Global Atmosphere Watch
World Calibration Centre for Surface Ozone
Carbon Monoxide and Methane

Swiss Federal Laboratories for Materials Testing
and Research (EMPA)

EMPA-WCC REPORT 01/4

Submitted to the

World Meteorological Organization

SYSTEM AND PERFORMANCE AUDIT

FOR SURFACE OZONE AT THE

GLOBAL GAW STATION AREMBEPE

BAHIA, BRAZIL, DECEMBER 2001

Submitted by

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WMO World Calibration Centre for Surface Ozone, Carbon Monoxide and Methane

EMPA Dübendorf, Switzerland

Contents:

EMPA is accredited as a calibration laboratory for ozone measuring instruments in accordance with EN SN 45'001

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C	SERVICE SUISSE D'ETALONAGE SERVIZIO SVIZZERA DI TARURA	SCS accreditation-No.	**SCS 089**
S	SWISS CALIBRATION SERVICE		

1. Abstract

A system and performance audit was conducted at the Global Atmosphere Watch station Arembepe from December 3 to 7, 2001 by the World Calibration Centre (WCC) for Surface Ozone, Carbon Monoxide and Methane. The results can be summarised as follows:

System Audit of the Observatory

The station building at Arembepe offers a good infrastructure for measurements of meteorological, chemical and physical parameters. However, only very few measurements were operational at the time of the audit, and the monitoring program of the station should be enlarged to obtain scientifically important information.

Audit of the Surface Ozone Measurement

Since ozone measurements started only recently at Arembepe and no previous calibrations have been performed, the calibration factors of the station instruments were adjusted during the audit. All previous ozone data were corrected accordingly. The inter-comparison, consisting of three multipoint runs between the WCC transfer standard and the ozone instrument of the station, demonstrated good agreement between the station analyser and the transfer standard. The recorded differences fulfilled the defined assessment criteria as "good" over the tested range up to 100 ppb (Figure 1).

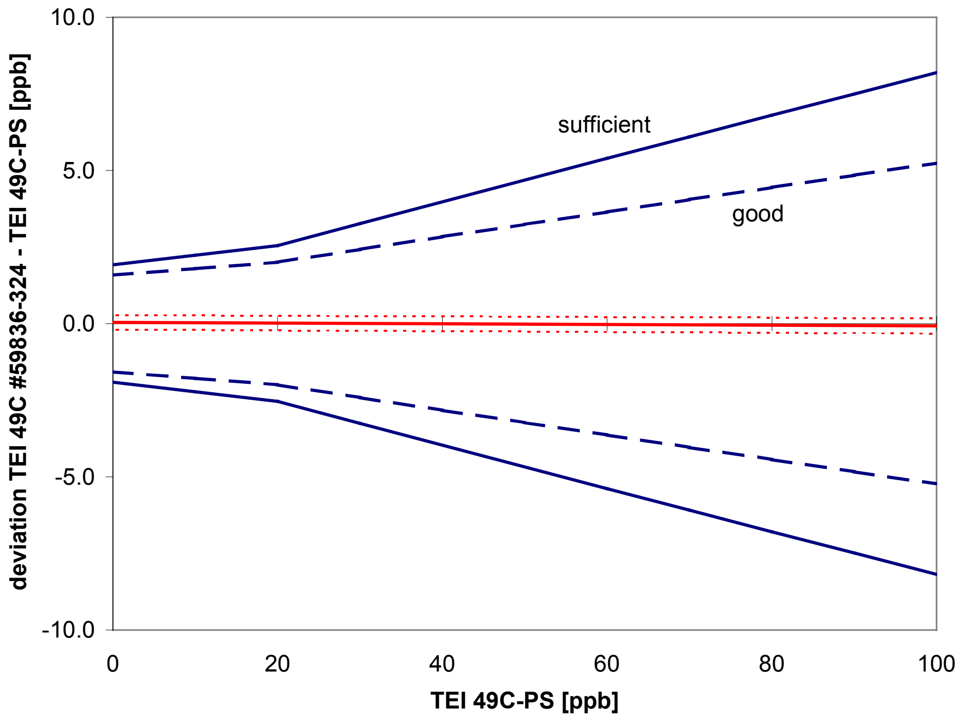

Figure 1: Intercomparison of the TEI 49C 359836-324 field instrument with the WCC transfer standard

The station calibrator was also inter-compared with the WCC transfer standard, and the results were also good after the calibration factors were adjusted.

The audit included a training in ozone measurement technique, and specific check lists were developed in collaboration with the station staff. Ozone measurements are now fully operational at the Arembepe GAW station.

Conclusions and Recommendations

After the audit of EMPA-WCC at the global GAW station Arembepe ozone measurements were fully operational. Calibration of the ozone instrumentation was done by EMPA-WCC, and the operators were trained on the new instrument set-up.

Several recommendations were made by EMPA-WCC concerning not only ozone measurements but the general operation of the station. The main recommendations are summarised below:

- The measurement program needs to be enlarged. Of crucial importance is the re-start with the measurements of meteorological parameters, that are scheduled to be re-started in 2002.
- Persistent problems with any of the measurements at Arembepe should be communicated to external partners and WMO. Communication should be re-established where necessary and maintained to ensure continuing support by external partners.

Dübendorf, 12. July 2002 EMPA Dübendorf, WCC

Project scientist Project manager

Dr. C. Zellweger Dr. B. Buchmann

2. Introduction

The **Global GAW Station Arembepe at the coast of Bahia** is part of Brazil's contribution to the World Meteorological Organization's (WMO) Global Atmosphere Watch (GAW) programme. The observatory was established within the framework of UNDP's Global Environment Facility (GEF) and is designated for long-term measurements of several chemical compounds and physical and meteorological parameters in the lower troposphere. The station was officially opened on September 17, 1997 but started its operation during summer 2000 with a reduced measurement programme. The leading office is the Instituo Nacional de Meteorologia (INMET) in Brasilia.

At the beginning of the GAW programme in Brazil in 1994, INPE (Instituto Nacional de Pesquisas Espacias) was designated to operate a GAW station. It was planned to build the station in Natal, but the project was not successful. In 1996, INMET became the responsible institute to operate the GAW site in Brazil, and Arembepe was chosen as the location. The station building was ready soon afterwards, but measurements were not performed. Several contacts to other institutions (Universidade Federal da Bahia and IBAMA – Instituto Brasiliera de Meio Ambiente) were established through INMET, but were not successful in starting measurements at Arembepe. A first result was achieved by Prof. Paolo Artaxo from the São Paulo University, who set up ozone measurements in June 2000. However, the station staff was never trained for any of the instruments (except for solar radiation) and was therefore not able to take any measures. This situation was recognised by the Finish Meteorological Institute (FMI), which co-operates with INMET for the measurements of meteorological parameters. FMI operates also the global GAW site in Pallas, Finland, and therefore decided to support the Arembepe station with a twinning partnership. The audit of EMPA-WCC was conducted as a joint audit by FMI and EMPA.

The air pollution and environmental technology section of the Swiss Federal Laboratories for Materials Testing and Research (EMPA) was assigned by the WMO to operate the GAW **World Calibration Center** (WCC) for Surface Ozone, Carbon Monoxide and Methane, thereby establishing a co-ordinated quality assurance programme for this part of GAW. The detailed goals and tasks of the WCC concerning surface ozone are described in the GAW report No. 104. System and performance audits at global GAW stations are conducted regularly based on mutual agreement about every two years.

In agreement with the director general of INMET, Augusto Cesar Vaz de Athayde, and the co-ordinator of meteorological matters, Alaor Moacyr Dall'Antonio Junior, a **system and performance audit** at the Observatory Arembepe was conducted by the WCC between December 3 and 7, 2001.

