00:36	7	10	10.19	10.39	0.11	0.07	0.20	2.0
2018-01-24 00:46	7	20	19.83	20.05	0.08	0.12	0.22	1.1
2018-01-24 00:56	7	50	49.82	49.93	0.12	0.19	0.11	0.2
2018-01-24 01:06	7	80	79.97	79.87	0.05	0.06	-0.10	-0.1
2018-01-24 01:16	8	0	0.12	0.30	0.08	0.04	0.18	NA
2018-01-24 01:26	8	40	39.86	40.03	0.15	0.14	0.17	0.4
2018-01-24 01:36	8	100	99.75	99.77	0.16	0.20	0.02	0.0
2018-01-24 01:56	8	200	199.87	199.93	0.12	0.12	0.06	0.0
2018-01-24 02:06	8	30	30.10	30.19	0.07	0.19	0.09	0.3
2018-01-24 02:16	8	80	79.93	80.03	0.07	0.12	0.10	0.1
2018-01-24 02:21	8	60	59.82	59.90	0.18	0.22	0.08	0.1
2018-01-24 02:26	8	50	49.99	50.10	0.17	0.15	0.11	0.2
2018-01-24 02:36	8	150	149.90	150.17	0.18	0.22	0.27	0.2
2018-01-24 02:46	8	10	10.50	10.74	0.27	0.24	0.24	2.3
2018-01-24 03:11	9	0	0.11	0.31	0.11	0.04	0.20	NA
2018-01-24 03:26	9	90	89.95	89.86	0.04	0.17	-0.09	-0.1
2018-01-24 03:36	9	30	29.93	29.95	0.13	0.13	0.02	0.1
2018-01-24 03:46	9	60	59.90	59.68	0.11	0.18	-0.22	-0.4
2018-01-24 03:56	9	70	69.99	69.84	0.05	0.09	-0.15	-0.2
2018-01-24 04:06	9	40	40.08	40.13	0.10	0.19	0.05	0.1
2018-01-24 04:16	9	10	10.30	10.34	0.14	0.23	0.04	0.4
2018-01-24 04:26	9	20	19.76	19.70	0.10	0.13	-0.06	-0.3
2018-01-24 04:36	9	50	49.86	49.73	0.16	0.13	-0.13	-0.3
2018-01-24 04:46	9	80	80.02	79.94	0.07	0.10	-0.08	-0.1
2018-01-24 04:56	10	0	0.42	0.31	0.09	0.08	-0.11	NA
2018-01-24 05:06	10	40	39.93	39.56	0.15	0.21	-0.37	-0.9
2018-01-24 05:16	10	100	99.84	99.58	0.11	0.19	-0.26	-0.3
2018-01-24 05:36	10	200	199.85	199.73	0.14	0.35	-0.12	-0.1
2018-01-24 05:46	10	30	30.17	29.96	0.17	0.25	-0.21	-0.7
2018-01-24 05:56	10	80	79.96	79.91	0.12	0.17	-0.05	-0.1
2018-01-24 06:01	10	60	59.84	59.73	0.21	0.32	-0.11	-0.2
2018-01-24 06:06	10	50	50.01	49.82	0.07	0.04	-0.19	-0.4
2018-01-24 06:16	10	150	149.82	149.53	0.19	0.10	-0.29	-0.2
2018-01-24 06:26	10	10	10.72	10.59	0.40	0.27	-0.13	-1.2
2018-01-24 06:51	11	0	0.31	0.26	0.09	0.09	-0.05	NA
2018-01-24 07:06	11	90	90.02	90.11	0.08	0.07	0.09	0.1
2018-01-24 07:16	11	30	29.83	30.03	0.10	0.09	0.20	0.7
2018-01-24 07:26	11	60	59.96	60.12	0.10	0.06	0.16	0.3
2018-01-24 07:36	11	70	70.02	70.24	0.06	0.05	0.22	0.3
2018-01-24 07:46	11	40	39.95	40.20	0.09	0.10	0.25	0.6
2018-01-24 07:56	11	10	10.24	10.42	0.08	0.17	0.18	1.8
2018-01-24 08:06	11	20	19.81	20.09	0.09	0.18	0.28	1.4
2018-01-24 08:16	11	50	49.79	50.03	0.24	0.19	0.24	0.5
2018-01-24 08:26	11	80	79.95	80.06	0.10	0.19	0.11	0.1
2018-01-24 08:36	12	0	0.16	0.36	0.05	0.11	0.20	NA

Date - Time	Run #	Level (ppb)	TS (ppb)	OA (ppb)	sdTS (ppb)	sdOA (ppb)	OA-TS (ppb)	OA-TS (%)
2018-01-24 08:46	12	40	39.88	39.93	0.10	0.11	0.05	0.1
2018-01-24 08:56	12	100	99.79	99.68	0.14	0.22	-0.11	-0.1
2018-01-24 09:16	12	200	199.89	200.21	0.29	0.22	0.32	0.2
2018-01-24 09:26	12	30	30.16	30.30	0.23	0.13	0.14	0.5
2018-01-24 09:36	12	80	79.96	80.14	0.07	0.18	0.18	0.2
2018-01-24 09:41	12	60	59.88	59.98	0.22	0.37	0.10	0.2
2018-01-24 09:46	12	50	49.92	50.25	0.11	0.09	0.33	0.7
2018-01-24 09:56	12	150	149.87	150.06	0.13	0.21	0.19	0.1
2018-01-24 10:06	12	10	10.53	10.71	0.23	0.25	0.18	1.7
2018-01-24 10:31	13	0	0.31	0.31	0.09	0.09	0.00	0.0
2018-01-24 10:46	13	90	90.01	90.00	0.12	0.12	-0.01	0.0
2018-01-24 10:56	13	30	29.85	29.86	0.09	0.11	0.01	0.0
2018-01-24 11:06	13	60	60.00	60.11	0.07	0.12	0.11	0.2
2018-01-24 11:16	13	70	69.95	69.88	0.09	0.12	-0.07	-0.1
2018-01-24 11:26	13	40	40.02	39.94	0.11	0.09	-0.08	-0.2
2018-01-24 11:36	13	10	10.46	10.44	0.23	0.19	-0.02	-0.2
2018-01-24 11:46	13	20	19.93	19.87	0.06	0.07	-0.06	-0.3
2018-01-24 11:56	13	50	49.88	49.74	0.16	0.20	-0.14	-0.3
2018-01-24 12:06	13	80	79.98	79.74	0.06	0.10	-0.24	-0.3
2018-01-24 12:16	14	0	0.32	0.36	0.06	0.08	0.04	NA
2018-01-24 12:26	14	40	39.81	39.66	0.09	0.13	-0.15	-0.4
2018-01-24 12:34	14	100	99.82	99.77	0.16	0.11	-0.05	-0.1

Table 13. Ten-minute aggregates computed from the last 5 of a total of 10 one-minute values for the comparison of the future PIL ozone analyser (OA) with the WCC-Empa travelling standard (TS).

