Comparing the year 2017 Total Ozone Column measurements at Uccle and Diekirch

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Abstract:

The total ozone column measurements made during the year 2017 at Uccle (WOUDC station 053) and Diekirch (WOUDC station 412) are compared, using only direct sun (DS) measurements.

The Uccle measurements were made by two different Brewer instruments, and as the Brewer #16 had two missing months, only direct sun measurements from the Brewer #178 were used in this comparison. The Diekirch measurements which by default are DS measurements, were made by two different broadband Microtops II instruments and homogenized into a single data series. The Diekirch readings follow the heavily changing Uccle data in a quite satisfying manner. The 183 same day measurements used for the comparison suggest a **calibration multiplier of 1.033** for the Microtops readings in order to make them comparable to the Uccle measurements. This calibration factor has remained practically constant since 2015.

The authors thank Dr. Hugo de Backer from RMIB for making available the Uccle measurements of 2017 not yet published by the WOUDC at the time of the writing of this report.

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1. The Diekirch Microtops II measurements.

Most of the **201** daily measurements during the year 2017 were made using the Microtops II broadband sun photometer from Solar Light Co., serial number 5375 (operator Francis Massen, location Bettendorf)). 63 measurements were made with the Microtops II, serial 3012 (operator Mike Zimmer, location Schieren). The two locations being very close to Diekirch (distance less than 10 km, practically same altitude), Diekirch is taken as the representative point of measurement. Several comparisons suggested to apply a multiplier of 0.9422 to the readings of instrument #3012, to make them comparable with those of instrument #5375. So the Diekirch data series has been homogenized as representative of instrument #5375. Only the "O3(corr)" readings which combine the three spectral channels of the Microtops instrument are used in this report. Contrary to the Brewer, most Microtops measurements were made around noon (at least three consecutive measurements merged into one average). Out of these 201 measurements, 183 are usable for a comparison of same-day, direct sun measurements by the Brewer #178 at Uccle.
The Diekirch Microtops raw data are available at the data archive of meteoLCD [**ref. 2**], the "O3(corr)" readings at the WOUDC side **[ref. 1]**

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2. The Uccle measurements.

Uccle measures TOC using two different Brewer instruments (Brewer #16 and Brewer #178, [**ref. 1**]); as Brewer #16 readings were unavailable for November and December due to instrument testing, only direct sun (DS) readings by Brewer #178 are used in this paper. This seems acceptable as a previous check made in 2016 showed that the 2 Brewers differ by less than 1 percent **[ref. 3].** There are 279 daily DS averages available for the Brewer #178 series of 2017.

The next table shows the average +/- standard deviation for both Uccle and Diekirch series, without regard to same or different day measurements.

	average	stdev
UCCLE Brewer #178 DS (279 data)	331.3	37.9
DIEKIRCH Microtops #5375 (201 data)	321.4	34.9

3. Comparing all DS measurements from Uccle with the same day measurements at Diekirch (= common day measurements)

There are 183 common day measurements available for comparison. The averages and standard deviations are given by the following table:

	average	stdev
UCCLE Brewer #178 DS	332.3	35.4
DIEKIRCH	321.2	34.7

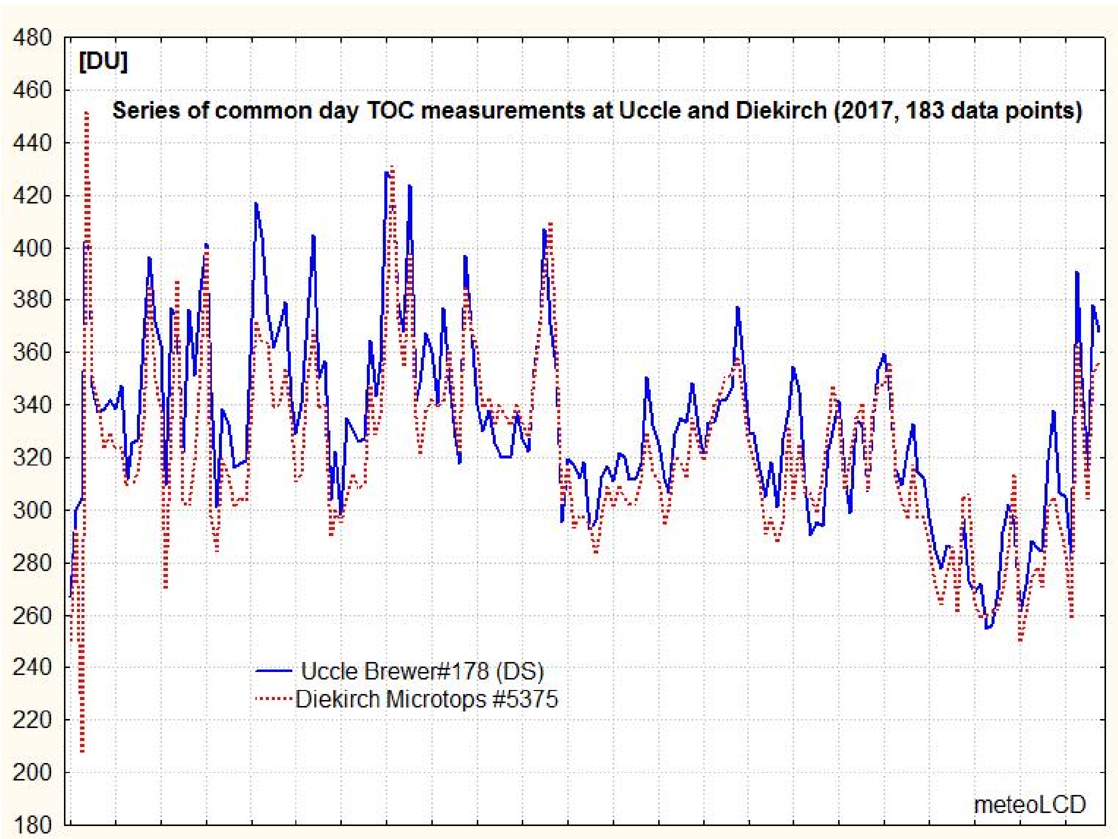

Fig.1. Uccle Brewer #178 and same day Diekirch TOC (DS only).

The plot (fig.1) shows the two data series (the x axis goes from January to December, but does not represent equidistant time intervals.

The Diekirch data are nearly always lower than those of Uccle; nevertheless the sudden TOC spikes are synchronous and well apparent in the plot.

The next XY plot gives the Uccle data (y variable) versus Diekirch (x variable). The linear regression forced through the origin suggests to apply a multiplier of **1.033** to the Microtops measurements to make them comparable to the Brewer readings. The coefficient of determination R^2 is practically 0.76, which is an acceptable value. The obvious outlier has not been corrected.