The scope of the audit was the whole measurement system in general and surface ozone measurements in particular. The entire system from the air inlet to the data processing and the quality assurance were reviewed during the audit procedure. The ozone audit was performed according to the "Standard Operating Procedure (SOP) for performance auditing ozone analysers at global and regional WMO-GAW sites", WMO-GAW Report No. 97. The assessment criteria for the ozone inter-comparison have been developed by EMPA based on WMO-GAW Report No. 97 (EMPA-WCC Report 98/5, "Traceability, Uncertainty and Assessment Criteria of ground based Ozone Measurements", July 2000, available on request from EMPA or downloadable from www.empa.ch/gaw). The present audit report is distributed to INMET, FMI and the World Meteorological Organization in Geneva.

Staff involved in the audit

INMET Brasilia	Augusto Cesar Vaz de Athayde	general program, organisation
	Alaor Moacyr Dall'Antonio Junior	contacts, general program, organisation
	Jorge Emílio Rodrigues	technical assistance at the observatory
Arembepe	Eduardo Gonçalves	technical assistance at the observatory
	Prof. Fernando Simões de Sant'Anna	technical assistance at the observatory
EMPA-WCC	Dr. Christoph Zellweger	lead auditor
FMI Finland	Dr. Jussi Paatero	assistant auditor

Previous audits at the GAW station Arembepe:

- none.

3. Global GAW Site Arembepe

3.1. Description of the Site

The Arembepe GAW station is located on the west coast of Brazil, approximately 55 km north-east of the city of Salvador. The station (12° 46' S - 38° 10' W) co-exists with a turtle sanctuary on the sea coast of the state of Bahia. Only few meteorological data is available. Temperature averaged 26.9°C from September to December 1997, with a mean relative humidity of 82%. The wind direction is characterised by steady trade wind flow from the Atlantic ocean (sector E), and wind speed averaged 4.2 m/s for the above period. The station is located directly at the beach about 2 km north of the village of Arembepe with about 5000 inhabitants. It is approx. 2 km east off the highway between Salvador and Praia do Forte.

Figure 2: Location of the Arembepe GAW station

Ozone Level at Arembepe

The distribution of the hourly mean values of all available O_3 data from June 2000 to September 2001 is shown in Figure 3. This data was corrected for the new calibration factors of the instrument. However, this data should still be considered preliminary, because the inlet filter of the instrument was never changed during this period.

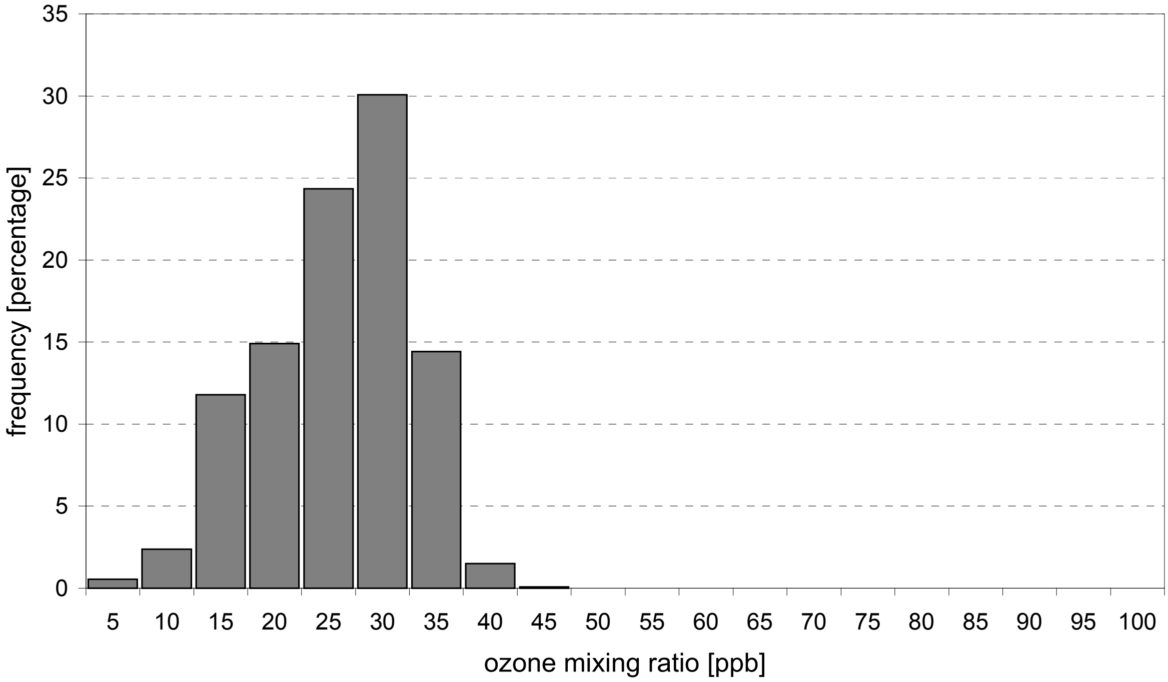

Figure 3: Frequency distribution of the hourly mean ozone mixing ratio (June 2000 to September 2001) at Arembepe. Availability of data: 49%.

3.2. Description of the Observatory

The Arembepe station building (Figure 4) consist of a one storey building and incorporates two laboratory rooms (Figure 5), an office room, a conference room and two bed rooms for visitors. The dimensions of the instrument laboratories are approx. 5 m x 7 m. The laboratory infrastructure consists of laboratory work benches, a fume hood, a balance, a water purification system and a laboratory oven.

Comment

- The station at Arembepe offers spacious laboratories which meet all requirements for the measurement of air pollutants.

Figure 4: View of the Arembepe GAW station

Figure 5: Ozone instruments at the Arembepe GAW Station

3.3. Staff / Operators

Table 1: Staff responsible for the GAW site Arembepe (by December 2001)

Name	Position and duty
Augusto Cesar Vaz de Athayde	Director general of INMET Permanent Representative of WMO of Brazil
Alaor Moacyr Dall'Antonia Junior	General Co-ordinator of Meteorological Matters, INMET
Eduardo Gonçalves	Station Manager
Fernando Simões de Sant'Anna	Consultant

4. System- and Performance Audit for Surface Ozone

The ozone measurement system was installed by Prof. Paolo Artaxo from the University of São Paulo in June 2000, and calibrated using the station calibrator by Luciana V. Gatti from IPEN (Instituto de Pesquisas Energeticas e Nucleares). However, the station operators were never trained to use the instruments, and no further action beside the download of the data was made. The audit included an intensive training in ozone measurement technique, and a maintenance schedule was developed together with the station staff. The calibration factors of the ozone instruments were adjusted during the audit, and previously recorded data was corrected accordingly. A failure of the data acquisition computer stopped measurements during September 2001. During the audit a new data acquisition computer was installed by the station operators, and measurements are now ongoing.

4.1. Monitoring Set-up and Procedures

4.1.1. Air Inlet System

Sampling-location: On top of the flat roof of the station building, 1.8 m above the roof, and approx. 6 m above sea level. Distance to the sea approx. 40 m.

Sample inlet:

Rain protection: The Inlet is protected against rain by an upside-down glass beaker.
Inlet-filter: Teflon inlet filter before analyser.

Sampling-line:

Dimensions:	inlet / manifold:	length = 1.8 m,	inner diameter = 3 cm
	manifold to TEI 49C:	length = 3 m,	inner diameter = 4 mm
Material:	inlet / manifold: glass		
	manifold to analyser: PFTE		

Flow rate:	inlet / manifold:	approx. 300 ℓ/min
	manifold to TEI 49C:	0.65 ℓ/min

Residence time in the sampling line: ca. 7 s

Comment

The PFTE tube was clean and free of dust. The inlet filter has never been changed, and the glass inlet was cleaned during the audit. Materials as well as residence time of the inlet system are adequate for trace gas measurements in particular with regard to minimal loss of ozone.