Date - Time	Run #	Level (ppb)	TS (ppb)	OA (ppb)	sdTS (ppb)	sdOA (ppb)	OA-TS (ppb)	OA-TS (%)
2018-01-31 13:03	1	0	0.31	-0.34	0.11	0.09	-0.65	NA
2018-01-31 13:13	1	90	89.96	90.44	0.11	0.15	0.48	0.5
2018-01-31 13:23	1	30	29.96	29.58	0.11	0.09	-0.38	-1.3
2018-01-31 13:33	1	60	60.01	59.87	0.08	0.05	-0.14	-0.2
2018-01-31 13:43	1	70	69.99	69.88	0.05	0.10	-0.11	-0.2
2018-01-31 13:53	1	40	39.99	39.63	0.08	0.06	-0.36	-0.9
2018-01-31 14:03	1	10	9.97	9.30	0.20	0.18	-0.67	-6.7
2018-01-31 14:13	1	20	20.02	19.37	0.09	0.13	-0.65	-3.2
2018-01-31 14:23	1	50	49.85	49.54	0.10	0.13	-0.31	-0.6
2018-01-31 14:33	1	80	80.02	79.93	0.04	0.16	-0.09	-0.1
2018-01-31 14:43	2	0	0.36	-0.39	0.11	0.03	-0.75	NA
2018-01-31 14:53	2	40	39.90	39.44	0.06	0.18	-0.46	-1.2
2018-01-31 15:03	2	100	99.94	99.97	0.05	0.10	0.03	0.0
2018-01-31 15:23	2	200	199.91	201.12	0.06	0.07	1.21	0.6
2018-01-31 15:33	2	30	30.03	29.69	0.07	0.13	-0.34	-1.1
2018-01-31 15:43	2	80	79.96	79.94	0.11	0.09	-0.02	0.0
2018-01-31 15:48	2	60	59.93	59.75	0.13	0.12	-0.18	-0.3
2018-01-31 15:53	2	50	50.03	49.83	0.08	0.09	-0.20	-0.4
2018-01-31 16:03	2	150	149.85	150.52	0.26	0.30	0.67	0.4

Date - Time	Run #	Level (ppb)	TS (ppb)	OA (ppb)	sdTS (ppb)	sdOA (ppb)	OA-TS (ppb)	OA-TS (%)
2018-01-31 16:13	2	10	10.32	9.72	0.12	0.09	-0.60	-5.8
2018-01-31 16:38	3	0	0.27	-0.22	0.06	0.10	-0.49	NA
2018-01-31 16:53	3	90	89.99	90.45	0.05	0.14	0.46	0.5
2018-01-31 17:03	3	30	29.95	29.96	0.11	0.14	0.01	0.0
2018-01-31 17:13	3	60	59.92	60.10	0.11	0.14	0.18	0.3
2018-01-31 17:23	3	70	70.00	70.22	0.11	0.23	0.22	0.3
2018-01-31 17:33	3	40	39.98	39.97	0.04	0.06	-0.01	0.0
2018-01-31 17:43	3	10	10.20	10.04	0.14	0.07	-0.16	-1.6
2018-01-31 17:53	3	20	19.83	19.64	0.12	0.19	-0.19	-1.0
2018-01-31 18:03	3	50	49.84	49.93	0.15	0.34	0.09	0.2
2018-01-31 18:13	3	80	80.06	80.39	0.08	0.12	0.33	0.4
2018-01-31 18:23	4	0	0.16	-0.32	0.03	0.07	-0.48	NA
2018-01-31 18:33	4	40	39.91	39.87	0.08	0.10	-0.04	-0.1
2018-01-31 18:43	4	100	99.85	100.14	0.11	0.14	0.29	0.3
2018-01-31 19:03	4	200	199.89	201.35	0.16	0.22	1.46	0.7
2018-01-31 19:13	4	30	30.09	30.08	0.13	0.15	-0.01	0.0
2018-01-31 19:23	4	80	79.96	80.25	0.06	0.15	0.29	0.4
2018-01-31 19:28	4	60	59.90	59.90	0.19	0.37	0.00	0.0
2018-01-31 19:33	4	50	49.97	49.88	0.08	0.12	-0.09	-0.2
2018-01-31 19:43	4	150	149.99	150.82	0.16	0.22	0.83	0.6
2018-01-31 19:53	4	10	10.49	10.02	0.12	0.15	-0.47	-4.5
2018-01-31 20:18	5	0	0.36	-0.10	0.12	0.09	-0.46	NA
2018-01-31 20:33	5	90	89.98	90.02	0.11	0.12	0.04	0.0
2018-01-31 20:43	5	30	29.94	29.58	0.17	0.15	-0.36	-1.2
2018-01-31 20:53	5	60	59.97	59.60	0.08	0.15	-0.37	-0.6
2018-01-31 21:03	5	70	70.03	69.81	0.05	0.14	-0.22	-0.3
2018-01-31 21:13	5	40	40.09	39.55	0.08	0.14	-0.54	-1.3
2018-01-31 21:23	5	10	10.43	9.96	0.25	0.29	-0.47	-4.5
2018-01-31 21:33	5	20	19.91	19.35	0.06	0.12	-0.56	-2.8
2018-01-31 21:43	5	50	49.81	49.55	0.21	0.26	-0.26	-0.5
2018-01-31 21:53	5	80	79.97	80.01	0.10	0.23	0.04	0.1
2018-01-31 22:03	6	0	0.34	-0.24	0.08	0.15	-0.58	NA
2018-01-31 22:13	6	40	39.90	39.43	0.09	0.04	-0.47	-1.2
2018-01-31 22:23	6	100	99.83	100.05	0.12	0.24	0.22	0.2
2018-01-31 22:43	6	200	199.88	201.12	0.29	0.31	1.24	0.6
2018-01-31 22:53	6	30	30.22	29.97	0.15	0.19	-0.25	-0.8
2018-01-31 23:03	6	80	80.01	80.28	0.12	0.22	0.27	0.3
2018-01-31 23:08	6	60	59.84	59.82	0.19	0.13	-0.02	0.0
2018-01-31 23:13	6	50	50.03	49.94	0.05	0.08	-0.09	-0.2
2018-01-31 23:23	6	150	149.88	150.43	0.08	0.12	0.55	0.4
2018-01-31 23:33	6	10	10.68	10.42	0.30	0.30	-0.26	-2.4
2018-01-31 23:58	7	0	0.26	-0.14	0.13	0.06	-0.40	NA
2018-02-01 00:13	7	90	89.95	90.45	0.15	0.26	0.50	0.6
2018-02-01 00:23	7	30	29.86	29.82	0.10	0.07	-0.04	-0.1
2018-02-01 00:33	7	60	59.96	60.19	0.07	0.10	0.23	0.4
2018-02-01 00:43	7	70	70.05	70.23	0.09	0.09	0.18	0.3
2018-02-01 00:53	7	40	40.02	40.05	0.03	0.06	0.03	0.1
2018-02-01 01:03	7	10	10.39	10.22	0.19	0.19	-0.17	-1.6

