Update of the RBCC-E Reference Triad

A. Berjón[1,2], A. Redondas[2], V. Carreño[2], J. López-Solano[1,2], F.C. Parra-Rojas[3], S.F. León-Luís[1,2], D. Santana[4]

[1] TRAGSATEC, Madrid, Spain. [2] Izaña Atmospheric Research Center, AEMET, Tenerife, Spain. [3] Interamerican University of Puerto Rico-Bayamón Campus, Bayamón, Puerto Rico. [4] LuftBlick Earth Observation Technologies, Innsbruck, Austria.

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VICEPRESIDENCIA TERCERA DEL GOBIERNO
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AEMet Agencia Estatal de Meteorología

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https://eubrewnet.aemet.es
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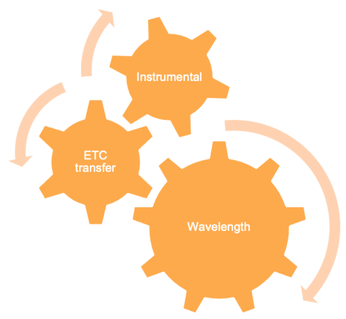
RBCC-E

In 2003, the WMO/GAW Regional Brewer Calibration Center for the RA-VI region (RBCC-E) was established at the Izaña Observatory of AEMET (Spain) [1]. Three double-monochromator (Mark III) type Brewers formed the original RBCC-E reference Triad: a Regional Primary Reference (Brewer #157), a Regional Secondary Reference (Brewer #183) and a Regional Travelling Standard (Brewer #185). RBCC-E transfers its own ozone absolute calibration to field instruments by inter-comparisons held annually, alternating between Davos (Switzerland) and the El Arenosillo Sounding Station of the Instituto Nacional de Técnica Aeroespacial (INTA) at Huelva (Spain). The reference transferred to the campaigns is the mean ozone of the three independently calibrated Brewer instruments.

Calibration process

RBCC-E Brewer spectrometer are calibrated independently by the Langley plot method at the Izaña Atmospheric Research Centre located at the Izaña mountain at 2367 m.a.s.l. on the Tenerife island. The calibration methodology can be summarized in three steps:

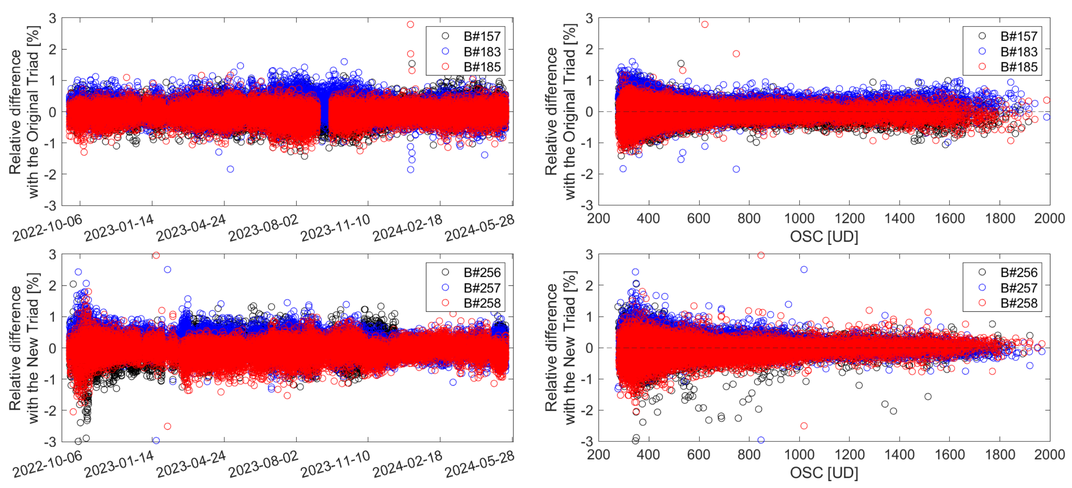


1. Instrumental characterisation:
   - Determination of linearity [2]
   - Temperature correction [3]
   - Filter attenuation [4].
2. Absorption coefficient obtained by measurements of the spectral lamp emission lines [5,6].
3. Extraterrestrial Constant (ETC) determined by Langley plot Method [7].

