Supplement of Atmos. Meas. Tech., 11, 4059–4072, 2018
https://doi.org/10.5194/amt-11-4059-2018-supplement
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Supplement of

Internal consistency of the Regional Brewer Calibration Centre for Europe triad during the period 2005–2016

Sergio Fabián León-Luis et al.

Correspondence to: Alberto Redondas (aredondasm@aemet.es)

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The Standard Lamp (SL) test has not been included in the main part of this article but the values recorded by the RBCC-E triad are presented as supplementary information.

Generally, the SL value (so-called R6 value) is used to check the Brewer calibration since this parameter can mirror the changes of the relative spectral sensitivity. The differences between the SL record with respect to a reference value give an idea of how much the configuration of the instrument has changed. This variation can be taken into account in the ozone retrieval as follows:

\[
O_3 = \frac{MS9 - ETC + (R6 - R6_{Reference})}{\alpha \cdot \mu} = \frac{MS9 - ETC}{\alpha \cdot \mu} + \frac{(R6 - R6_{Reference})}{\alpha \cdot \mu}
\]

where it is assumed that variation in the R6 value corresponds to a similar change in the Extraterrestrial constant (ETC). Therefore, the second term, \((R6 - R6_{Reference})/(\alpha \cdot \mu)\) represents the ozone correction by standard lamp. However, there are changes in the characteristics of the instrument that can not be detected with a SL test such as variations of the attenuation filters, iris and pointing. Therefore, the SL value does not represent the best indicator to check the calibration of our instruments. This justifies why the Brewers participate in the intercomparison campaign where their data are compared against a reference Brewer.

The importance of having established the Regional Brewer Calibration Center in the Izaña Atmospheric Observatory is because this place presents ideal conditions for the Langley technique which allow us an absolute and independent derivation of ETC of each brewer. In this respect, the Langley method is the ideal calibration technique to check the state of an instrument and, hence, at the RBCC-E the SL correction does not usually apply to our instruments with some exceptions (see section Brewer#183). In general, the ETC detects the large changes in the calibration of an instrument while the smaller changes can be tracked with the SL records. Normally, when an instrument presents an irregular behavior, the SL allow us to track better the evolution of the instrument than the ETC calculation. This is due to the ETC being calculated from data obtained during several weeks of observation, a period where it is required that the instrument works uniformly.

Routinely since 2009, monthly calibrations are performed for the three instruments of the RBCC-E triad following the same procedure as described Redondas et al. (2018). This includes the instrument characterization (dead time, filter attenuation and temperature coefficients determination), the wavelength calibration and the ETC transfer. The ETC value are compared with the Langley calibration which is finally used. This calibration reports are available on the RBCC-E website (see for example León-Luis et al. (2016)), and the calibration of the travelling reference before and after the travels are part of the intercomparison reports (Redondas et al., 2015; Redondas and Rodríguez-Franco, 2016; Redondas and Rodríguez-Franco, 2015). During these routine calibrations a history of the calibrations is produced and the events which produce a change in the calibration (ETC) and/or Standard Lamp record are noted.

In the following figures and tables a calibration history of the RBCC-E Triad are shown, these events are identified with vertical lines in each figure and the dates on which these events have taken place are indicated in the corresponding table. Most of the changes are due to maintenance, hardware changes, testing and incidents on the instruments due to the storms which affect at the observatory. The figures show the calibration derived from the Langley technique and the ETC (Figures and Tables 1,3,5), and the Standard lamp corrections between calibrations (Figures and Tables 2,4,6).

**Brewer#157**

The Brewer#157 was installed at the observatory in 1998, since 2004 it shows small changes mostly due to maintenance as shown in Figure S1 and Table S1. From 1998 to 2010 Brewer#157 was calibrated yearly by were yearly calibrated by International Ozone Services (IOS), the comparison of the Langley calibration with the travelling shows a good agreement with difference lower than 0.5% (Redondas et al., 2013). Note that during this period IOS calibration and not Langley were used for the data evaluation. During the period 2013-2015 is when the instrument presented a more irregular behaviour as can be observed by the number of calibrations and the large changes in the ETC operative value. This unstable period is mirrored in the SL records, see Figure S2 and Table S2.
Brewer#183

On the record of the Brewer#183, we have to consider that this is our testing instrument where new routines and hardware changes are tested before being introduced on the Triad (Figure S3 and Table S3. This instrument were strongly affected by the Delta tropical Storm in November 2005 (Jorba et al., 2008) and we not considered stable until 2011, after that only small changes are noticed. A reprocessing of the calibration will improve the results during the 2006-2009 period, after the fixing of the instrument. Also, the SL record tracks this irregular period, especially in 2009. From 2012, the ETC has changed on numerous occasions. However, the R6 records and its reference value do not show large differences between them, see Figure S4 and Table S4. This is a sign of a stable behavior of the instrument from this date.