Date - Time	Run #	Level (ppb)	TS (ppb)	OA (ppb)	sdTS (ppb)	sdOA (ppb)	OA-TS (ppb)	OA-TS (%)
2018-02-01 01:13	7	20	19.84	19.60	0.09	0.10	-0.24	-1.2
2018-02-01 01:23	7	50	49.83	49.85	0.18	0.10	0.02	0.0
2018-02-01 01:33	7	80	80.00	80.38	0.12	0.22	0.38	0.5
2018-02-01 01:43	8	0	0.07	-0.20	0.10	0.06	-0.27	NA
2018-02-01 01:53	8	40	39.94	40.04	0.17	0.11	0.10	0.3
2018-02-01 02:03	8	100	99.80	100.17	0.13	0.21	0.37	0.4
2018-02-01 02:23	8	200	199.84	201.27	0.24	0.28	1.43	0.7
2018-02-01 02:33	8	30	30.19	29.98	0.15	0.17	-0.21	-0.7
2018-02-01 02:43	8	80	79.99	80.20	0.02	0.08	0.21	0.3
2018-02-01 02:48	8	60	59.90	59.91	0.20	0.26	0.01	0.0
2018-02-01 02:53	8	50	50.03	49.87	0.05	0.06	-0.16	-0.3
2018-02-01 03:03	8	150	149.91	150.88	0.18	0.17	0.97	0.6
2018-02-01 03:13	8	10	10.49	10.06	0.12	0.16	-0.43	-4.1
2018-02-01 03:38	9	0	0.47	-0.19	0.07	0.07	-0.66	NA
2018-02-01 03:53	9	90	89.95	90.07	0.06	0.17	0.12	0.1
2018-02-01 04:03	9	30	29.90	29.52	0.09	0.13	-0.38	-1.3
2018-02-01 04:13	9	60	59.97	59.87	0.13	0.14	-0.10	-0.2
2018-02-01 04:23	9	70	70.00	69.95	0.05	0.10	-0.05	-0.1
2018-02-01 04:33	9	40	40.03	39.78	0.11	0.12	-0.25	-0.6
2018-02-01 04:43	9	10	10.39	9.90	0.18	0.12	-0.49	-4.7
2018-02-01 04:53	9	20	19.94	19.56	0.05	0.10	-0.38	-1.9
2018-02-01 05:03	9	50	49.81	49.61	0.20	0.09	-0.20	-0.4
2018-02-01 05:13	9	80	79.97	79.94	0.18	0.11	-0.03	0.0
2018-02-01 05:23	10	0	0.52	-0.16	0.05	0.07	-0.68	NA
2018-02-01 05:33	10	40	39.92	39.65	0.11	0.05	-0.27	-0.7
2018-02-01 05:43	10	100	99.81	100.19	0.13	0.18	0.38	0.4
2018-02-01 06:03	10	200	199.84	200.85	0.22	0.11	1.01	0.5
2018-02-01 06:13	10	30	30.12	29.97	0.12	0.03	-0.15	-0.5
2018-02-01 06:23	10	80	79.97	80.26	0.07	0.13	0.29	0.4
2018-02-01 06:28	10	60	59.89	59.98	0.17	0.21	0.09	0.2
2018-02-01 06:33	10	50	49.99	50.05	0.14	0.21	0.06	0.1
2018-02-01 06:43	10	150	149.91	150.87	0.13	0.20	0.96	0.6
2018-02-01 06:53	10	10	10.48	10.20	0.20	0.16	-0.28	-2.7
2018-02-01 07:18	11	0	0.16	-0.15	0.08	0.05	-0.31	NA
2018-02-01 07:33	11	90	89.95	90.36	0.11	0.07	0.41	0.5
2018-02-01 07:43	11	30	29.92	29.89	0.10	0.19	-0.03	-0.1
2018-02-01 07:53	11	60	59.96	60.21	0.03	0.25	0.25	0.4
2018-02-01 08:03	11	70	69.99	70.27	0.04	0.10	0.28	0.4
2018-02-01 08:13	11	40	40.05	40.09	0.17	0.19	0.04	0.1
2018-02-01 08:23	11	10	10.06	9.99	0.17	0.19	-0.07	-0.7
2018-02-01 08:33	11	20	19.78	19.61	0.10	0.09	-0.17	-0.9
2018-02-01 08:43	11	50	49.79	50.01	0.19	0.16	0.22	0.4
2018-02-01 08:53	11	80	80.01	80.30	0.07	0.10	0.29	0.4
2018-02-01 09:03	12	0	0.08	-0.24	0.08	0.11	-0.32	NA
2018-02-01 09:13	12	40	39.91	39.74	0.09	0.15	-0.17	-0.4
2018-02-01 09:23	12	100	99.81	100.27	0.16	0.11	0.46	0.5
2018-02-01 09:43	12	200	199.84	201.21	0.19	0.12	1.37	0.7
2018-02-01 09:53	12	30	30.20	29.96	0.27	0.25	-0.24	-0.8

Date - Time	Run #	Level (ppb)	TS (ppb)	OA (ppb)	sdTS (ppb)	sdOA (ppb)	OA-TS (ppb)	OA-TS (%)
2018-02-01 10:03	12	80	79.93	80.21	0.15	0.18	0.28	0.4
2018-02-01 10:08	12	60	59.88	59.88	0.19	0.31	0.00	0.0
2018-02-01 10:13	12	50	50.04	49.98	0.08	0.13	-0.06	-0.1
2018-02-01 10:23	12	150	149.88	150.85	0.14	0.23	0.97	0.6
2018-02-01 10:33	12	10	10.63	9.94	0.17	0.30	-0.69	-6.5
2018-02-01 10:58	13	0	0.47	-0.18	0.10	0.10	-0.65	NA
2018-02-01 11:13	13	90	89.98	90.06	0.03	0.14	0.08	0.1
2018-02-01 11:23	13	30	30.05	29.63	0.20	0.13	-0.42	-1.4
2018-02-01 11:33	13	60	59.98	59.95	0.07	0.07	-0.03	-0.1
2018-02-01 11:43	13	70	70.01	70.15	0.14	0.12	0.14	0.2
2018-02-01 11:53	13	40	40.00	39.58	0.03	0.06	-0.42	-1.0
2018-02-01 12:03	13	10	10.39	9.93	0.22	0.27	-0.46	-4.4
2018-02-01 12:13	13	20	20.03	19.57	0.12	0.10	-0.46	-2.3
2018-02-01 12:23	13	50	49.84	49.67	0.18	0.14	-0.17	-0.3

Table 14. Ten-minute aggregates computed from the last 5 of a total of 10 one-minute values for the comparison of the future USH backup ozone analyser (OA) with the WCC-Empa travelling standard (TS).