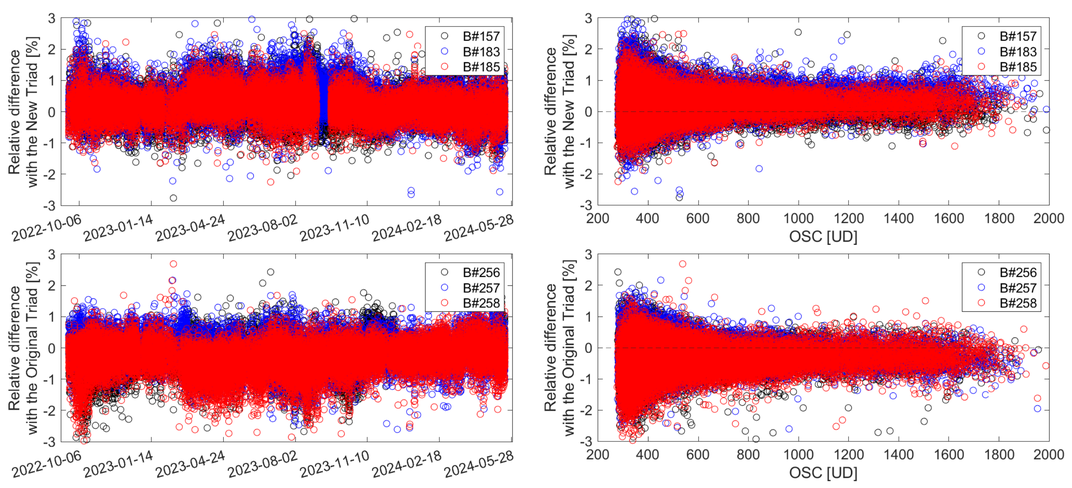
RBCC-E Triads

In 2021, AEMET procured three new brewers as a new Triad for the RBCC-E (serial numbers #256, #257, and #258). After some mechanical adjustments, the three new instruments have been operational since September 2022. The Original Triad (#157, #183 and #185) and New Triad (#256, #257 and #258) have remained at the Izaña Observatory from then until May 2024, except for the time when Brewers #185 and #256 have travelled to participate in calibration campaigns at El Arenosillo (Spain) and Santa Maria (Brazil). During this period of approximately one and a half years, the two Triads have been both separately and cross analysed.