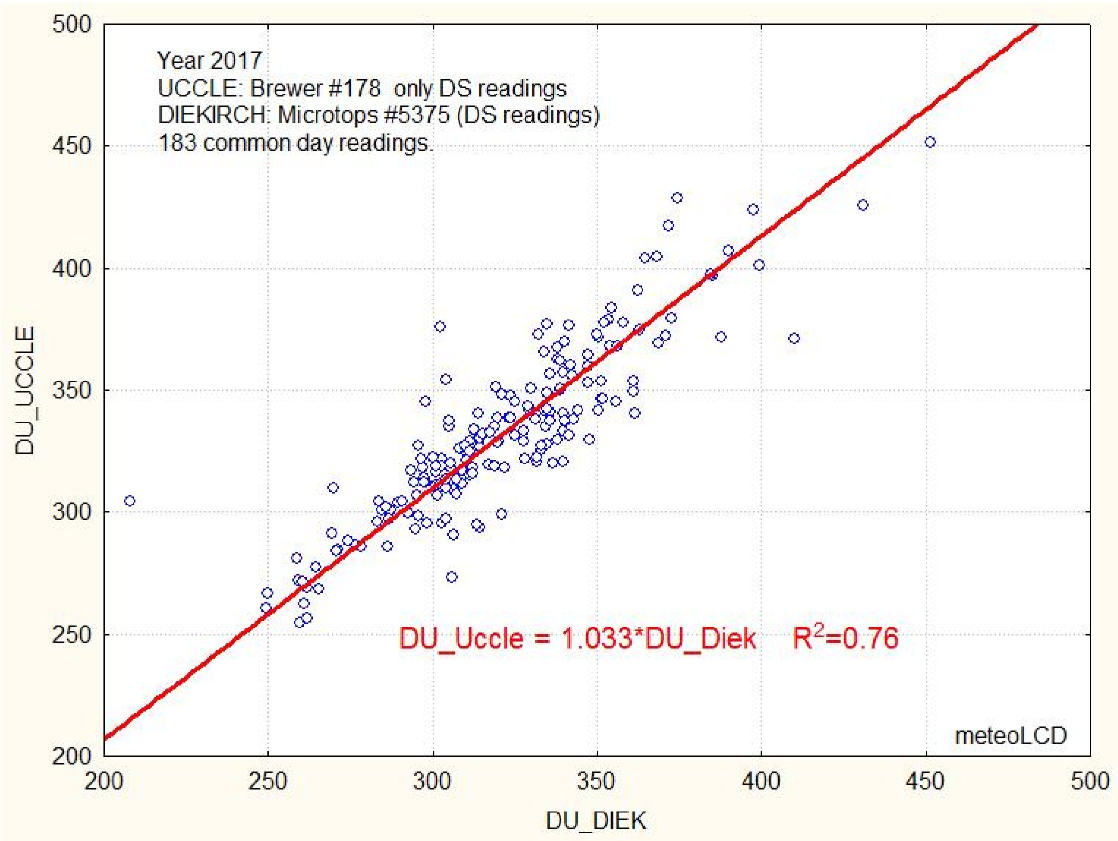

Fig.2. Uccle Brewer#178 versus same day Diekirch measurements

Clearly there is quite a lot of spread, and one should not ignore that the meteorological conditions between Diekirch and Uccle (distance ~170 km) are usually not identical.

The differences Delta = DU_Uccle – DU_Diek are more or less normally distributed, as shown by the following histogram:

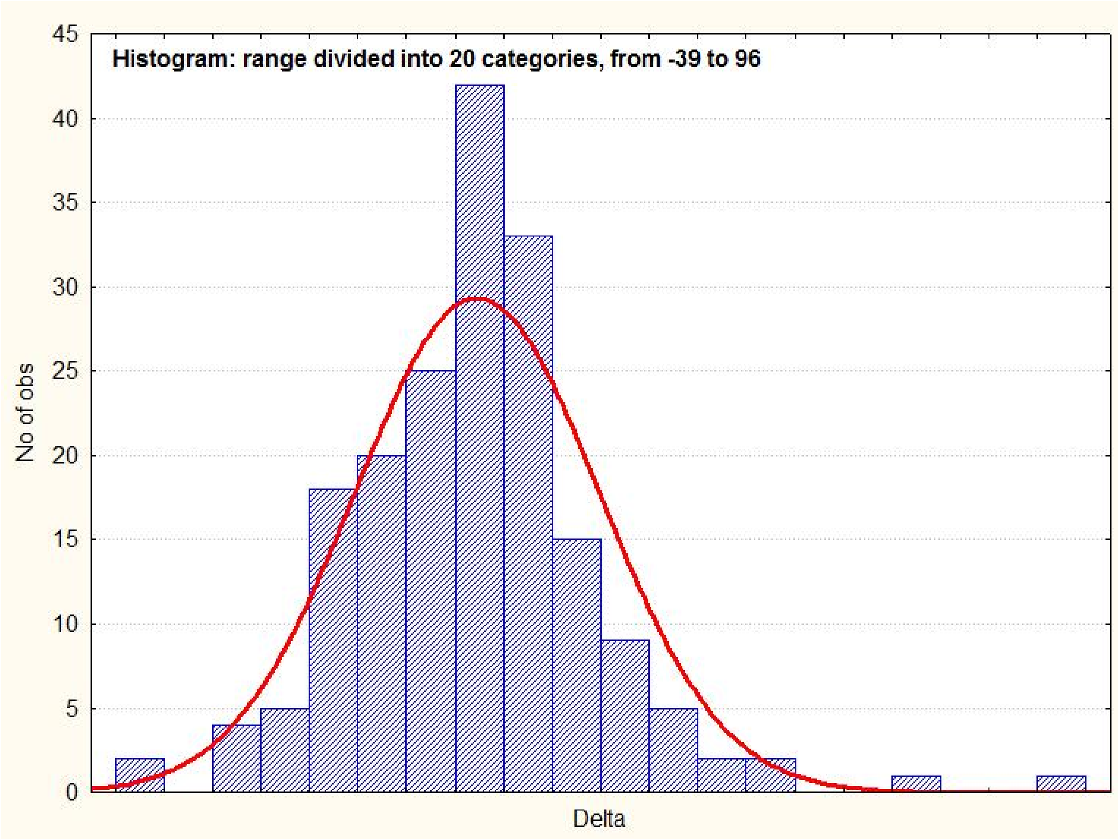

Fig.3. Distribution of Delta with fit to Gaussian normal curve. The mean of the differences = 11.2 (standard deviation = 17.0)

Let us restrict the common measurements to the subset where the sky condition at Diekirch was "blue sky"; the sky conditions at Uccle are not known and may be different. The next table shows the averages and standard deviations for this subset of 34 data points.

	average	**stdev**
UCCLE Brewer #178 DS	325.4	33.6
DIEKIRCH, blue sky only	312.2	29.7

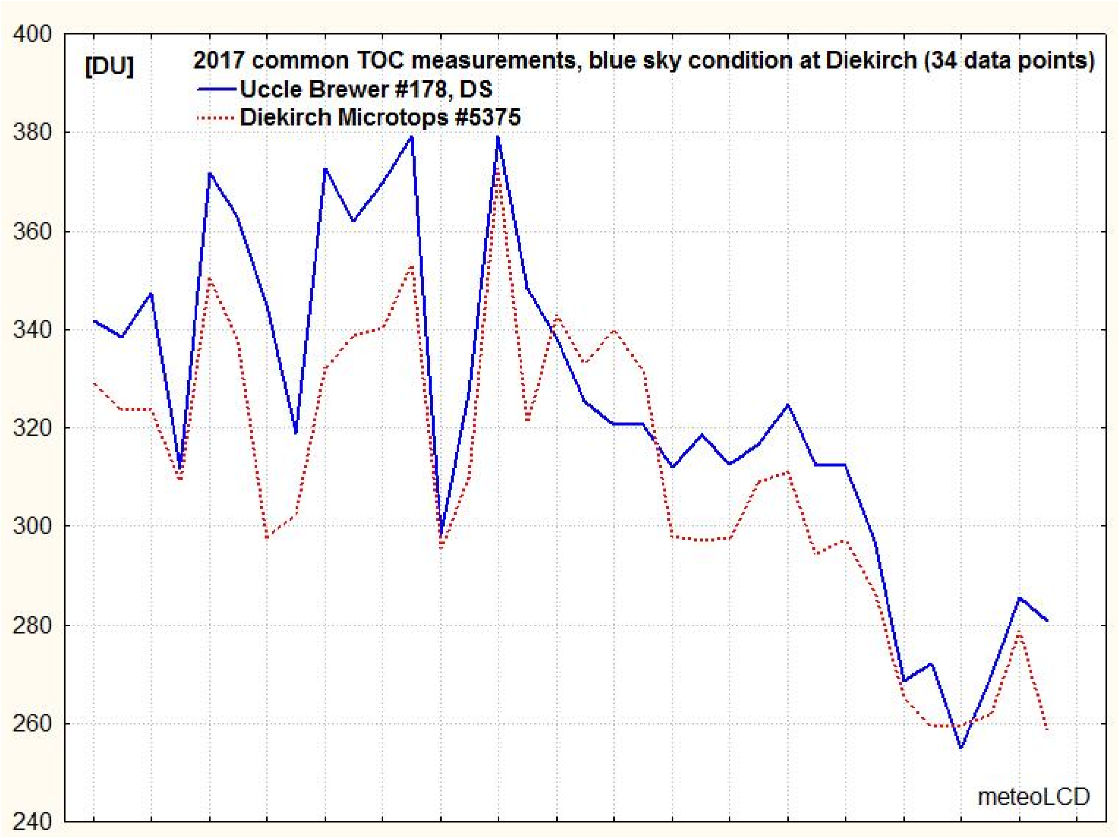

Fig.4. Uccle Brewer #178 DS and same day Diekirch TOC (blue sky only).