Date - Time	Run #	Level (ppb)	TS (ppb)	OA (ppb)	sdTS (ppb)	sdOA (ppb)	OA-TS (ppb)	OA-TS (%)
2018-01-31 13:03	1	0	0.31	0.20	0.11	0.05	-0.11	NA
2018-01-31 13:13	1	90	89.96	90.96	0.11	0.08	1.00	1.1
2018-01-31 13:23	1	30	29.96	30.22	0.11	0.12	0.26	0.9
2018-01-31 13:33	1	60	60.01	60.23	0.08	0.06	0.22	0.4
2018-01-31 13:43	1	70	69.99	70.52	0.05	0.10	0.53	0.8
2018-01-31 13:53	1	40	39.99	40.02	0.08	0.14	0.03	0.1
2018-01-31 14:03	1	10	9.97	9.86	0.20	0.22	-0.11	-1.1
2018-01-31 14:13	1	20	20.02	19.73	0.09	0.14	-0.29	-1.4
2018-01-31 14:23	1	50	49.85	49.93	0.10	0.10	0.08	0.2
2018-01-31 14:33	1	80	80.02	80.38	0.04	0.11	0.36	0.4
2018-01-31 14:43	2	0	0.36	0.17	0.11	0.10	-0.19	NA
2018-01-31 14:53	2	40	39.90	39.77	0.06	0.14	-0.13	-0.3
2018-01-31 15:03	2	100	99.94	100.42	0.05	0.11	0.48	0.5
2018-01-31 15:23	2	200	199.91	201.46	0.06	0.23	1.55	0.8
2018-01-31 15:33	2	30	30.03	30.09	0.07	0.07	0.06	0.2
2018-01-31 15:43	2	80	79.96	80.26	0.11	0.19	0.30	0.4
2018-01-31 15:48	2	60	59.93	60.27	0.13	0.14	0.34	0.6
2018-01-31 15:53	2	50	50.03	50.17	0.08	0.09	0.14	0.3
2018-01-31 16:03	2	150	149.85	151.16	0.26	0.41	1.31	0.9
2018-01-31 16:13	2	10	10.32	10.02	0.12	0.04	-0.30	-2.9
2018-01-31 16:38	3	0	0.27	0.13	0.06	0.12	-0.14	NA
2018-01-31 16:53	3	90	89.99	90.78	0.05	0.17	0.79	0.9
2018-01-31 17:03	3	30	29.95	30.35	0.11	0.15	0.40	1.3
2018-01-31 17:13	3	60	59.92	60.39	0.11	0.15	0.47	0.8
2018-01-31 17:23	3	70	70.00	70.67	0.11	0.08	0.67	1.0
2018-01-31 17:33	3	40	39.98	40.30	0.04	0.06	0.32	0.8

Date - Time	Run #	Level (ppb)	TS (ppb)	OA (ppb)	sdTS (ppb)	sdOA (ppb)	OA-TS (ppb)	OA-TS (%)
2018-01-31 17:43	3	10	10.20	10.45	0.14	0.16	0.25	2.5
2018-01-31 17:53	3	20	19.83	20.19	0.12	0.15	0.36	1.8
2018-01-31 18:03	3	50	49.84	50.42	0.15	0.20	0.58	1.2
2018-01-31 18:13	3	80	80.06	80.90	0.08	0.12	0.84	1.0
2018-01-31 18:23	4	0	0.16	0.23	0.03	0.09	0.07	NA
2018-01-31 18:33	4	40	39.91	40.31	0.08	0.09	0.40	1.0
2018-01-31 18:43	4	100	99.85	100.73	0.11	0.19	0.88	0.9
2018-01-31 19:03	4	200	199.89	201.58	0.16	0.25	1.69	0.8
2018-01-31 19:13	4	30	30.09	30.55	0.13	0.05	0.46	1.5
2018-01-31 19:23	4	80	79.96	80.50	0.06	0.19	0.54	0.7
2018-01-31 19:28	4	60	59.90	60.32	0.19	0.32	0.42	0.7
2018-01-31 19:33	4	50	49.97	50.38	0.08	0.14	0.41	0.8
2018-01-31 19:43	4	150	149.99	151.22	0.16	0.22	1.23	0.8
2018-01-31 19:53	4	10	10.49	10.45	0.12	0.21	-0.04	-0.4
2018-01-31 20:18	5	0	0.36	0.09	0.12	0.09	-0.27	NA
2018-01-31 20:33	5	90	89.98	90.36	0.11	0.16	0.38	0.4
2018-01-31 20:43	5	30	29.94	29.76	0.17	0.16	-0.18	-0.6
2018-01-31 20:53	5	60	59.97	60.11	0.08	0.13	0.14	0.2
2018-01-31 21:03	5	70	70.03	70.32	0.05	0.12	0.29	0.4
2018-01-31 21:13	5	40	40.09	40.07	0.08	0.07	-0.02	0.0
2018-01-31 21:23	5	10	10.43	10.17	0.25	0.18	-0.26	-2.5
2018-01-31 21:33	5	20	19.91	19.56	0.06	0.10	-0.35	-1.8
2018-01-31 21:43	5	50	49.81	49.88	0.21	0.11	0.07	0.1
2018-01-31 21:53	5	80	79.97	80.49	0.10	0.14	0.52	0.7
2018-01-31 22:03	6	0	0.34	-0.01	0.08	0.06	-0.35	NA
2018-01-31 22:13	6	40	39.90	39.83	0.09	0.18	-0.07	-0.2
2018-01-31 22:23	6	100	99.83	100.40	0.12	0.16	0.57	0.6
2018-01-31 22:43	6	200	199.88	201.59	0.29	0.34	1.71	0.9
2018-01-31 22:53	6	30	30.22	30.30	0.15	0.11	0.08	0.3
2018-01-31 23:03	6	80	80.01	80.50	0.12	0.21	0.49	0.6
2018-01-31 23:08	6	60	59.84	60.24	0.19	0.13	0.40	0.7
2018-01-31 23:13	6	50	50.03	50.41	0.05	0.06	0.38	0.8
2018-01-31 23:23	6	150	149.88	150.95	0.08	0.17	1.07	0.7
2018-01-31 23:33	6	10	10.68	10.72	0.30	0.30	0.04	0.4
2018-01-31 23:58	7	0	0.26	0.09	0.13	0.10	-0.17	NA
2018-02-01 00:13	7	90	89.95	90.80	0.15	0.20	0.85	0.9
2018-02-01 00:23	7	30	29.86	30.04	0.10	0.10	0.18	0.6
2018-02-01 00:33	7	60	59.96	60.70	0.07	0.17	0.74	1.2
2018-02-01 00:43	7	70	70.05	70.71	0.09	0.10	0.66	0.9
2018-02-01 00:53	7	40	40.02	40.36	0.03	0.08	0.34	0.8
2018-02-01 01:03	7	10	10.39	10.60	0.19	0.06	0.21	2.0
2018-02-01 01:13	7	20	19.84	20.03	0.09	0.06	0.19	1.0
2018-02-01 01:23	7	50	49.83	50.21	0.18	0.17	0.38	0.8
2018-02-01 01:33	7	80	80.00	80.67	0.12	0.06	0.67	0.8
2018-02-01 01:43	8	0	0.07	0.23	0.10	0.09	0.16	NA
2018-02-01 01:53	8	40	39.94	40.30	0.17	0.23	0.36	0.9
2018-02-01 02:03	8	100	99.80	100.66	0.13	0.27	0.86	0.9
2018-02-01 02:23	8	200	199.84	201.57	0.24	0.27	1.73	0.9