4.1.2. Instrumentation

The monitoring system at the global GAW station Arembepe consists of an ozone analyser and an ozone calibrator as detailed in Table 2. Both instruments are installed in an environmentally controlled room, but at the time of the audit the air-conditioning was not working. The instruments are not exposed to direct sunlight.

The zero air unit of the calibrator consists of the following:
rubin gel - pump –- activated charcoal – filter

Table 2: Ozone instruments at Arembepe

	ozone instrument	station ozone calibrator
type	TEI 49 C #59836-324	TEI 49 C-PS #59893-324
method	UV absorption	UV absorption
at Arembepe	since 1997	since 1997
Start of Measurement	June 2000	
range	0-200 ppb	0-200 ppb
settings	prior to audit: BKG: 0.4; COEF: 0.953 after audit: BKG: -0.1; COEF: 1.027	prior to audit: BKG: 0.0; COEF: 1.000 after audit: BKG: 0.3; COEF: 1.038
analog output	0-10 V	0-10 V
digital output	RS-232	RS-232

Operation and Maintenance

Operation and maintenance were identified as points where significant improvements could be made at the GAW station Arembepe. The station operators were never trained in ozone measurement technique. The problems were discussed with the station staff, and recommendations of EMPA-WCC are summarised in section 4.3 (for ozone measurements) and in section 6 (general, parameter independent recommendations).

The station staff was aware of the problems and agreed with the maintenance schedule as described below.

- On a regular working day, the person in charge inspects the instruments for general operation.
- Station specific check lists have to be filled in every 5 days for the ozone analyser. They include inlet filter exchange, inlet cleaning, basic instrument checks as well as download and save of the ozone data. It was agreed with the station manager that he regularly informs EMPA-WCC about the instrument status.
- Every three months, the station analyser should be inter-compared with the station calibrator. For this purpose, a specific check list was developed.

4.1.3. Data Handling

Data Acquisition and –transfer

Data Acquisition is made with the C series communication software (version 2.0, upgraded during the audit to version 2.2.0 by EMPA-WCC) from Thermo Environmental Instruments. The data (5 minute average values) is stored every five days on the data acquisition computer, and the data transfer is done by floppy disc.

Data Treatment

Data should be checked weekly for plausibility after downloading from the data logger. This should be done by visual check of time series and by comparison with the station log book. It was also agreed with the station manager that data should be submitted to EMPA-WCC.

Data Submission

At present surface ozone data is not reported to the database of the GAW World Data Centre for Surface Ozone (WDCSO) at NILU. Furthermore, surface ozone data were also not submitted to other groups. It was agreed during the audit that data should be submitted to INMET Brasilia (to the meteorological data centre, Maria Ines Moreira de Araújo) from where it should be made available to external data centres and data users.

4.1.4. Documentation

Since the station staff was never trained in ozone measurement technique, no documentation has been made to date. It was agreed with the station manager that the audit should be a new start. Specific checklists were developed in collaboration with the station operators.

Logbooks

New checklists are available for the ozone instruments. They should be filled in every five days (analyser) and 3-monthly (calibrator) along with additional information concerning instrument operation and maintenance.

Standard Operating Procedures (SOPs)

The manuals for the ozone analyzer and calibrator are available at the site.

Comment

It was agreed with the station operators that the whole documentation needs to be significantly improved.

4.2. Inter-comparison of Ozone Instruments

Note that the calibration factors were adjusted by EMPA-WCC during the audit (see Table 2). The adjustment was made because the instruments were never traced back to other references, but calibration factors have been changed during the installation in June 2000. The results presented here therefore show the agreement between EMPA-WCC and Arembepe after the change of the calibration factors. All previous ozone data was corrected according to the new calibration factors assuming a stable instrument.

4.2.1 Experimental Set-up

The WCC transfer standard TEI 49C PS (details see Appendix I-III) was operated in stand-by mode for warming up for 22 hours. During this stabilisation time the transfer standard and the PFA tubing connections to the instruments were conditioned with 700 ppb ozone for 120 minutes. Afterwards, three comparison runs between the field instruments and the WCC transfer standard were performed. Table 3 shows the experimental details and Figure 6 the experimental set-up during the audit.

The audit procedure included a direct inter-comparison of the TEI 49C-PS WCC transfer standard with the Standard Reference Photometer SRP#15 (NIST UV photometer) before and after the audit in the calibration laboratory at EMPA. The results are shown in Appendix I.

Table 3: Experimental details of the ozone inter-comparison

reference	EMPA: TEI 49C-PS #54509-300 transfer standard
field instruments	TEI 49C #59836-324 (analyser) TEI 49C-PS #59893-324 (calibrator)
ozone source	WCC: TEI 49C-PS, internal generator
zero air supply	EMPA: silica gel - inlet filter 5 µm - metal bellow pump - Purafil (potassium permanganate) - activated charcoal - outlet filter 5 µm
data acquisition system	16-channel ADC circuit board with acquisition software (Hunter & Caprez)
pressure transducer readings	TEI 49C-PS (WCC): 1010.9 hPa TEI 49C #59836-324: 987.8, adjusted to 1011.1 hPa TEI 49C-PS #59893-324: 974.4, adjusted to 1010.9 hPa
concentration range	0 - 100 ppb
number of concentrations	5 + zero air at start and end
approx. concentration levels	10 / 20 / 30 / 50 / 90 ppb
sequence of concentrations	random
averaging interval per concentration	5 minutes after end of drifts
number of runs	1 x on Dec 4 and 2 x on Dec 5, 2001
connection between instruments	about 1.5 meter of 1/4" PFA tubing

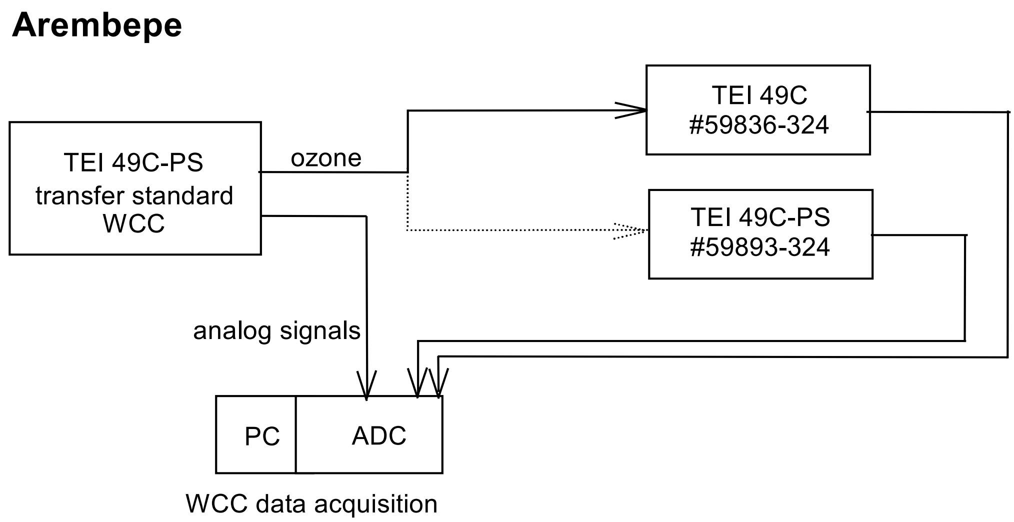

Figure 6: Experimental set up for the ozone inter-comparison at Arembepe

4.2.2. Results

Ozone Analyser

The results comprise the inter-comparison between the TEI 49C field instrument and the WCC transfer standard TEI 49C-PS, carried out on December 4 and 5, 2001.

