CEOS RBCC-E Huelva 2011 intercomparison results

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Introduction

The VI Regional Brewer Calibration Center for Europe (RBCC-E) intercomparison was held at *El Arenosillo Atmospheric Sounding Station* of the "Instituto Nacional de Técnica Aeroespacial" (INTA) during the period July 5-15, 2011. This VI campaign was a joint exercise of the Regional Dobson Calibration Center for Europe (RDCC-E) and the Regional Brewer Calibration Center for Europe (RBCC-E) in collaboration with the Area of Instrumentation and Atmospheric Research of INTA, with the support of the Global Atmospheric Watch (GAW) program of the World Meteorological Organization (WMO) and a CEOS project of the European Space Agency (ESA). At the Arenosillo campaign 17th Brewer instruments participated from seven countries. In addition, five Dobson instruments participated in the parallel RDCC-E campaign.

Figure 1: Group photo of the participants of the VI RBCC-E campaign.

Institution	Name	Brewer	Country
RBCC-E AEMET	Alberto Redondas Juan J. Rodriguez Virgilio Carreño	#185-MKIII	Spain
IOS	Ken Lamb / Martin Stanek	#017-MKII	Canada
INTA	J. M. Vilaplana	#150-MKIII	Spain
DMN	Zaidouni Taoufik	#051-MKII	Morocco
	Zaydi Mustapha	#165-MKIII	Morocco
AEMET	María López	#070-MKIV	Spain
	José Montero	#186-MKIII	Spain
	J.M Anastasio	#166-MKIV	Spain
	J. Antonio Parodi	#117-MKIV	Spain
	Francisco García	#151-MKIV	Spain
UKMO	John Rimmer	#075-MKIV	U.K.
	Peter Kelly	#126-MKII	U.K.
		#172-MKIII	U.K.
WRC	Gregor Hülsen	#163-MKIII	Switzerland
		QASUME	Switzerland
K&Z	Clive Lee	#158-MKIII	Netherlands
	Arjan Hoogendoorn	#201-MKIII	Spain
York University MSC	Tom McElroy Volodya Savastiouk	#145-MKIII	Canada

Table 1: Participants of the VI RBCC-E campaign.

Date	Actions	Notes
4th	Installation	
5rd	Installation	"Blind Days"
6th	O3 Measurements	
7th	O3 Measurements	
8th	O3 Calibration	Adjustments
9th	O3 Calibration	Maintenance
10th	O3 Calibration	
11th	O3 final /UV (blind)	UV comparison
12th	O3 final /UV (blind)	with QASUME
13th	O3 final /UV (blind)	
14th	Brewer/Dobson	Brewer/Dobson
15th	Brewer/Dobson	comparisons

Table 2: VI RBCC-E campaign schedule.

The intercomparisons are scheduled on three different periods, the first days of the campaigns are dedicated to determine the current status of the instrument (**"blind days"**), the next days are dedicated to **characterize** the instruments and perform the necessary adjustments, this is the "**maintenance period**". Once this is finished, the final calibration is performed during the "**final days**".

Data Dissemination

All the observations and calibration process are available on the RBCC-E web page www.rbcc-e.org. The calibration results are summarized on calibration check files which are open and self described worksheets where you can track the calibration process. A more complete calibration report is produced after the campaign for each participating instrument.

Brewer ozone calibration

The Brewer instrument measures the intensity of direct sunlight at six wavelengths in the UV (303.2, 306.3, 310.1, 313.5, 316.8 and 320.1 nm) each covering a bandwidth of 0.5 nm (resolution power λ/dλ of around 600). The spectral measurement is achieved by a holographic grating in combination with a slit mask which selects the channel to be analyzed by a photomultiplier. The longest four wavelengths are used for the ozone calculation. Based on the Lambert Beer's law, the Brewer algorithm can be expressed as:

$$O_3 = \frac{F - ETC}{\alpha * m}$$

Where *F* is Rayleigh corrected the measured double ratios, *α* is the ozone absorption coefficient, *m* is the ozone air mass factor and *ETC* is the extra-terrestrial constant. *F, α* and *ETC* parameters are weighed functions at the operational wavelengths with weighting coefficients w_i [1, -0.5, -2.2, 1.7].