The main difference with respect to the full data set is that the calibration factor changes slightly from 1.033 to 1.043, and that R^2 increases from 0.76 to 0.83 (fig.5).

Again, one can not infer that blue sky conditions happen simultaneously between Uccle and Diekirch, so the main information from this subset is that Diekirch standard deviations are smaller for this blue sky subset (but counter-intuitively are more different from those at Uccle).

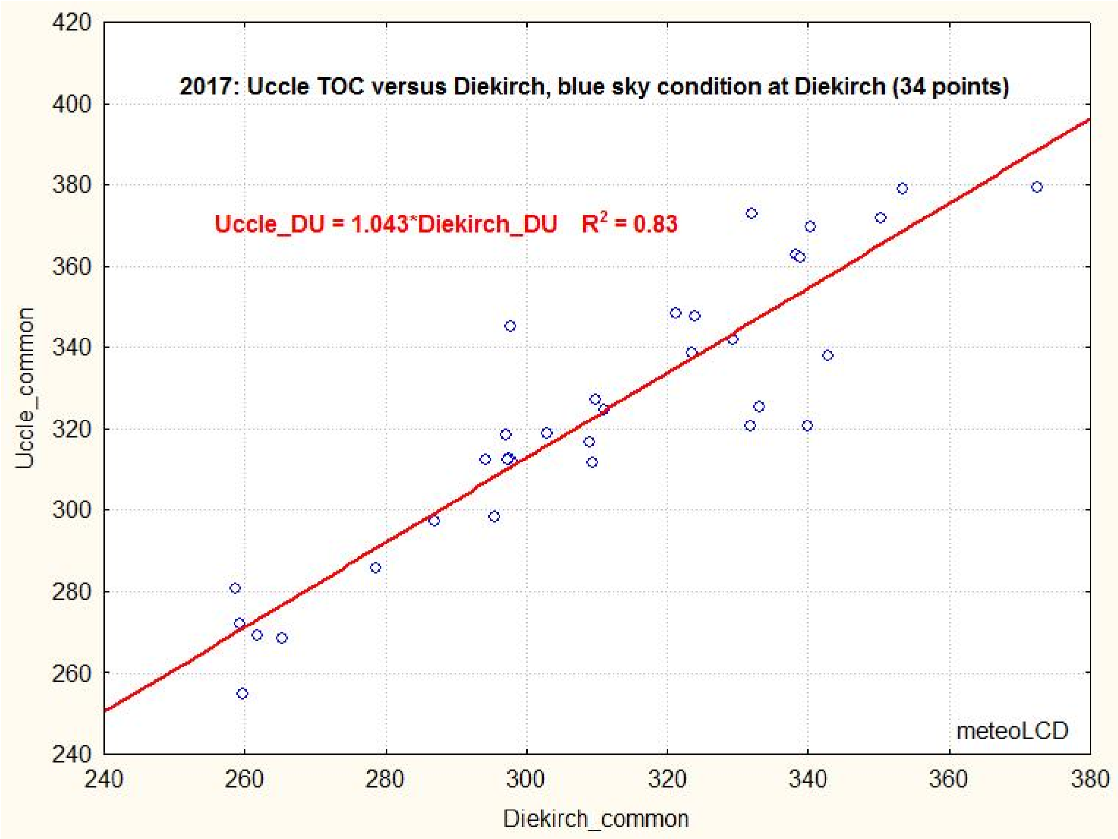

Fig.5. Uccle Brewer#178 versus same day Diekirch measurements, blue sky only

4. The channel problem

Several authors **[ref. 5, 6]** suggest to use exclusively the channel 1 readings of the Microtops instrument. Microtops relies on 3 wave-lengths to compute the TOC: 305, 312 and 320 nm. The usual measurement called O3(corr) is computed from the selective absorption of these wave-lengths. The instrument also shows signals computed from the 305/312 (display: O3(1/2) and 312/320 pair (display: O3(2/3). The display O3(corr) will be called here channel 0, that of O3(1/2) channel 1 readings.