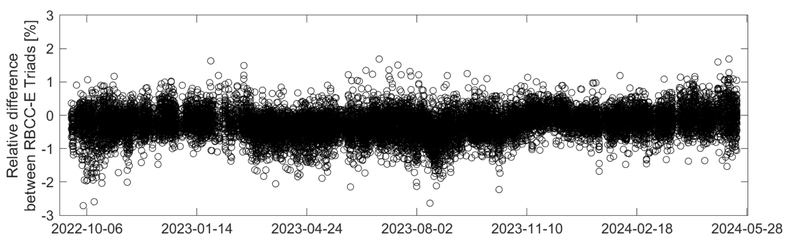
Separate analysis



Cross-analysis



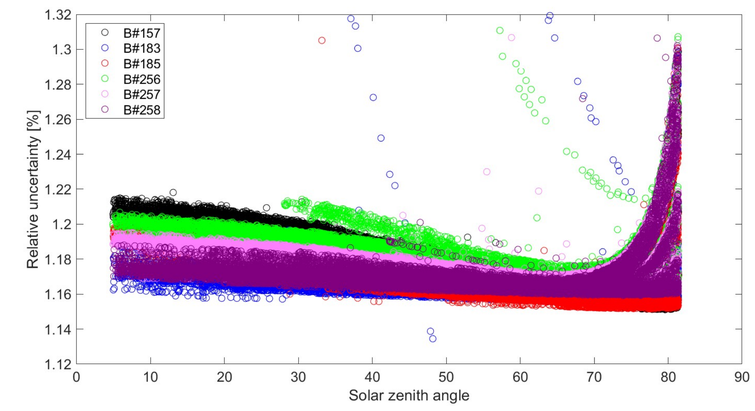
Difference between the Triads

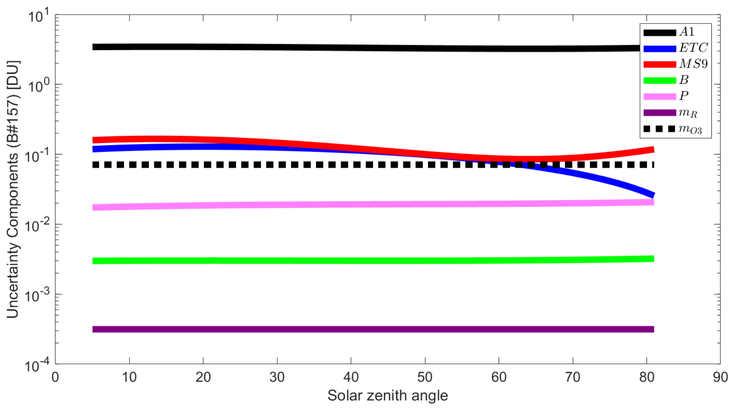


In the separate analysis, the relative differences between Eubrewnet L1.5 ozone of each Brewer with its Triad are shown. The average relative differences are between 0.03% and 0.10%, with standard deviations around 0.3%. From this analysis, it can be seen that the behaviour of the two triads are very similar. The cross-analysis shows the relative differences of each Brewer with respect to the other Triad. In this case, averages increase up to 0.37%, with standard deviations around 0.5%. No significant dependencies are found in any case with the ozone slant column (OSC), although in the case of cross-anaysis there is a slight deviation from zero. The comparison between the triads shows a mean difference of 0.3% with a standard deviation of 0.4%.

RBCC-E Triad Uncertainty

Uncertainty of the Total Ozone Column provided by Eubrewnet has been implemented using the following expressions for both level 1.0 and level 1.5. Level 1.0 takes into account the uncertainty of the extraterrestrial constant (ETC), the measurement (MS9), the ozone absorption coefficient (A1), the Rayleigh coefficient (B), the pressure (P) and the optical air masses of Rayleigh (m_R) and ozone (m_{O3}). For the uncertainty of the level 1.5 product, the effect of the Standard Lamp, Stray Light, and Neutral Filter correction is also considered. The implementation in Eubrewnet is done without considering correlations between the different components, although work is currently underway to implement the effect of these correlations. The figure on the right shows the relative uncertainty of the six RBCC-E Brewers at Izaña between September 2022 and May 2024. The average uncertainty value is 1.2%, reaching up to 1.3% for angles greater than 70°. The figure on the left shows the principal uncertainty components (A1, ETC, MS9, B, P, m_R and m_{O3}) versus solar zenith angle for Brewer #157. The principal component is that associated with the absorption coefficient, A1, due to the error associated with the Bass and Paur cross-section used in the algorithm, which is independent of the Brewer. A detailed description of the whole calculation can be found in [8] and [9].





$$u^2_{O_3(L1.0)} = (\frac{\delta O_3}{\delta etc})^2 u^2_{etc} + (\frac{\delta O_3}{\delta MS9})^2 u^2_{MS9} + (\frac{\delta O_3}{\delta A1})^2 u^2_{A1} + (\frac{\delta O_3}{\delta B})^2 u^2_B + (\frac{\delta O_3}{\delta P})^2 u^2_P + (\frac{\delta O_3}{\delta m_R})^2 u^2_{m_R} + (\frac{\delta O_3}{\delta m_{O_3}})^2 u^2_{m_{O_3}}$$

$$u^2_{O_3(L1.5)} = u^2_{O_3(L1.0)} + u^2_{StandardLamp} + u^2_{StrayLight} + u^2_{Filter}$$

In the case of the RBCC-E Triads, the ETC is calculated by the Langley plot method. To determine the uncertainty associated to the ETC, both the uncertainty obtained from the linear fit (using the York method to consider the uncertainty of the optical air mass) and the uncertainty due to the dispersion of the obtained ETCs have been considered. In practice, the uncertainty due to the linear fit is less than 5% of the uncertainty associated with the dispersion of the ETCs, so it is considered negligible, and the uncertainty of the ETC is considered to be the standard error of the mean.

$$u^2_{ETC} = \sum_i \frac{u^2_{ETC_i}}{n^2} = \sum_i \frac{u^2_{York_i} + u^2_{std}}{n^2} \approx \sum_i \frac{u^2_{std}}{n^2}$$

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