The resulting mean values of each ozone concentration and the standard deviations (s_d) of ten 30-second-means are presented in Table 4. For each mean value the differences between the tested instrument and the transfer standard are calculated in ppb and in %.

Examination of the residuals for each concentration as shown in Figure 7 revealed no systematic time-dependence, indicating that all runs can be treated as a single data set. Residuals as a function of ozone concentration delivered by the WCC transfer standard are shown in Figure 8. Figure 9 shows the linear regression together with the assessment criteria for GAW field instruments.

Table 4: Inter-comparison of the ozone field instrument

run index	WCC TEI 49C-PS conc. ppb	WCC TEI 49C-PS s_d ppb	TEI 49C #59836-324 conc. ppb	TEI 49C #59836-324 s_d ppb	deviation from reference ppb	deviation from reference %
1	0.0	0.1	0.2	0.2	0.2	
2	89.9	0.1	89.9	0.3	0.0	0.0%
3	10.1	0.1	10.2	0.1	0.1	0.9%
4	19.8	0.1	19.9	0.1	0.1	0.3%
5	49.8	0.1	49.9	0.2	0.1	0.1%
6	29.9	0.1	30.0	0.1	0.1	0.3%
7	0.0	0.1	0.0	0.1	0.0	
8	0.3	0.1	0.4	0.1	0.2	
9	9.9	0.1	9.9	0.1	-0.1	-0.6%
10	30.0	0.1	29.8	0.2	-0.2	-0.7%
11	20.0	0.2	19.9	0.2	-0.1	-0.7%
12	50.0	0.1	49.8	0.1	-0.2	-0.4%
13	90.0	0.1	90.0	0.2	0.0	0.0%
14	0.1	0.1	0.2	0.1	0.1	
15	0.2	0.1	0.2	0.1	0.0	
16	90.0	0.1	90.0	0.2	0.0	0.0%
17	20.1	0.1	20.0	0.1	-0.1	-0.7%
18	10.4	0.1	10.3	0.1	0.0	-0.4%
19	50.0	0.1	49.9	0.1	-0.1	-0.2%
20	29.9	0.1	30.1	0.1	0.1	0.4%
21	0.2	0.1	0.2	0.1	0.0	

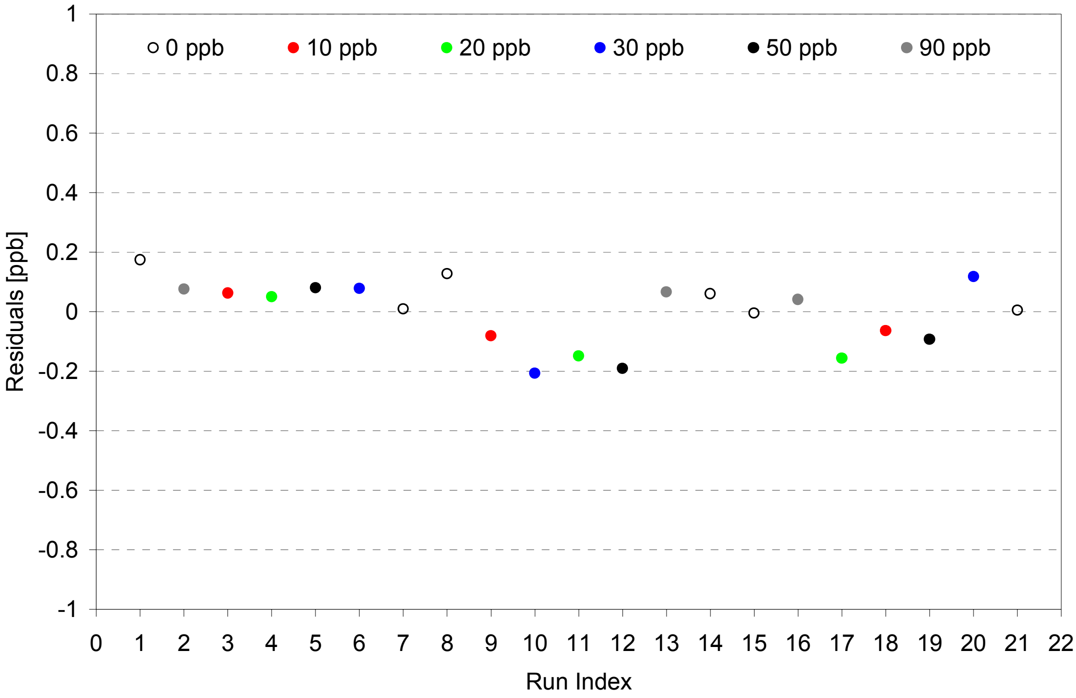

Figure 7: Residuals of the linear regression function (TEI 49C #59836-324) vs the run index (time dependence)

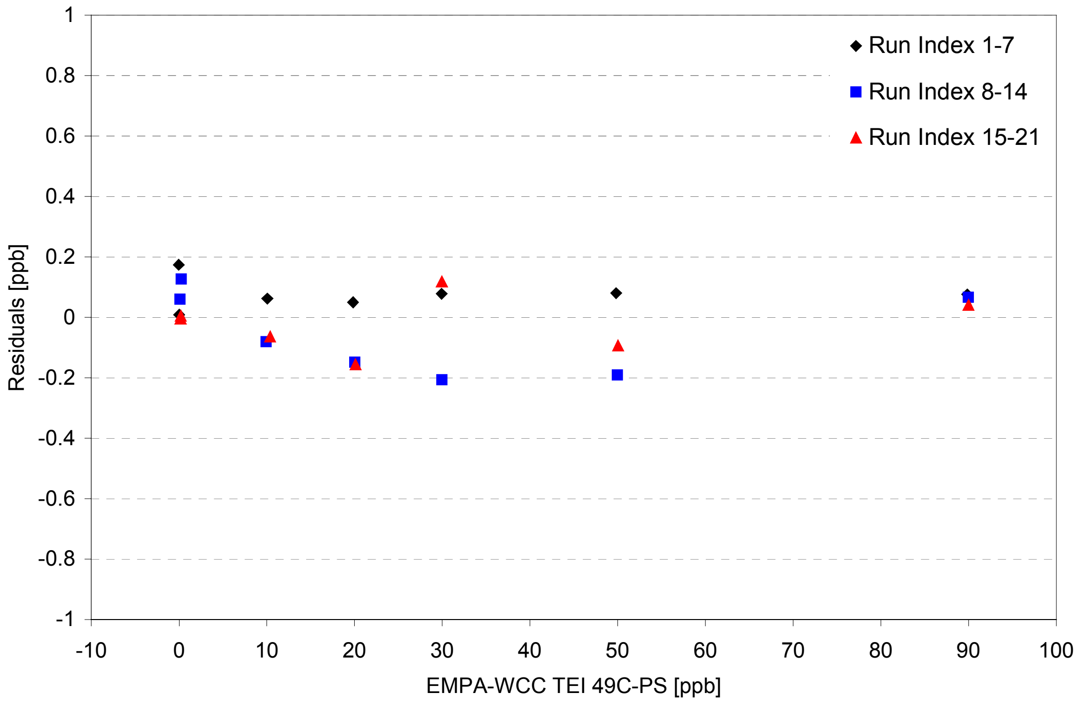

Figure 8: Residuals of the linear regression function (TEI 49C #59836-324) vs the concentration of the WCC transfer standard (concentration dependence)