Brewer#185

The Brewer#185 is the travelling instrument and was the last instrument installed at the observatory. Figure S5 shows that the ETC values were stable between 2005-2010, except for a few months in 2008, see Table S5. Between the years 2011-2013, two abrupt changes in the ETC can be observed, in first place due to changes on the micrometer after a campaign in Huelva in 2011 and an optical focus realignment in 2013. From 2013, the ETC has varied in a few units. The R6 has evolved similarly to ETC value, see Figure S5 and Table S6.

Figure S1. The vertical red lines correspond to events which have produced a change in the operative ETC configuration which is indicated with a horizontal green line. The red and blue dots denote the daily ETC values calculated by the Langley method before and after solar noon, respectively. The black line corresponds to the ETC weekly mean and the dark and light gray areas represent the 95% confidence interval and the standard deviation, respectively.
Table S1. ETC Reference values used in the Brewer#157 and events which have produced its change during the period 2005-2016.

<table>
<thead>
<tr>
<th>Event</th>
<th>Date</th>
<th>ETC Operative</th>
<th>Event</th>
<th>Date</th>
<th>ETC Operative</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. SL Replacement</td>
<td>31/05/2005</td>
<td>1605</td>
<td>2. Storm</td>
<td>01/03/2010</td>
<td>1600</td>
</tr>
<tr>
<td>5. Maintenance Kipp&amp;Zonen</td>
<td>24/10/2012</td>
<td>1605</td>
<td>6. Hg replacement</td>
<td>30/04/2013</td>
<td>1600</td>
</tr>
<tr>
<td>13. Maintenance IOS 2015</td>
<td>06/06/2015</td>
<td>1610</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure S2. The vertical red lines indicate events which have produced a change in the R6 Reference value which is indicated with a horizontal black line. The green dots are the R6 value measured by the Brewer#157. In contrast, the red dots represents the ozone correction value calculated from the difference R6-R6 Reference, assuming a ozone absorption coefficient and an airmass equal to 0.3995 and 2, respectively.

Table S2. R6 Reference values used in the Brewer#157 and events which have produced its change during the period 2005-2016.

<table>
<thead>
<tr>
<th>Event</th>
<th>Date</th>
<th>R6 Reference</th>
<th>Event</th>
<th>Date</th>
<th>R6 Reference</th>
</tr>
</thead>
</table>
Figure S3. The vertical red lines correspond to events which have produced a change in the operative ETC configuration which is indicated with a horizontal green line. The red and blue dots denote the daily ETC values calculated by the Langley method before and after solar noon, respectively. The black line corresponds to the ETC weekly mean and the dark and light gray areas represent the 95% confidence interval and the standard deviation, respectively.

Table S3. ETC Reference values used in the Brewer and events which have produced its change during the period 2005-2016.

<table>
<thead>
<tr>
<th>Event</th>
<th>Date</th>
<th>ETC Operative</th>
<th>Event</th>
<th>Date</th>
<th>ETC Operative</th>
</tr>
</thead>
<tbody>
<tr>
<td>7. Wavelength calibration</td>
<td>04/08/2011</td>
<td>1580</td>
<td>8. Wavelength calibration</td>
<td>24/03/2012</td>
<td>1590</td>
</tr>
<tr>
<td>9. SL replacement</td>
<td>10/12/2012</td>
<td>1600</td>
<td>10. Slitmask issue</td>
<td>07/03/2013</td>
<td>1645</td>
</tr>
<tr>
<td>11. Old board test</td>
<td>09/10/2013</td>
<td>1575</td>
<td>12. Hg replacement</td>
<td>12/03/2014</td>
<td>1570</td>
</tr>
<tr>
<td>15. Maintenance IOS 2015</td>
<td>09/06/2015</td>
<td>1630</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Figure S4. The vertical red lines indicate events which have produced a change in the R6 Reference value which is indicated with a horizontal black line. The green dots are the R6 value measured by the Brewer®. In contrast, the red dots represent the ozone correction value calculated from the difference R6-R6 Reference, assuming an ozone absorption coefficient and an airmass equal to 0.3995 and 2, respectively.