$$F = \sum_{i=1}^{4} w_i \left[\log(I_i) + \beta_i \, \mu \, p / p_o\right]$$

$$\alpha = \sum_{i=1}^{4} w_i \, \alpha_i \qquad ETC = \sum_{i=1}^{4} \log(I_{oi})$$

Where *I* and *Io* are the measured and extra-terrestrial intensities at wavelengths *i*, *β* are the rayleigh coefficient and *μ* the air mass factor for molecular scattering.
The precise wavelengths of every instrument are slightly different from instrument to instrument. The weights (w_i) has been chosen to minimize the influence of SO_2 and also widely eliminates absorption features which depends in local approximation linearly on wavelength like the aerosol extinction since:

$$\sum_{1}^{4} w_i = 0, \quad \sum_{i=1}^{4} w_i \lambda_i \approx 0$$

Once the values of *α* and *ETC* are know the air mass factor can be calculated and the ozone is derived from the measurement *F*. The values of *α* and *ETC* are derived from the calibration process. This process can be divided in main steps: instrumental, wavelength calibration and *ETC* transfer.

Instrumental calibration: The instrumental calibration includes all the instrument parameters that affect the measured counts (*F*), which are determined by characterization of the instrument.

Wavelength calibration: In contrast with the Dobson, where all the instruments are assumed to operate with the same wavelength, every Brewer operates with slightly different wavelengths. These particular wavelengths are determined in a two-step procedure: first, the "optimal wavelength is selected based on the "SUN-SCAN", this election depends on Ozone Station climatology. Once these optimal wavelengths are chosen, based on measurements of spectral discharge lamps (dispersion procedure), the slit function is determined and the ozone absorption coefficient is calculated by convolution of Bass & Paur ozone cross section.

ETC transfer : Finally, the *ETC* transfer is performed by comparison with the reference instrument or by Langley regression at suitable locations.

$$ETC_i = F_i - O_{3REF} \, \alpha * m_i$$

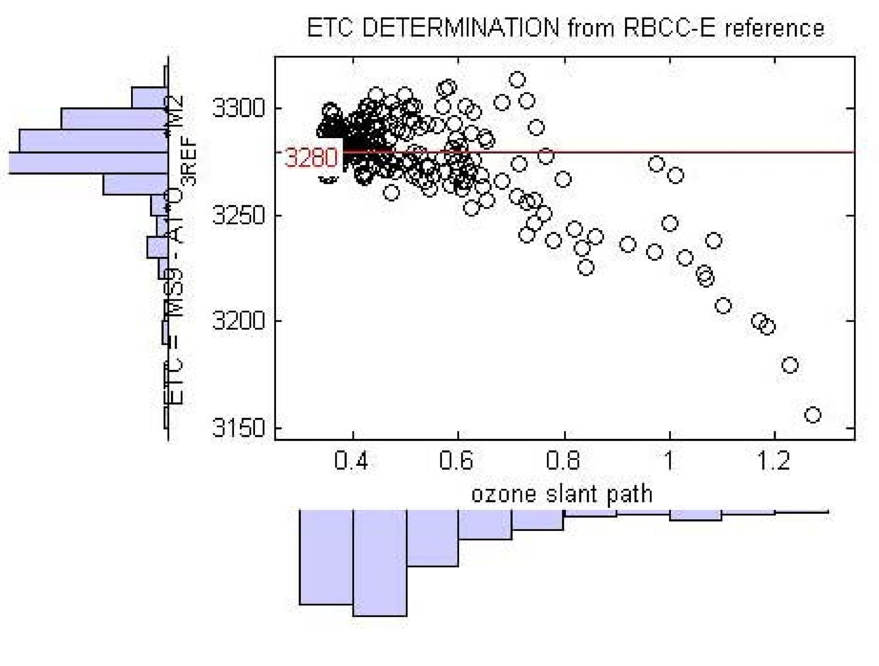

Figure 2: ***ETC*** **determination for a single brewer, final** ***ETC*** **constant is the mean of (1) of the "Stray Light" free region, in this case the flat region from .3 to .8**

Changes in instrumental characterization and in wavelength calibration affect the final *ETC*, the calibration procedure has to be viewed as a cycle where one parameter affects the others.