In the following comparison, only same day measurements by the Uccle Brewer #178 and the Diekirch Microtops #5375 will be used (excluding homogenized Microtops #3012 readings). This gives a subset of 91 data points over the full year 2017. Fig 6 shows the time series of the Uccle and Diekirch channel 0 and channel 1 readings:

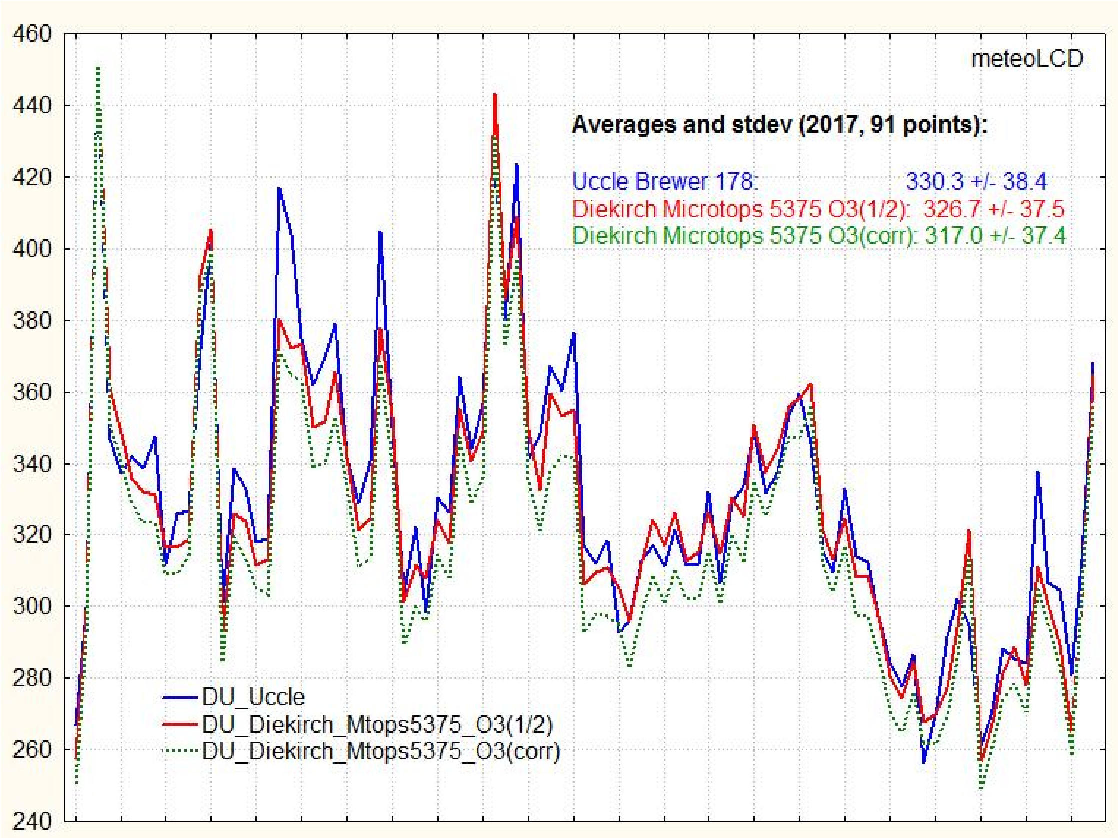

Fig.6. Uccle and Microtops #5375 channel 0 and channel 1 readings.