Date - Time	Run #	Level (ppb)	TS (ppb)	OA (ppb)	sdTS (ppb)	sdOA (ppb)	OA-TS (ppb)	OA-TS (%)
2018-02-01 02:33	8	30	30.19	30.21	0.15	0.14	0.02	0.1
2018-02-01 02:43	8	80	79.99	80.54	0.02	0.06	0.55	0.7
2018-02-01 02:48	8	60	59.90	60.30	0.20	0.22	0.40	0.7
2018-02-01 02:53	8	50	50.03	50.11	0.05	0.11	0.08	0.2
2018-02-01 03:03	8	150	149.91	151.30	0.18	0.19	1.39	0.9
2018-02-01 03:13	8	10	10.49	10.35	0.12	0.10	-0.14	-1.3
2018-02-01 03:38	9	0	0.47	0.06	0.07	0.11	-0.41	NA
2018-02-01 03:53	9	90	89.95	90.29	0.06	0.09	0.34	0.4
2018-02-01 04:03	9	30	29.90	29.94	0.09	0.10	0.04	0.1
2018-02-01 04:13	9	60	59.97	60.21	0.13	0.09	0.24	0.4
2018-02-01 04:23	9	70	70.00	70.41	0.05	0.05	0.41	0.6
2018-02-01 04:33	9	40	40.03	40.11	0.11	0.11	0.08	0.2
2018-02-01 04:43	9	10	10.39	10.20	0.18	0.25	-0.19	-1.8
2018-02-01 04:53	9	20	19.94	19.91	0.05	0.11	-0.03	-0.2
2018-02-01 05:03	9	50	49.81	49.96	0.20	0.18	0.15	0.3
2018-02-01 05:13	9	80	79.97	80.37	0.18	0.08	0.40	0.5
2018-02-01 05:23	10	0	0.52	0.15	0.05	0.06	-0.37	NA
2018-02-01 05:33	10	40	39.92	40.05	0.11	0.04	0.13	0.3
2018-02-01 05:43	10	100	99.81	100.51	0.13	0.15	0.70	0.7
2018-02-01 06:03	10	200	199.84	201.26	0.22	0.11	1.42	0.7
2018-02-01 06:13	10	30	30.12	30.30	0.12	0.05	0.18	0.6
2018-02-01 06:23	10	80	79.97	80.58	0.07	0.13	0.61	0.8
2018-02-01 06:28	10	60	59.89	60.34	0.17	0.23	0.45	0.8
2018-02-01 06:33	10	50	49.99	50.37	0.14	0.16	0.38	0.8
2018-02-01 06:43	10	150	149.91	151.05	0.13	0.15	1.14	0.8
2018-02-01 06:53	10	10	10.48	10.63	0.20	0.16	0.15	1.4
2018-02-01 07:18	11	0	0.16	0.20	0.08	0.08	0.04	NA
2018-02-01 07:33	11	90	89.95	90.78	0.11	0.07	0.83	0.9
2018-02-01 07:43	11	30	29.92	30.40	0.10	0.06	0.48	1.6
2018-02-01 07:53	11	60	59.96	60.44	0.03	0.14	0.48	0.8
2018-02-01 08:03	11	70	69.99	70.75	0.04	0.10	0.76	1.1
2018-02-01 08:13	11	40	40.05	40.38	0.17	0.14	0.33	0.8
2018-02-01 08:23	11	10	10.06	10.24	0.17	0.17	0.18	1.8
2018-02-01 08:33	11	20	19.78	19.93	0.10	0.09	0.15	0.8
2018-02-01 08:43	11	50	49.79	50.26	0.19	0.11	0.47	0.9
2018-02-01 08:53	11	80	80.01	80.75	0.07	0.10	0.74	0.9
2018-02-01 09:03	12	0	0.08	0.10	0.08	0.12	0.02	NA
2018-02-01 09:13	12	40	39.91	40.14	0.09	0.17	0.23	0.6
2018-02-01 09:23	12	100	99.81	100.61	0.16	0.10	0.80	0.8
2018-02-01 09:43	12	200	199.84	201.68	0.19	0.08	1.84	0.9
2018-02-01 09:53	12	30	30.20	30.28	0.27	0.15	0.08	0.3
2018-02-01 10:03	12	80	79.93	80.56	0.15	0.16	0.63	0.8
2018-02-01 10:08	12	60	59.88	60.12	0.19	0.26	0.24	0.4
2018-02-01 10:13	12	50	50.04	50.15	0.08	0.09	0.11	0.2
2018-02-01 10:23	12	150	149.88	151.30	0.14	0.21	1.42	0.9
2018-02-01 10:33	12	10	10.63	10.34	0.17	0.31	-0.29	-2.7
2018-02-01 10:58	13	0	0.47	0.07	0.10	0.09	-0.40	NA
2018-02-01 11:13	13	90	89.98	90.52	0.03	0.06	0.54	0.6

Date - Time	Run #	Level (ppb)	TS (ppb)	OA (ppb)	sdTS (ppb)	sdOA (ppb)	OA-TS (ppb)	OA-TS (%)
2018-02-01 11:23	13	30	30.05	29.95	0.20	0.10	-0.10	-0.3
2018-02-01 11:33	13	60	59.98	60.28	0.07	0.13	0.30	0.5
2018-02-01 11:43	13	70	70.01	70.41	0.14	0.08	0.40	0.6
2018-02-01 11:53	13	40	40.00	40.05	0.03	0.08	0.05	0.1
2018-02-01 12:03	13	10	10.39	10.17	0.22	0.13	-0.22	-2.1
2018-02-01 12:13	13	20	20.03	19.76	0.12	0.10	-0.27	-1.3
2018-02-01 12:23	13	50	49.84	50.04	0.18	0.16	0.20	0.4

Table 15. Ten-minute aggregates computed from the last 5 of a total of 10 one-minute values for the comparison of the TLL ozone analyser (OA) with the WCC-Empa travelling standard (TS).