The inter-comparisons of the TEI 49C field instrument with the TEI 49C-PS transfer standard from EMPA for the range of 0-100 ppb ozone can be summarised by the linear relationship:

TEI 49C #59836-324:

$$\text{TEI 49C} = 0.999 \times \text{TEI 49C-PS} + 0.04 \text{ ppb}$$

TEI 49C = O_3 mixing ratio in ppb, determined with TEI 49C #59836-324

TEI 49C-PS = O_3 mixing ratio in ppb, determined with TEI 49C-PS #54509-300

Standard deviation of:	- slope s_m	0.001	(f = 19) f = degree of freedom
	- offset S_b in ppb	0.03	(f = 19)
	- residuals in ppb	0.10	(n = 21)

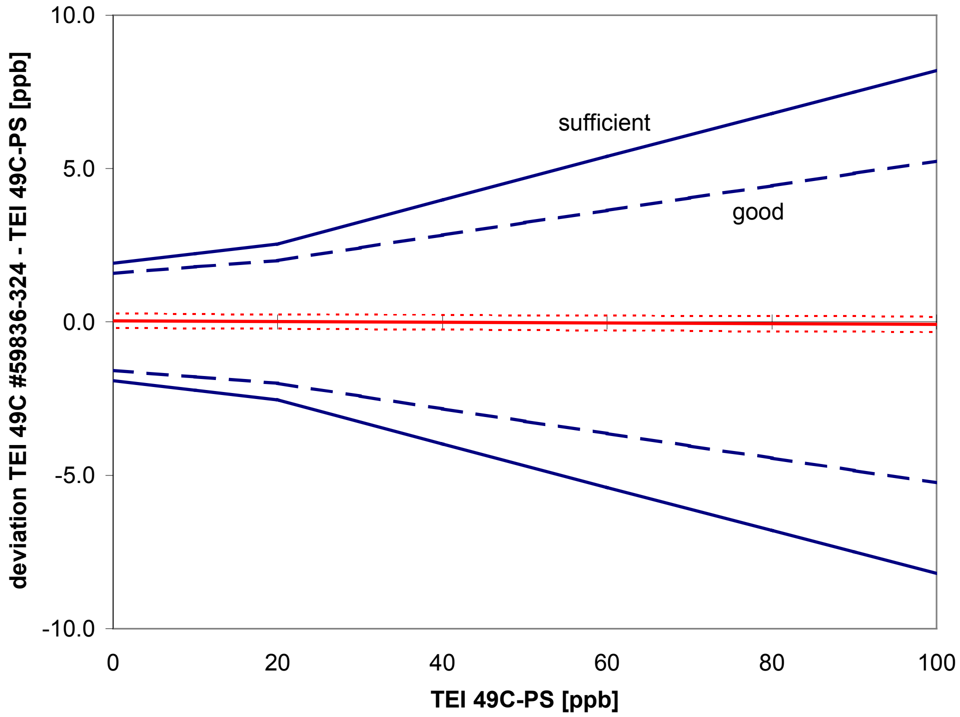

Figure 9: Inter-comparison of instrument TEI 49C #59836-324

Ozone Calibrator

In addition to the ozone analyser, an inter-comparison of the station ozone calibrator TEI 49C-PS with the WCC transfer standard was made. Experimental details are also summarised in Table 3.

The resulting mean values of each ozone concentration and the standard deviations (s_d) of ten 30-second-means are presented in Table 5. For each mean value the differences between the tested instrument and the transfer standard are calculated in ppb and in %.

Figures 10 and 11 show the residuals of the linear regression analysis of the field instrument compared to the EMPA transfer standard. The residuals versus the run index are shown in Figure 10 (time dependence), and the residuals versus the concentration of the WCC transfer standard are shown in Figure 11 (concentration dependence). The summary result is presented in Figure 12 with the assessment criteria for GAW field instruments.

Table 5: Inter-comparison of the ozone calibrator TEI 49C-PS

	WCC TEI 49C-PS		TEI 49C-PS #59893-324			
run index	conc.	s_d	conc.	s_d	deviation from reference	
	ppb	ppb	ppb	ppb	ppb	%
1	0.0	0.1	-0.2	0.2	-0.1	
2	89.9	0.1	89.3	0.3	-0.6	-0.7%
3	10.1	0.1	9.6	0.2	-0.5	-4.5%
4	19.8	0.1	19.7	0.3	-0.2	-0.9%
5	49.8	0.1	49.5	0.3	-0.3	-0.7%
6	29.9	0.1	29.7	0.2	-0.2	-0.8%
7	0.0	0.1	0.0	0.3	0.0	
8	0.3	0.1	0.1	0.4	-0.2	
9	9.9	0.1	9.6	0.3	-0.3	-3.3%
10	30.0	0.1	29.8	0.3	-0.2	-0.8%
11	20.0	0.2	20.0	0.3	-0.1	-0.3%
12	50.0	0.1	50.2	0.2	0.2	0.4%
13	90.0	0.1	90.2	0.4	0.3	0.3%
14	0.1	0.1	0.3	0.3	0.2	
15	0.2	0.1	0.2	0.2	0.1	
16	90.0	0.1	90.2	0.3	0.2	0.2%
17	20.1	0.1	20.4	0.3	0.3	1.7%
18	10.4	0.1	10.4	0.3	0.0	0.2%
19	50.0	0.1	50.2	0.2	0.2	0.4%
20	29.9	0.1	30.2	0.3	0.3	1.0%
21	0.2	0.1	0.4	0.3	0.2	

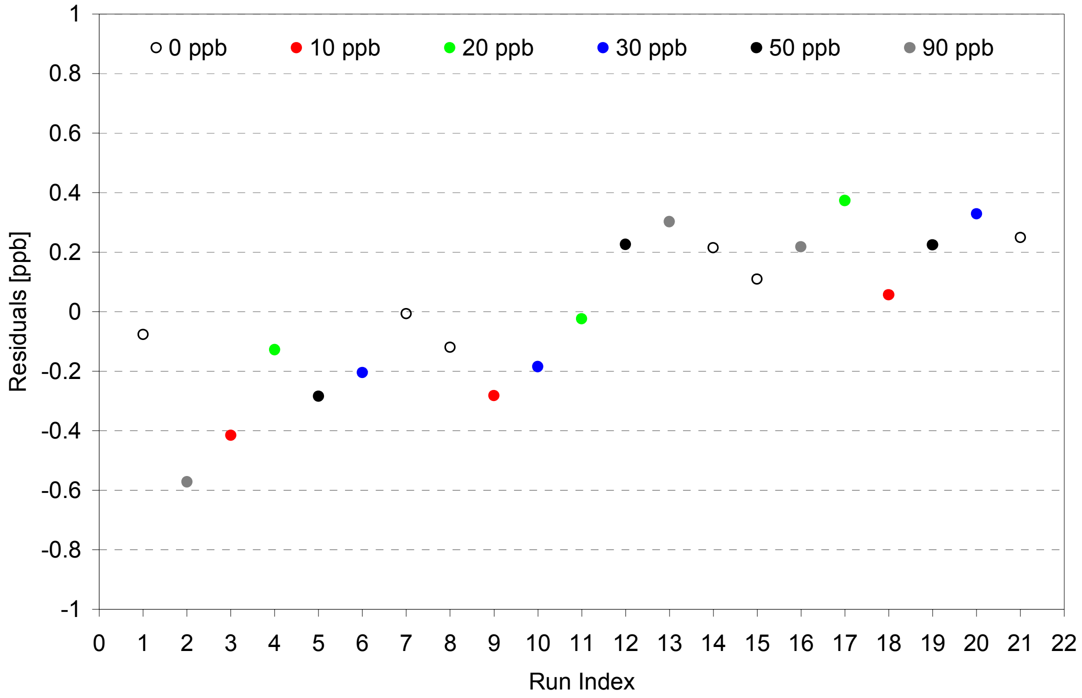

Figure 10: Residuals of the linear regression function (TEI 49C-PS #59893-324) vs the run index (time dependence)