The channel 1 readings (red line) are visibly closer to the Uccle measurements (blue line) as are the yearly averages: 326.7 (= relative difference **1.09%**) versus 317.0 (= relative difference **4.03%)**

Fig. 7 displays the difference between the Uccle Brewer and the two channel readings more clearly. The channel 1 readings O3(1/2) in red are nearly all smaller in absolute value than the channel 0 readings in blue.

Fig. 8 shows the Uccle measurements versus these two channels, together with a linear fit forced through the origin whose slope is the calibration multiplier.

The usual channel 0 suggests a multiplier of **1.041**, whereas channel 1 one of **1.011**. R^2 for both linear fits is the same (0.92) and very high, noticeably greater than the $R^2 = 0.76$ for the homogenized much longer full series shown in fig.2.

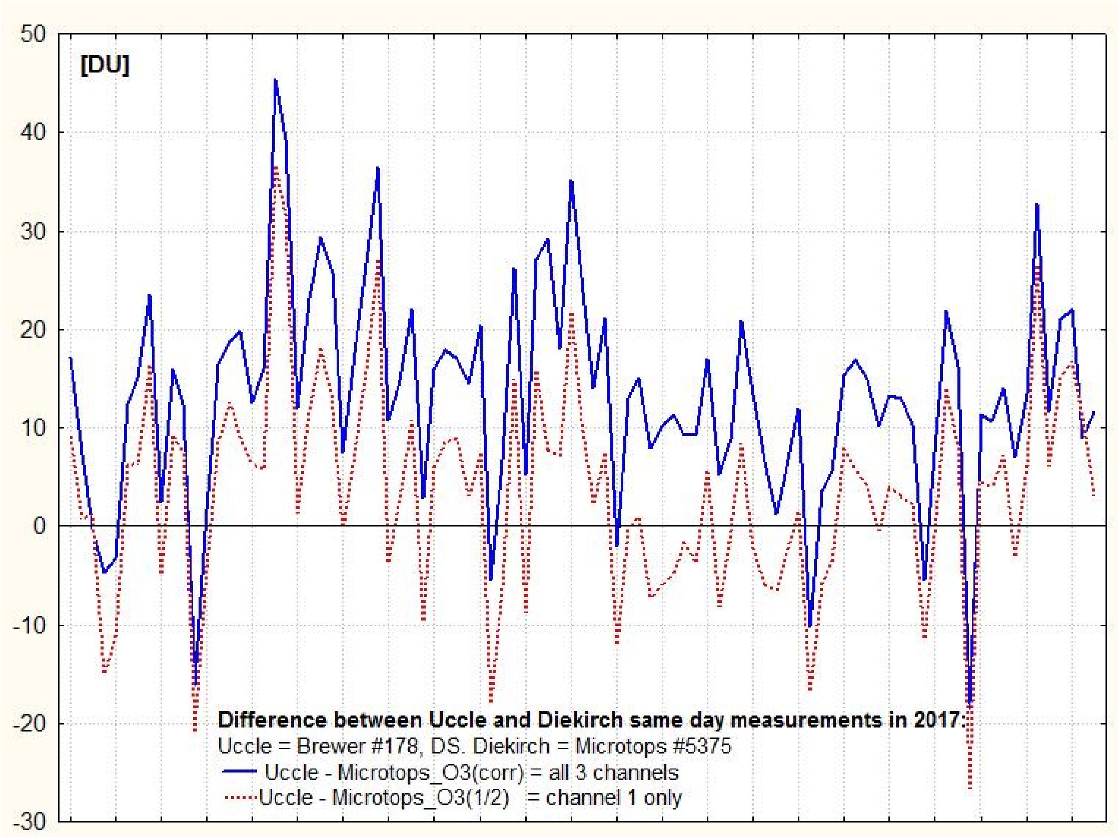

Fig.7. Difference of the two readings O3(corr) and O3(1/2) and the Uccle Brewer from January to December.

The maximum absolute difference is 45.4 (= 10.9%) for the usual series, and 36.6 (= 8.8%) for the channel 1, both at the same day (23 March 2017).

Several authors insist on the increasing error with higher **air mass**. Air mass is defined here as the secant of the solar zenithal angle: air mass = sec(SZA) = 1/cos(SZA).