Date - Time	Run #	Level (ppb)	TS (ppb)	OA (ppb)	sdTS (ppb)	sdOA (ppb)	OA-TS (ppb)	OA-TS (%)
2017-12-12 20:03	1	0	0.67	1.42	0.15	0.08	0.75	NA
2017-12-12 20:18	1	50	49.99	50.77	0.12	0.24	0.78	1.6
2017-12-12 20:33	1	90	89.96	90.88	0.04	0.13	0.92	1.0
2017-12-12 20:48	1	20	20.07	20.74	0.10	0.18	0.67	3.3
2017-12-12 21:03	1	70	70.03	71.00	0.04	0.06	0.97	1.4
2017-12-12 21:18	1	80	80.00	80.95	0.07	0.23	0.95	1.2
2017-12-12 21:33	1	10	10.62	11.23	0.89	0.73	0.61	5.7
2017-12-12 21:48	1	40	40.05	40.69	0.05	0.08	0.64	1.6
2017-12-12 22:03	1	60	59.99	60.97	0.09	0.11	0.98	1.6
2017-12-12 22:18	2	0	0.67	1.23	0.11	0.11	0.56	NA
2017-12-12 22:33	2	100	100.02	101.01	0.07	0.14	0.99	1.0
2017-12-12 22:48	2	25	25.00	25.47	0.10	0.12	0.47	1.9
2017-12-12 23:03	2	200	199.93	201.14	0.07	0.17	1.21	0.6
2017-12-12 23:18	2	150	149.99	151.07	0.10	0.19	1.08	0.7
2017-12-12 23:33	2	50	50.00	50.71	0.08	0.18	0.71	1.4
2017-12-12 23:48	2	175	174.96	176.15	0.04	0.11	1.19	0.7
2017-12-13 00:03	2	125	125.01	125.98	0.04	0.08	0.97	0.8
2017-12-13 00:18	2	75	75.03	75.88	0.08	0.10	0.85	1.1
2017-12-13 00:33	3	0	0.47	1.14	0.13	0.09	0.67	NA
2017-12-13 00:48	3	40	40.01	40.63	0.08	0.16	0.62	1.5
2017-12-13 01:03	3	80	80.03	80.98	0.05	0.07	0.95	1.2
2017-12-13 01:18	3	10	10.19	10.69	0.20	0.36	0.50	4.9
2017-12-13 01:33	3	30	30.05	30.78	0.10	0.23	0.73	2.4
2017-12-13 01:48	3	90	90.00	90.96	0.09	0.25	0.96	1.1
2017-12-13 02:03	3	60	59.94	60.79	0.04	0.15	0.85	1.4
2017-12-13 02:18	3	20	19.97	20.46	0.16	0.09	0.49	2.5
2017-12-13 02:33	3	50	49.97	50.64	0.06	0.13	0.67	1.3
2017-12-13 02:48	3	70	69.99	70.87	0.05	0.15	0.88	1.3
2017-12-13 03:03	4	0	0.60	0.88	0.10	0.13	0.28	NA
2017-12-13 03:18	4	50	50.02	50.83	0.06	0.20	0.81	1.6
2017-12-13 03:33	4	90	89.89	90.66	0.09	0.10	0.77	0.9
2017-12-13 03:48	4	20	20.01	20.50	0.08	0.05	0.49	2.4
2017-12-13 04:03	4	70	69.98	70.68	0.13	0.19	0.70	1.0
2017-12-13 04:18	4	80	79.99	80.75	0.04	0.22	0.76	1.0

Date - Time	Run #	Level (ppb)	TS (ppb)	OA (ppb)	sdTS (ppb)	sdOA (ppb)	OA-TS (ppb)	OA-TS (%)
2017-12-13 04:33	4	10	10.23	10.75	0.30	0.30	0.52	5.1
2017-12-13 04:48	4	40	40.02	40.57	0.07	0.18	0.55	1.4
2017-12-13 05:03	4	60	59.94	60.75	0.12	0.16	0.81	1.4
2017-12-13 05:18	5	0	0.49	0.83	0.24	0.10	0.34	NA
2017-12-13 05:33	5	100	99.99	100.88	0.06	0.14	0.89	0.9
2017-12-13 05:48	5	25	25.03	25.45	0.17	0.18	0.42	1.7
2017-12-13 06:03	5	200	200.08	201.46	0.06	0.24	1.38	0.7
2017-12-13 06:18	5	150	150.01	150.97	0.07	0.18	0.96	0.6
2017-12-13 06:33	5	50	49.94	50.64	0.07	0.20	0.70	1.4
2017-12-13 06:48	5	175	175.03	176.26	0.10	0.30	1.23	0.7
2017-12-13 07:03	5	125	124.97	125.97	0.09	0.26	1.00	0.8
2017-12-13 07:18	5	75	75.03	75.74	0.07	0.22	0.71	0.9
2017-12-13 07:33	6	0	0.42	0.82	0.10	0.06	0.40	NA
2017-12-13 07:48	6	40	39.99	40.58	0.08	0.11	0.59	1.5
2017-12-13 08:03	6	80	80.06	80.84	0.10	0.27	0.78	1.0
2017-12-13 08:18	6	10	10.01	10.36	0.10	0.06	0.35	3.5
2017-12-13 08:33	6	30	29.97	30.41	0.10	0.16	0.44	1.5
2017-12-13 08:48	6	90	90.04	91.06	0.06	0.20	1.02	1.1
2017-12-13 09:03	6	60	60.01	60.74	0.04	0.21	0.73	1.2
2017-12-13 09:18	6	20	20.01	20.48	0.10	0.12	0.47	2.3
2017-12-13 09:33	6	50	50.02	50.74	0.03	0.16	0.72	1.4
2017-12-13 09:48	6	70	70.01	70.73	0.06	0.23	0.72	1.0
2017-12-13 10:03	7	0	0.43	0.81	0.14	0.10	0.38	NA
2017-12-13 10:18	7	50	49.95	50.41	0.09	0.10	0.46	0.9
2017-12-13 10:33	7	90	89.98	90.70	0.07	0.23	0.72	0.8
2017-12-13 10:48	7	20	20.04	20.44	0.10	0.12	0.40	2.0
2017-12-13 11:03	7	70	70.02	70.82	0.07	0.13	0.80	1.1
2017-12-13 11:18	7	80	79.95	80.66	0.07	0.16	0.71	0.9
2017-12-13 11:33	7	10	10.27	10.68	0.33	0.38	0.41	4.0
2017-12-13 11:48	7	40	39.96	40.62	0.09	0.21	0.66	1.7
2017-12-13 12:03	7	60	60.02	60.59	0.06	0.18	0.57	0.9
2017-12-13 12:18	8	0	0.44	0.89	0.19	0.22	0.45	NA
2017-12-13 12:33	8	100	99.95	100.83	0.07	0.10	0.88	0.9