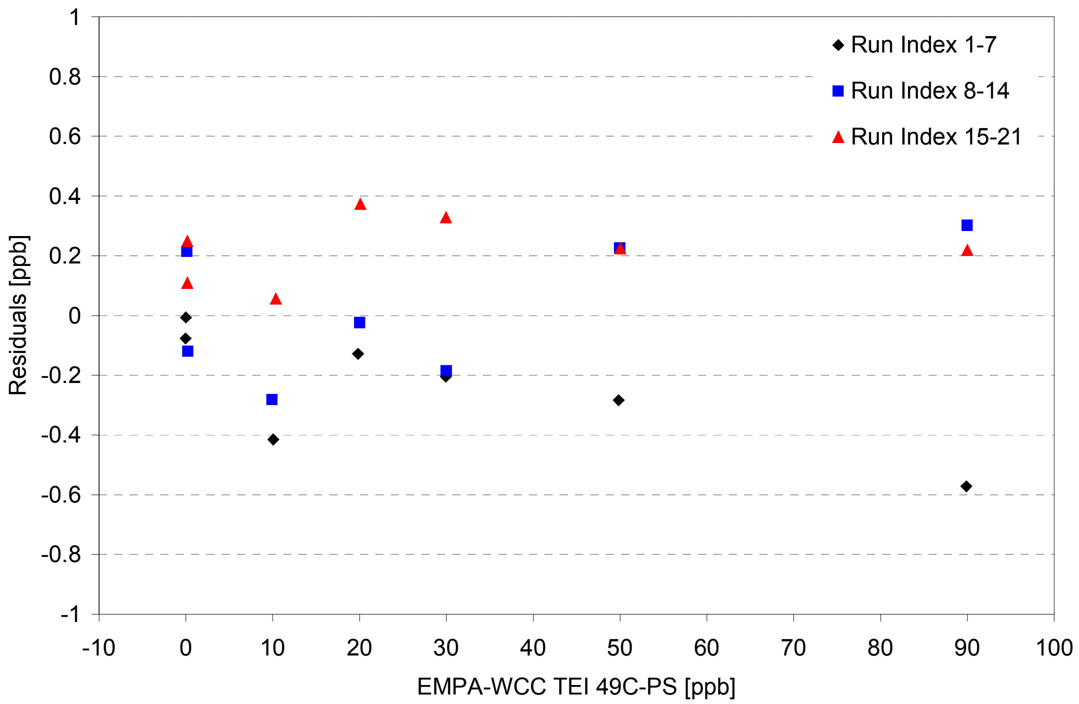

Figure 11: Residuals of the linear regression function (TEI 49C-PS #59893-324) vs the concentration of the WCC transfer standard (concentration dependence)

The inter-comparisons of the TEI 49C-PS field calibrator with the TEI 49C-PS transfer standard from EMPA-WCC for the range of 0-100 ppb ozone can be summarised by the linear relationship:

TEI 49C-PS #59893-324:

$$\text{TEI 49C-PS (ARE)} = 1.000 \times \text{TEI 49C-PS (WCC)} - 0.04 \text{ ppb}$$

TEI 49C-PS (ARE) = O_3 mixing ratio in ppb, determined with TEI 49C-PS #59893-324

TEI 49C-PS (WCC)= O_3 mixing ratio in ppb, determined with TEI 49C-PS #54509-300

Standard deviation of:	- slope s_m	0.002	(f = 19) f = degree of freedom
	- offset S_b in ppb	0.08	(f = 19)
	- residuals in ppb	0.20	(n = 21)

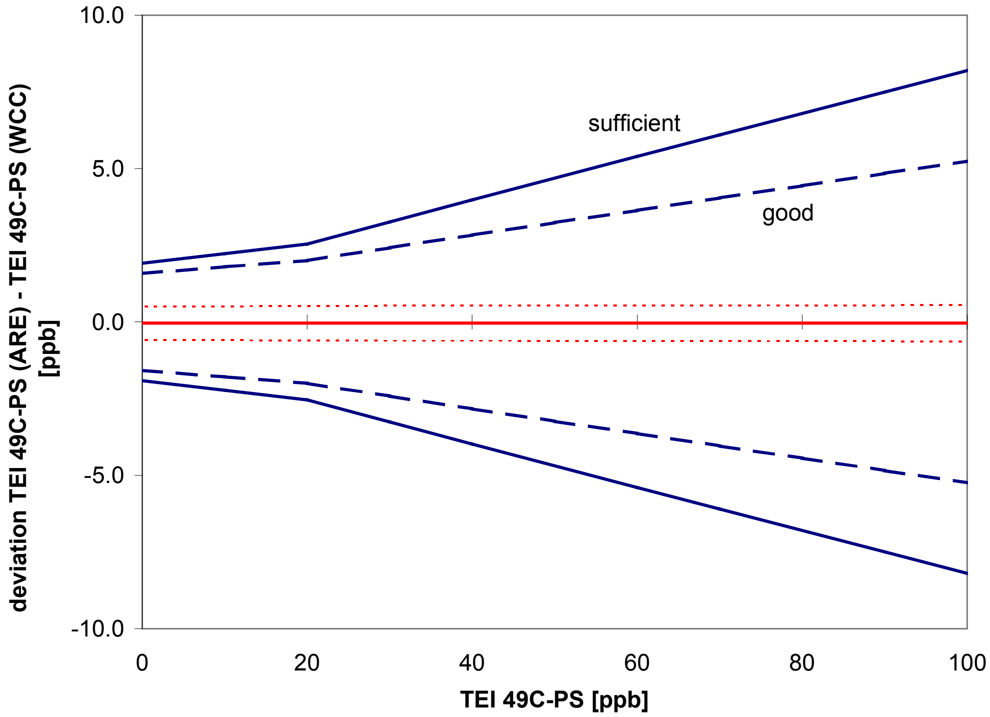

Figure 12: Inter-comparison of instrument TEI 49C-PS #59893-324

Comment

The ozone concentrations observed at Arembepe (June 00 to September 01) ranged between 10 and 30 ppb (5 and 95 percentile of hourly mean values), defining the station's relevant concentration range. The calibration factors of the analyser and the calibrator were changed by EMPA-WCC for an optimal result (see Table 2, section 4.1.2). After this both instruments (ozone analyser and calibrator) clearly fulfilled the assessment criteria as "good" over the tested range up to 100 ppb.

The ozone calibrator was significantly less stable compared to the ozone analyser. The values of the flow in the diagnostics menu were not in agreement with the actual flow (e.g. it did not change when the pump stopped). The problem could not be solved during the audit, but was identified to be an electronic problem (one of the digital boards). A replacement of the flow meters with spare parts from EMPA-WCC did not resolve the issue.

4.3. Recommendations for Ozone Measurements

The following recommendations are made by EMPA-WCC concerning the ozone measurements. Please refer also to section 5 for general recommendations suggested by EMPA-WCC.

- All actions concerning ozone measurements should be carefully documented in a log book.
- The checklists should be completed by the responsible person for the ozone measurements. It was agreed that data should be submitted to EMPA-WCC.
- Data should be checked weekly for plausibility using time series plots.
- Regular back-ups of the measurement data are strongly encouraged.
- The inter-comparisons with the station calibrator have to be performed manually. A 3-monthly interval for inter-comparisons is suggested by EMPA-WCC.
- Submission of the data to the GAW World Data Centre for Surface Ozone (WDCSO) at NILU is recommended as soon as longer time series become available. QA/SAC Switzerland is ready to offer assistance as needed.
- The station calibrator TEI 49C-PS should be serviced by the manufacturer or a representative.