RBCC-E travelling calibration

The calibration of the RBCC-E travelling reference is assured by three different process:

1. The RBCC-E triad is regularly linked to the World Calibration Triad through IOS travelling and/or direct comparison with the triad.

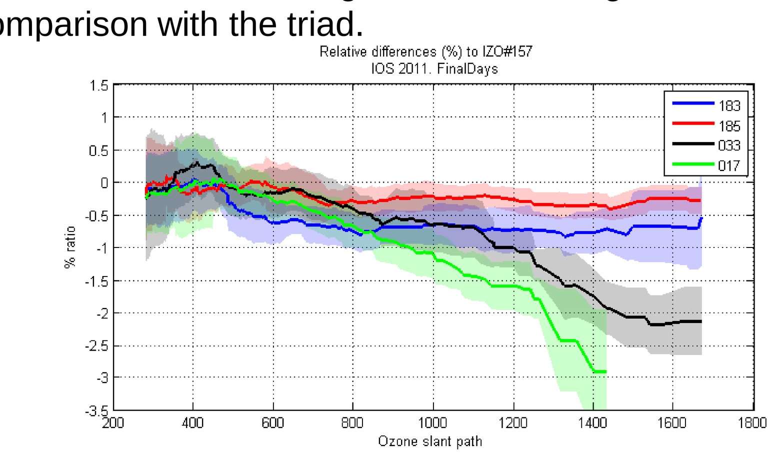

Figure 3: RBCC-E triad comparison against IOS travelling after Huelva campaign.

2. The travelling is compared with the triad before and after every campaign.

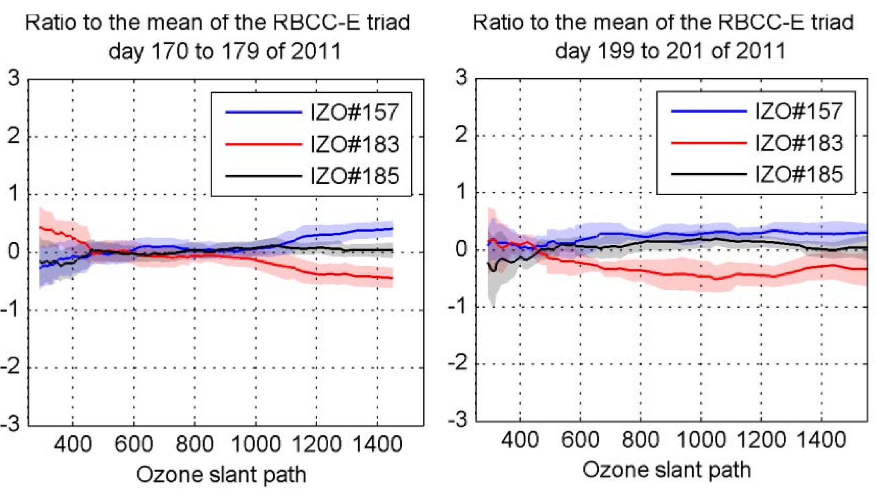

Figure 4: RBCC-E triad comparison against IOS travelling after Huelva campaign.

Periods	#157 med	157 std	#183 med	183 std	#185 med	#185 std	n obs
Before	-0.03	0.3	0.11	0.35	-0.07	0.27	140
After	0.19	0.23	-0.19	0.32	0	0.26	66

Table 3: Mean of relative differences and its standard deviation of the ozone measured by REBC-E Brewer triad against the mean of #157 and #185, before and after Huelva campaign.