WCC-Empa Ozone Reference

The WCC-Empa travelling standard (TS) was compared with the Standard Reference Photometer before and after the audit. The following instruments were used:

WCC-Empa ozone reference: NIST Standard Reference Photometer SRP #15 (Master)

WCC-Empa TS: Thermo Scientific 49C-PS # 56891-310, BKG -0.3, COEF 1.007

Zero air source: Pressurized air - Dryer – Breitfuss zero air generator – Purafil – charcoal – outlet filter

The results of the TS calibration before the audit and the verification of the TS after the audit are given in Table 16. The TS passed the assessment criteria defined for maximum acceptable bias before and after the audit (Klausen et al., 2003) (cf. Figure 23). The data were pooled and evaluated by linear regression analysis, considering uncertainties in both instruments. From this, the unbiased ozone mixing ratio produced (and measured) by the TS can be computed (Equation 6a). The uncertainty of the TS (Equation 6b) was estimated previously (cf. equation 19 in (Klausen et al., 2003)).

$$X_{TS}\ (ppb) = ([TS] - 0.03\ ppb) / 1.0032$$

$$u_{TS}\ (ppb) = \sqrt{((0.43\ ppb)^2 + (0.0034 * X)^2)}$$

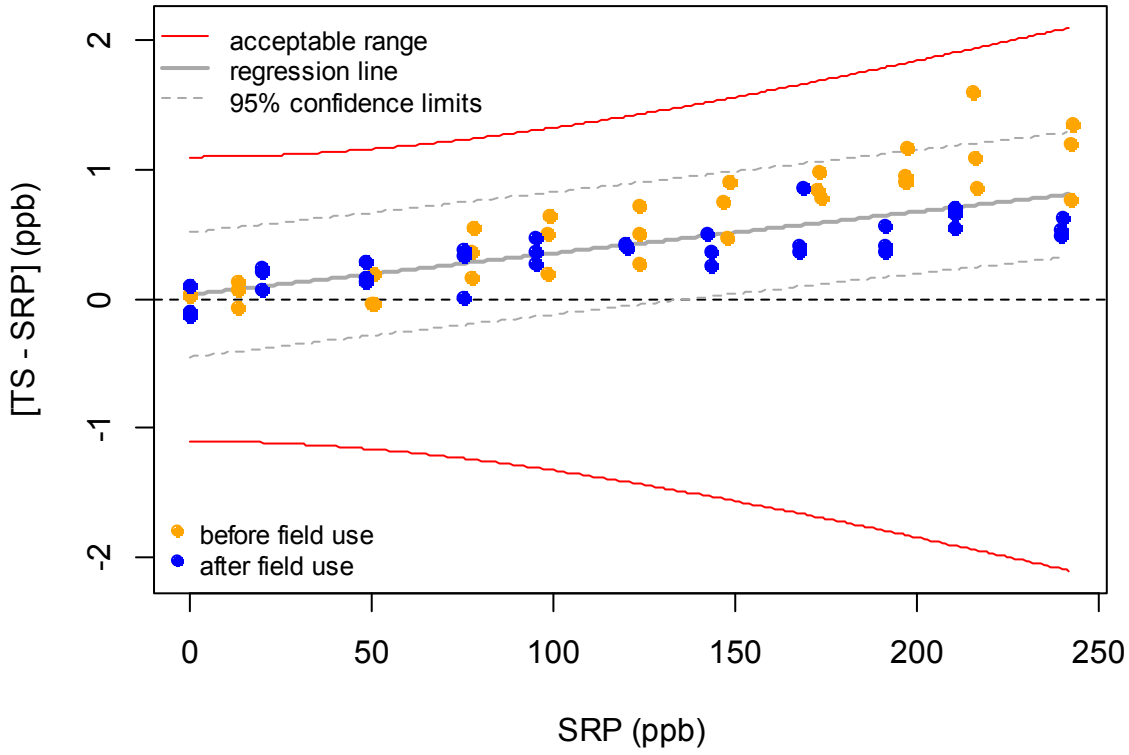

Figure 23. *Deviations between traveling standard (TS) and Standard Reference Photometer (SRP) before and after use of the TS at the field site.*

Table 16. Five-minute aggregates computed from 10 valid 30-second values for the comparison of the Standard Reference Photometer (SRP) with the WCC-Empa traveling standard (TS).