Table S4. R6 Reference values used in the Brewer® and events which have produced its change during the period 2005-2016.

<table>
<thead>
<tr>
<th>Event</th>
<th>Date</th>
<th>R6 Reference</th>
<th>Event</th>
<th>Date</th>
<th>R6 Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>5. Storm</td>
<td>02/03/2010</td>
<td>350</td>
<td>6. Micrometer issue</td>
<td>19/03/2010</td>
<td>360</td>
</tr>
<tr>
<td>9. New board replacement</td>
<td>07/03/2012</td>
<td>345</td>
<td>10. SL. replacement</td>
<td>10/12/2012</td>
<td>350</td>
</tr>
<tr>
<td>15. Prism Alignment</td>
<td>26/12/2013</td>
<td>325</td>
<td>16. Hg replacement</td>
<td>12/03/2014</td>
<td>320</td>
</tr>
</tbody>
</table>
Figure S5. The vertical red lines correspond to events which have produced a change in the operative ETC configuration which is indicated with a horizontal green line. The red and blue dots denote the daily ETC values calculated by the Langley method before and after solar noon, respectively. The black line corresponds to the ETC weekly mean and the dark and light gray areas represent the 95% confidence interval and the standard deviation, respectively.

Table S5. ETC Reference values used in the Brewer#185 and events which have produced its change during the period 2005-2016.

<table>
<thead>
<tr>
<th>Event</th>
<th>Date</th>
<th>ETC Operative</th>
<th>Event</th>
<th>Date</th>
<th>ETC Operative</th>
</tr>
</thead>
<tbody>
<tr>
<td>5. Wavelength calibration</td>
<td>02/03/2012</td>
<td>1435</td>
<td>6. Wavelength Calibration</td>
<td>27/03/2012</td>
<td>1455</td>
</tr>
<tr>
<td>7. Changed Langley</td>
<td>30/06/2012</td>
<td>1460</td>
<td>8. Storm</td>
<td>31/10/2012</td>
<td>1445</td>
</tr>
<tr>
<td>9. Packing Kipp&amp;Zonen.Focus align.</td>
<td>02/03/2013</td>
<td>1616</td>
<td>10. Wavelength calibration</td>
<td>30/04/2013</td>
<td>1585</td>
</tr>
<tr>
<td>11. Wavelength calibration</td>
<td>05/05/2013</td>
<td>1620</td>
<td>12. Zero update to 1730</td>
<td>07/05/2013</td>
<td>1605</td>
</tr>
<tr>
<td>13. UV calibration</td>
<td>12/08/2013</td>
<td>1600</td>
<td>14. Hg replacement</td>
<td>29/10/2013</td>
<td>1580</td>
</tr>
<tr>
<td>17. Calibration</td>
<td>13/07/2016</td>
<td>1575</td>
<td>18. Storm</td>
<td>05/12/2016</td>
<td>1570</td>
</tr>
</tbody>
</table>
**Figure S6.** The vertical red lines indicate events which have produced a change in the R6 Reference value which is indicated with a horizontal black line. The green dots are the R6 value measured by the Brewer#185. In contrast, the red dots represents the ozone correction value calculated from the difference R6-R6 Reference, assuming a ozone absorption coefficient and an airmass equal to 0.3995 and 2, respectively.

**Table S6.** R6 Reference values used in the Brewer#185 and events which have produced its change during the period 2005-2016.

<table>
<thead>
<tr>
<th>Event</th>
<th>Date</th>
<th>R6 Reference</th>
<th>Event</th>
<th>Date</th>
<th>R6 Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>5. Laboratory</td>
<td>11/04/2012</td>
<td>218</td>
<td>6. Focus alignment</td>
<td>02/03/2013</td>
<td>350</td>
</tr>
<tr>
<td>7. Zero update to 1730</td>
<td>07/05/2013</td>
<td>325</td>
<td>8. Zero update to 1733</td>
<td>13/05/2013</td>
<td>330</td>
</tr>
<tr>
<td>9. Mix Fixed</td>
<td>17/05/2013</td>
<td>335</td>
<td>10. Laboratory</td>
<td>12/08/2013</td>
<td>320</td>
</tr>
</tbody>
</table>
References