5. General Recommendations

The following general recommendations are made to ensure the long-term operation of the GAW station Arembepe.

- The measurement program at the station should be enlarged to meet scientific needs. In particular meteorological parameters are of crucial importance for the interpretation of the data. The installation of an automated weather station is planned for 2002.
- The solar radiation equipment should be re-started, and communication with NREL (National Renewable Energy Laboratory) should be re-established.
- If new measurements are set up at the station, the initial training of the station staff is of highest priority. With the exception of the solar radiation measurements no training was given to the station staff until the date of this audit.
- Persistent problems with any of the measurements at Arembepe should be communicated to external partners and WMO. Communication should be re-established where necessary and maintained to ensure continuing support of external partners.

6. Conclusions

The global GAW station Arembepe officially opened in September 1997. Since June 2000, ozone data became available but time series covered only approx. 50% of the period until the audit. Besides ozone, no other parameters were measured.

The situation concerning ozone measurements significantly improved during the audit. The station staff was – for the first time – trained in ozone measurement technique. Station specific check lists were developed, and ozone measurements are now fully operational.

The geographical position of the Arembepe station within the GAW programme is regarded as important, since ground based measurements of air pollutants from tropical regions are limited. Furthermore, the station offers excellent infrastructure concerning accessibility and laboratory facilities. To take advantage of this, national and international co-operation for both technical and scientific staff (workshops, exchange programs, scientific partnerships) is regarded as important.

The station will require regular training for some years to come. Training is of crucial importance if new measurements are started at the station. All possibilities for twinning should be explored. A first positive step is the engagement of the Finish Meteorological Institute (FMI) to support the Arembepe station with a twinning partnership.

Appendix

I EMPA Transfer Standard TEI 49C-PS

The Model 49C-PS is based on the principle that ozone molecules absorb UV light at a wavelength of 254 nm. The UV absorption is proportional to the concentration as described by the Lambert-Beer Law.

Zero air is supplied to the Model 49C-PS through the zero air bulkhead and is split into two gas streams, as shown in Figure 13. One gas stream flows through a pressure regulator to the reference solenoid valve to become the zero reference gas. The second zero air stream flows through a pressure regulator, ozonator, manifold and the sample solenoid valve to become the sample gas. Ozone from the manifold is delivered to the ozone bulkhead. The solenoid valves alternate the reference and sample gas streams between cells A and B every 10 seconds. When cell A contains reference gas, cell B contains sample gas and vice versa.

The UV light intensities of each cell are measured by detectors A and B. After the solenoid valves switch the reference and sample gas streams to opposite cells, the light intensities are ignored for several seconds to allow the cells to be flushed. The Model 49C-PS then determines the ozone concentration for each cell and outputs the average concentration.

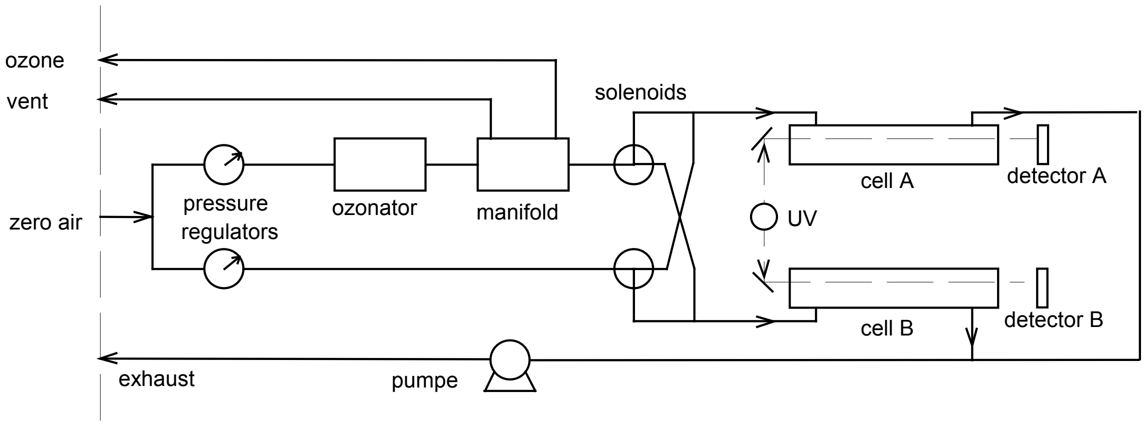

Figure 13: Flow schematic of TEI 49C-PS

II Stability of the Transfer Standard TEI 49C-PS

To exclude errors that might result from transportation of the transfer standard, the TEI 49C PS #54509-300 was compared with the SRP#15 before and after the field audit.

The procedure and instrumental details of this inter-comparison at the EMPA calibration laboratory are summarised in Table 6 and Figure 14.

Table 6: Intercomparison procedure SRP - TEI 49C-PS

pressure transducer:	zero and span check (calibrated barometer) at start and end of procedure
concentration range:	0 - 200 ppb
number of concentrations:	5 + zero air at start and end
approx. concentration levels:	30 / 60 / 90 / 140 / 190 ppb
sequence of concentration:	random
averaging interval per concentration:	5 minutes
number of runs:	3 before and 3 after audit
zero air supply:	Pressurised air - zero air generator (CO catalyst, Purafil, charcoal)
ozone generator:	SRP's internal generator
data acquisition system:	SRP's ADC and acquisition

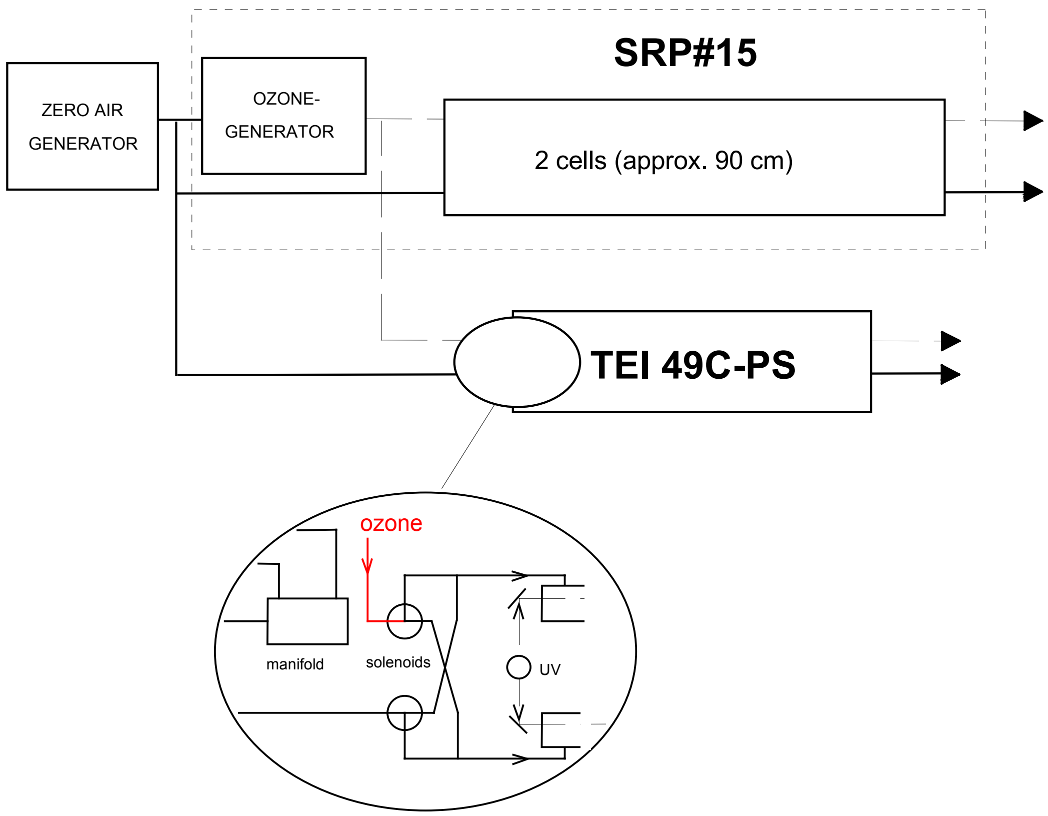

Figure 14: Instruments set up SRP -TEI 49C-PS

The stability of the transfer standard was thoroughly examined with respect to the uncertainties of the different components (systematic error and precision). For the GAW transfer standard of the WCC-O_3 (TEI 49C-PS) the assessment criteria, taking into account the uncertainty of the SRP, are defined to approximately ±(1 ppb + 0.5%).