Date	Run	Level[#]	SRP (ppb)	sdSRP (ppb)	TS (ppb)	sdTS (ppb)
2017-05-09	1	80	13.12	0.16	13.05	0.12
2017-05-09	1	0	172.84	0.32	173.82	0.49
2017-05-09	1	215	123.77	0.26	124.48	0.12
2017-05-09	1	125	-0.11	0.25	-0.08	0.11
2017-05-09	1	170	148.22	0.60	149.14	0.25
2017-05-09	1	195	78.02	0.31	78.57	0.08
2017-05-09	1	15	216.36	0.20	217.22	0.22
2017-05-09	1	50	98.30	0.29	98.80	0.10
2017-05-09	1	100	196.89	0.37	197.80	0.18
2017-05-09	1	145	50.07	0.24	50.04	0.14
2017-05-09	1	240	242.75	0.29	244.11	0.25
2017-05-09	2	80	172.28	0.25	173.12	0.10
2017-05-09	2	170	-0.12	0.34	-0.08	0.10
2017-05-09	2	15	148.08	0.45	148.56	0.16
2017-05-09	2	100	50.24	0.34	50.21	0.12
2017-05-09	2	215	98.62	0.38	99.27	0.04
2017-05-09	2	145	13.16	0.25	13.23	0.06
2017-05-09	2	50	216.10	0.30	217.19	0.25
2017-05-09	2	0	123.59	0.22	124.10	0.06
2017-05-09	2	195	196.81	0.47	197.76	0.21
2017-05-09	2	125	77.46	0.25	77.62	0.15
2017-05-09	2	240	242.57	0.37	243.34	0.29
2017-05-09	3	125	98.11	0.36	98.30	0.11
2017-05-09	3	50	77.46	0.35	77.84	0.20
2017-05-09	3	215	215.42	0.36	217.03	0.35
2017-05-09	3	195	-0.02	0.17	-0.13	0.18
2017-05-09	3	80	173.83	0.65	174.61	0.29
2017-05-09	3	15	123.82	0.29	124.09	0.07
2017-05-09	3	100	12.97	0.17	13.11	0.11
2017-05-09	3	170	50.42	0.22	50.61	0.08
2017-05-09	3	0	197.31	0.28	198.47	0.16
2017-05-09	3	145	146.92	0.33	147.68	0.26
2017-05-09	3	240	242.42	0.20	243.62	0.22
2018-03-29	4	20	19.67	0.25	19.88	0.16
2018-03-29	4	170	167.79	0.36	168.17	0.13
2018-03-29	4	120	119.84	0.30	120.25	0.13
2018-03-29	4	0	0.20	0.16	0.11	0.08
2018-03-29	4	145	143.46	0.36	143.71	0.07
2018-03-29	4	75	75.17	0.18	75.51	0.08
2018-03-29	4	210	210.74	0.22	211.40	0.13
2018-03-29	4	95	95.23	0.19	95.51	0.07
2018-03-29	4	190	191.34	0.19	191.70	0.08
2018-03-29	4	50	48.48	0.20	48.76	0.08
2018-03-29	4	240	239.86	0.23	240.34	0.10
2018-03-29	5	170	167.83	0.25	168.25	0.06
2018-03-29	5	0	0.17	0.35	0.04	0.12
2018-03-29	5	145	143.36	0.34	143.73	0.06
2018-03-29	5	50	48.52	0.20	48.69	0.14
2018-03-29	5	95	95.01	0.23	95.37	0.09
2018-03-29	5	20	19.88	0.17	19.95	0.10

Date	Run	Level[#]	SRP (ppb)	sdSRP (ppb)	TS (ppb)	sdTS (ppb)
2018-03-29	5	210	210.73	0.22	211.28	0.10
2018-03-29	5	120	119.80	0.30	120.24	0.04
2018-03-29	5	190	191.29	0.31	191.70	0.14
2018-03-29	5	75	75.15	0.21	75.53	0.11
2018-03-29	5	240	239.78	0.19	240.32	0.17
2018-03-29	6	95	95.11	0.27	95.58	0.11
2018-03-29	6	75	75.39	0.23	75.40	0.07
2018-03-29	6	210	210.64	0.20	211.34	0.14
2018-03-29	6	0	0.00	0.17	0.11	0.08
2018-03-29	6	170	168.81	0.51	169.67	0.43
2018-03-29	6	120	120.20	0.24	120.59	0.10
2018-03-29	6	20	19.77	0.10	20.01	0.09
2018-03-29	6	50	48.50	0.27	48.64	0.15
2018-03-29	6	190	191.12	0.12	191.69	0.09
2018-03-29	6	140	142.50	0.33	143.00	0.07
2018-03-29	6	240	239.97	0.24	240.60	0.14

[#]the level is only indicative.

References

Anet, J. G., Steinbacher, M., Gallardo, L., Velásquez Álvarez, P. A., Emmenegger, L., and Buchmann, B.: Surface ozone in the Southern Hemisphere: 20 years of data from a site with a unique setting in El Tololo, Chile, Atmos. Chem. Phys., 17, 6477-6492, 2017.

Klausen, J., Zellweger, C., Buchmann, B., and Hofer, P.: Uncertainty and bias of surface ozone measurements at selected Global Atmosphere Watch sites, Journal of Geophysical Research-Atmospheres, 108, 4622, doi:4610.1029/2003JD003710, 2003.

Schultz, M. G., et al.: Tropospheric Ozone Assessment Report, links to Global surface ozone datasets. In: Supplement to: Schultz, MG et al. (2017): Tropospheric Ozone Assessment Report: Database and Metrics Data of Global Surface Ozone Observations. Elementa - Science of the Anthropocene, 5:58, 26 pp, https://doi.org/10.1525/elementa.244, PANGAEA, 2017.

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

WMO: WMO Global Atmosphere Watch (GAW) Implementation Plan: 2016-2023 World Meteorological Organization, Geneva, Switzerland, 2017.

Zellweger, C., Buchmann, B., Sanchez, R., and Carbajal Benitez, G.: SMN/WMO/GAW IV Tropospheric Ozone Analyzer Intercomparison, WCC-Empa Report 10/5, Dübendorf, Switzerland, 2010.

Zellweger, C., Emmenegger, L., Firdaus, M., Hatakka, J., Heimann, M., Kozlova, E., Spain, T. G., Steinbacher, M., van der Schoot, M. V., and Buchmann, B.: Assessment of recent advances in measurement techniques for atmospheric carbon dioxide and methane observations, Atmos. Meas. Tech., 9, 4737-4757, 2016a.

Zellweger, C., Klausen, J., and Buchmann, B.: System and Performance Audit of Surface Ozone and Carbon Monoxide at the Global GAW Station Ushuaia, Argentina, November 2003, WCC-Empa Report 03/4, Dübendorf, Switzerland, 41 pp., 2003.

Zellweger, C., Steinbacher, M., and Buchmann, B.: System and Performance Audit of Surface Ozone and Carbon Monoxide at the Global GAW Station Ushuaia, Argentina, February 2016, WCC-Empa Report 16/1, Dübendorf, Switzerland, 32 pp., 2016b.

List of abbreviations

ABP	Arembepe
BKG	Background
CCL	Central Calibration Laboratory
CETESB	Companhia Ambiental do Estado de São Paulo
CHC	Chacaltaya
COEF	Coefficient
DQO	Data Quality Objective
GAW	Global Atmosphere Watch
GAWSIS	GAW Station Information System
GHG	Greenhouse Gases
KNMI	Royal Netherlands Meteorological Institute
MAO	Manaus
MBI	Marambio
NA	Not Applicable
NAT	Natal
NIST	National Institute for Standards and Technology
LQO	La Quiaca
OA	Ozone Analyser
OC	Ozone Calibrator
PIL	Pilar
PMO	Paramaribo
RCC-III	Regional Calibration Centre for Surface Ozone WMO/GAW region III
SAG	Salto Grande
SJA	San Julián Aero
SNL	San Lorenzo
SMN	Servicio Meteorológico Nacional
SOP	Standard Operating Procedure
SRP	Standard Reference Photometer
TLL	El Tololo
TOAR	Tropospheric Ozone Assessment Report
TS	Traveling Standard
USH	Ushuaia
WCC-Empa	World Calibration Centre Empa
WDC	World Data Centre
WDCGG	World Data Centre for Greenhouse Gases
WDCRG	World Data Centre for Reactive Gases
WMO	World Meteorological Organization