3. The travelling, (and the RBCC-E triad) is calibrated

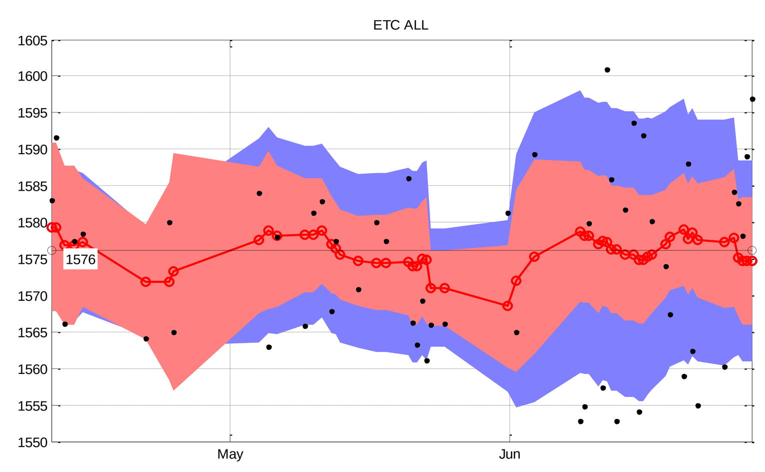

Figure 5: Langley ETC calculations at Izaña Atmospheric Observatory before the campaign.

Reference instruments comparison

The reference instruments enumerated below are routinely used for ozone transfer calibration. With the exception of #017 from IOS, all of them are double Brewers:

B#017: International Ozone Services travelling
B#145: Environmental Canada double travelling
B#158: Kipp & Zonen travelling reference
B#185: RBCC-E travelling reference
D#064: RDCC-E travelling reference

The mean relative difference against the RBCC-E reference #185 of the Brewer #145 is -0.6% and even better for #158 (-0.2%). Finally, the Brewer #017 shows a mean difference of 0.4% for OSC lower than 0.7. The ratios for the Dobson 64 shows an mean underestimation, against #185, of AD and CD pair observations of 1.1 % and 2.6% respectively. The comparison with the Dobson is discussed in another post

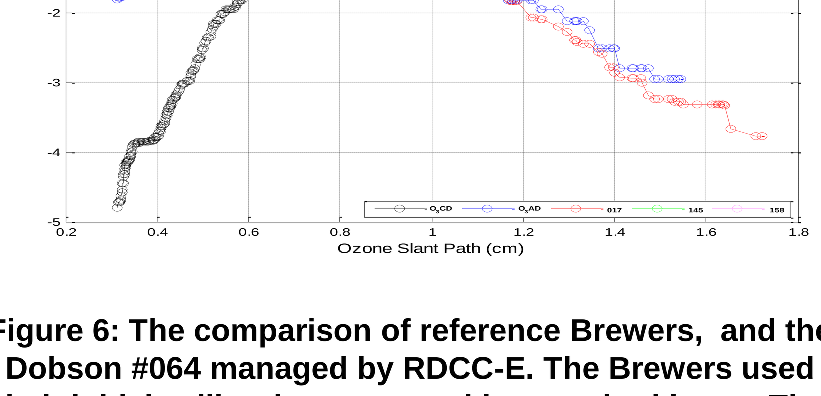

Figure 6: The comparison of reference Brewers, and the Dobson #064 managed by RDCC-E. The Brewers used their initial calibration corrected by standard lamp . The analysis uses more than 300 simultaneous measurements (5 min) on Brewer spectrophotometer and around 90 in the Dobson's. The comparison comprises the 300 to 1500 DU OSC range.

Blind days comparison

The Blind comparison shows how the instruments performs at their own stations and could be considered as representative of the general status of the network. The observations for the Blind days are processed with the "user provided" calibration and corrected according to standard lamp results. With the exception of two no operative Brewers, the relative difference of all participating instruments is in the range [-1.5, 1%], 80% of them are +/- 1% and two thirds of that shows a perfect agreement +/-0.5%.