Figures 15 and 16 show the resulting linear regression and the corresponding 95% precision interval for the comparisons of TEI 49C-PS vs. SRP#15. The results show that the EMPA transfer standard fulfilled the recommended criteria for the period of the audit, including transportation.

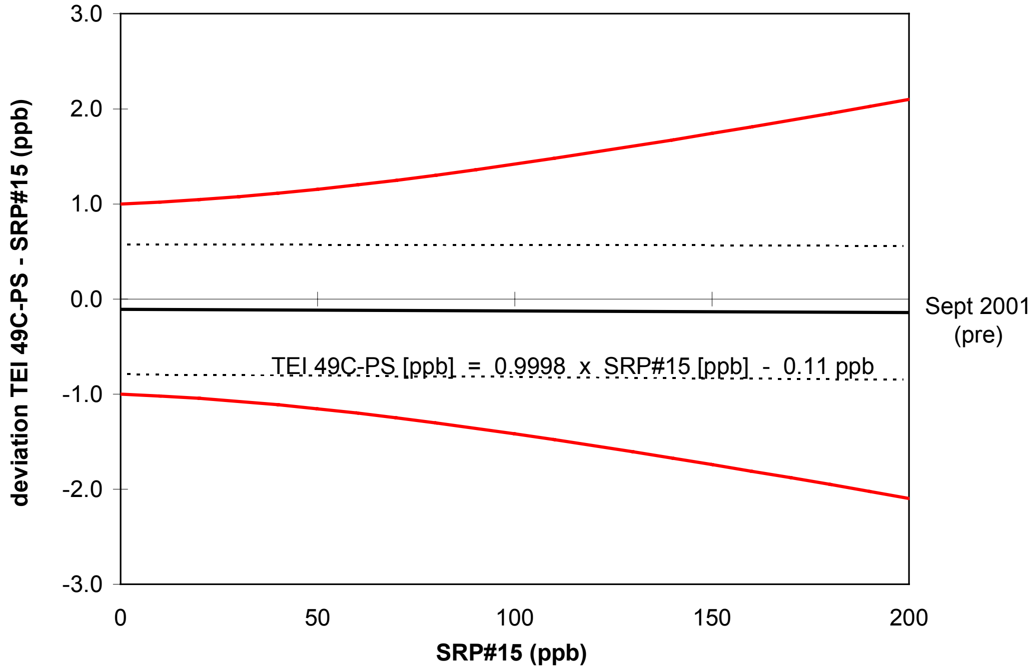

Figure 15: Transfer standard before audit

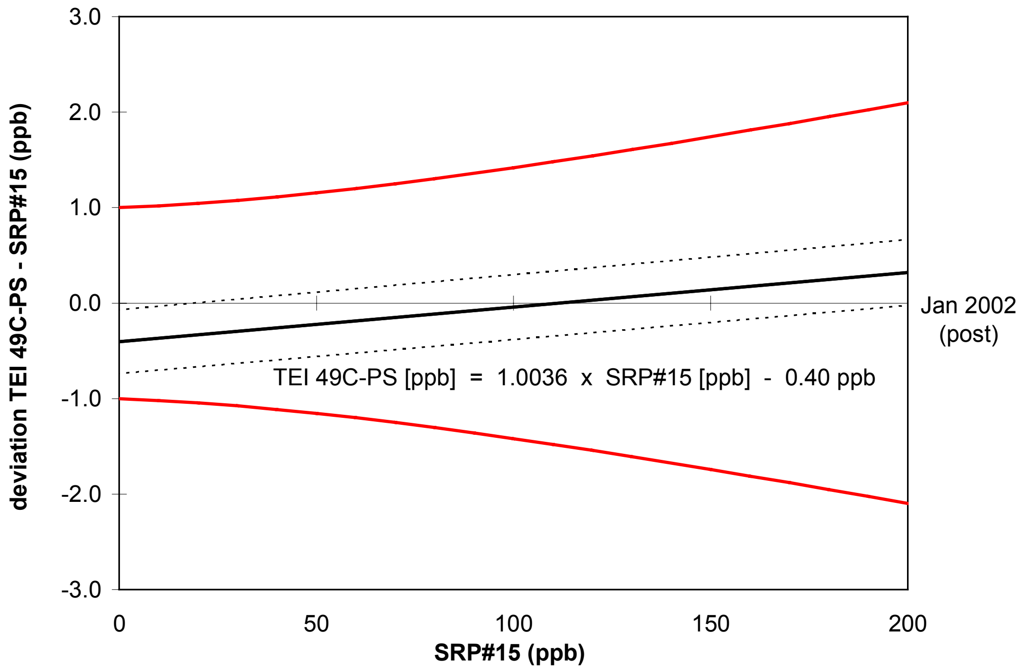

Figure 16: Transfer standard after audit

III Weekly checklist for the ozone analyzer

The weekly checklist is an Excel file that should be filled in every 5 days.

GLOBAL GAW STATION AREMBEPE - CHECK LIST						
Date						
Operator						
General Information						
Time and Date Correct						
Data Downloaded						
File Name						
Inlet Pump Working						
Inlet Filter Exchanged?						
Laboratory Temp. (ºC)						
O3 Analyzer						
Bench Temperature (ºC)						
Bench Lamp Temperature (ºC)						
Flow Cell #A (LPM)						
Flow Cell #B (LPM)						
Frequency Cell#A						
Frequencie Cell#B						
Noise Cell#A						
Noise Cell#B						
Calibration Factors						
O3 Background PPB						
O3 Coefficient						
Pressure Correction						
Temperature Correction						
Remarks						

IV 3-Monthly checklist for ozone inter-comparison

GLOBAL GAW STATION AREMBEPE – CHECKLIST (TO BE FILLED IN EVERY 3 MONTHS)

DATE

OPERATOR

CELLS: CHECKED: ANALYZER ☐ CALIBRATOR ☐
CLEANED: ANALYZER ☐ CALIBRATOR ☐

LEAK CHECK: PRESSURE DROPS < 250 mmHg WITHIN 20 s: ANALYZER ☐ CALIBRATOR ☐

INLET AND INLET LINE CLEAN? ☐ Yes

O3 INTER-COMPARISON

SET POINT	READING CALIBRATOR	READING ANALYZER	DEVIATION [ppb]	DEVIATION [%]

DATA (1 MIN AVG) OF CALIBRATION DOWNLOADED? ☐ Yes

CALIBRATON FACTORS

Before calibration	After calibration
O3 Background ppb ___________	O3 Background ppb ___________
O3 Coefficient ___________	O3 Coefficient ___________

REMARKS