	186	187	188	189	190	191	192	193	194	195	avg.	std.	N
17	-0.5	-0.5	-0.2	-0.4	-0.6	-0.4	-0.1	-0.7	-1.9		-0.4	0.1	431
51		-0.1	-0.5	-0.7	-0.3	-0.7	-0.1	-0.2	-0.3	-0.2	-0.4	0.1	424
70	-0.1	0.7	0.4	0	-0.5	0.9	0.7	0.5	0.9	0.9	0.4	0.2	307
75	-20	-23	18	23	19	23	23	20			10.	1.4	275
117	0.6	-0.5	0	-0.5	-0.4	-0.4	0.2	0	-0.2	-0.6	-0.2	0.2	463
126	-1.3	-1.8	-1.2	-1.5	-1.6	-1.6	-1.2	-1.2			-1.5	0.2	201
145	-1.2	-0.3	-0.7	-0.6	-0.9	-0.3	-0.3	-0.3	-0.3		-0.6	0.1	442
150	-0.1	0	0	-0.2	0.1	-0.5	-0.1	0	-0.2	0	-0.1	0.1	344
151	-32	-33	-31	-31	-21	-25	-30	-27	-30	-33	-29	1.2	387
158	0.1	0	-0.3	-0.1	-0.3	-0.4	-0.2	-0.3	-0.2	-0.4	-0.2	0.1	471
163			-1.1	-1.1	-1.4	-0.6	-0.8	-0.7	-0.2		-0.9	0.1	347
165	-0.3	-0.2	0.1	-0.1	0.2	0.1	0.4	-0.3	-1	-0.1	0	0.1	371
166	1.4	0.9	1	1.1	1.1	0.6	1.5	0.8	1.2	1.1	1.1	0.2	463
172	-0.6	-0.5	-0.2	-0.4	-0.2	-0.5	-0.4	-0.5			-0.4	0.1	395
186	-0.1	0.5	0.8	0.9	0.6	0.6	0.2	0.5	0.9	-0.7	0.4	0.1	419
209	-0.3	-1.7	-0.8	-1.2	-1.2	-1.2	-1.2	-0.5	-1.3		-1.1	0.2	398
CD		-3.3	-1.9	-3	-1.8		-3.5	-2.1			-2.6	0.4	87
AD		-1.2	-0.8	-1	-1.3		-1.4	-1.3			-1.1	0.1	87

Table 4: Daily mean percentage differences to RBCC-E reference.

Final days comparison

After the maintenance and final adjustments, all the instruments behave with daily mean lower than 0.5 %.

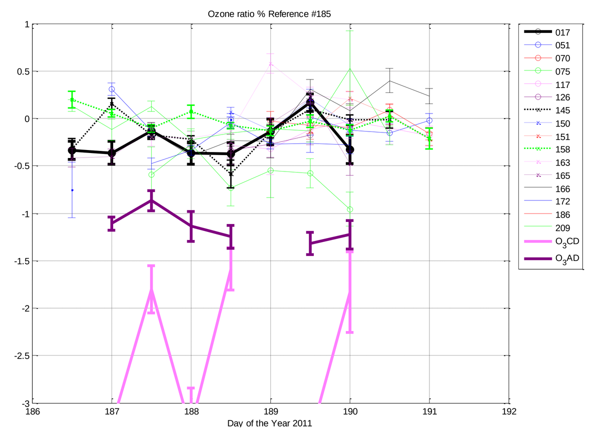

Figure 7: Final days, daily mean percentage ratio to RBCC-E.

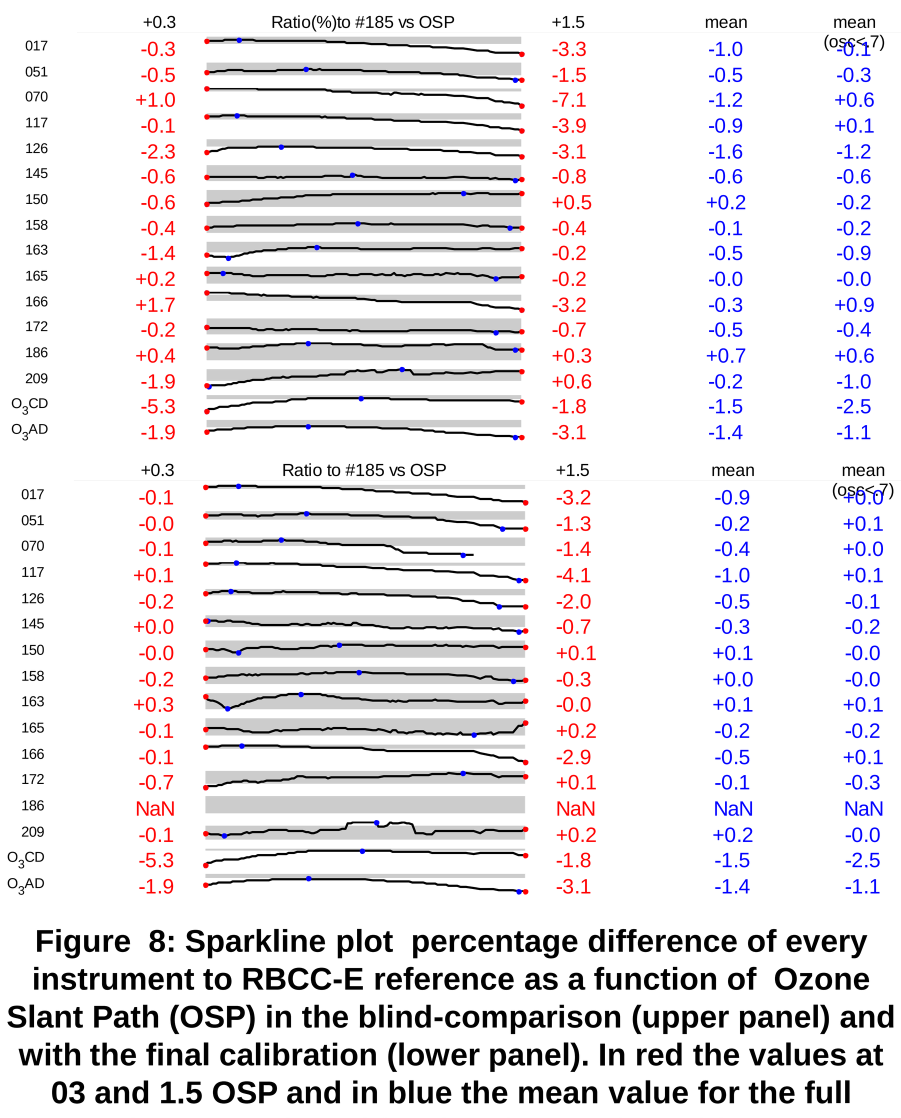

Figure 8: Sparkline plot percentage difference of every instrument to RBCC-E reference as a function of Ozone Slant Path (OSP) in the blind-comparison (upper panel) and with the final calibration (lower panel). In red the values at 03 and 1.5 OSP and in blue the mean value for the full range (0,3 1.5 cm) and for the observation with OSP<0.7 cm are presented The grey area of the plot represents the +/- 1% on the upper panel and +/-05 % on the Lower panel .

Conclusions

The Arenosillo campaign with 17 instruments can be representative of the status of the Brewer network:

- ✓ The RBCC-E triad shows a precision of 0.25%.
- ✓ The Brewer reference instruments agree around 0.5%.
- ✓ The agreement of network instruments after two years calibration, are within +/- 1% in the 80% of cases and 66% shows a perfect agreement within +/- 0.5%.
- ✓ After calibration the agreement for all the instruments are better than 0.5%.