For the Diekirch series used in this chapter, air mass varies from 3.54 in January, down to 1.12 in June and again up to 3.55 in December, approx. in a slightly asymmetric U shape. The Pearson correlation between air mass and the two delta-series is opposite, but not statistically significant: -0.19 for the Delta0 series (i.e. difference with channel 0), and +0.04 with the Delta1 series (difference with channel 1). These conflicting results do not allow to conclude for a general positive correlation between air mass and "error" measurement, even if the somewhat lower errors during mid-year when air mass is smaller would suggest .

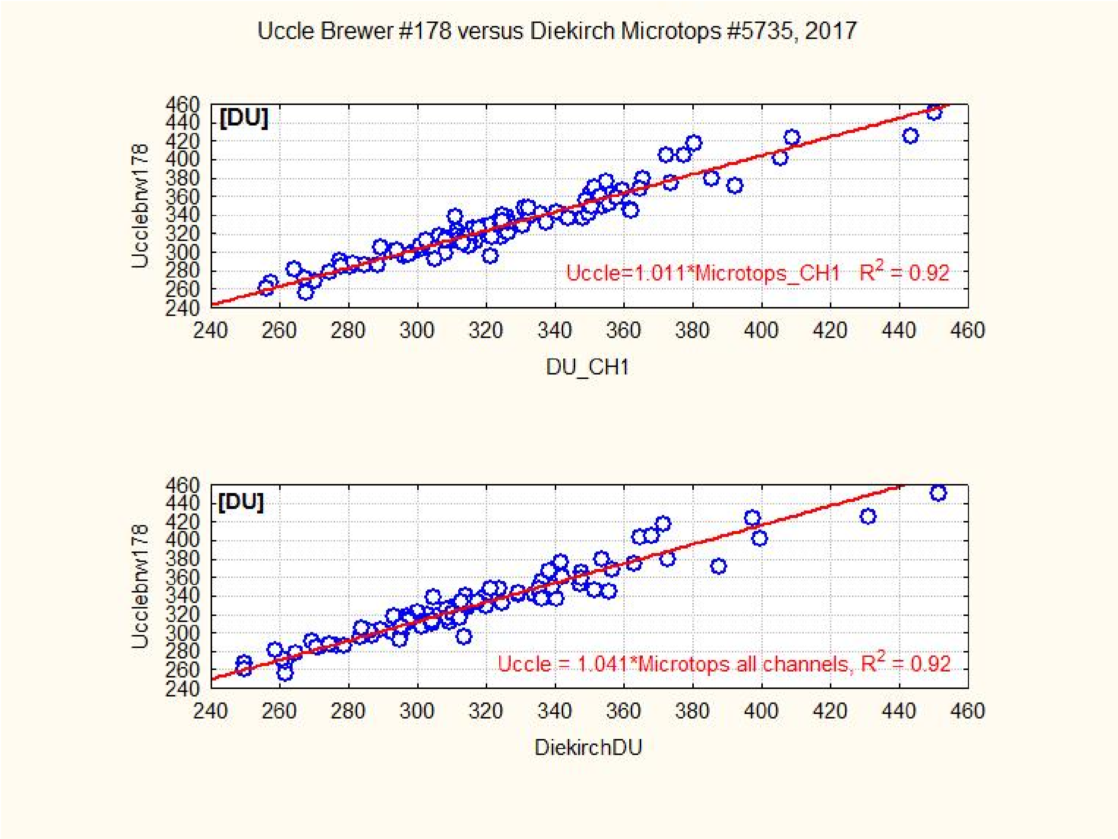

Fig. 8. Calibration factors for channel 0 and channel 1 of Microtops 5375.

5. Conclusion

The calibration factors for O3(corr), rounded to 3 decimals, found in the intercomparisons made during the last years are the following **[ref.3]**:

2011	1.060	Brewer 178
2012	1.029	Brewer 16
2014	1.044	Brewer 178
2015	1.033	Brewer 178
2016	1.034	Brewer 16 & 178
2017	**1.033**	**Brewer 178**

R^2 is always close to 0.8. These numbers show that the Microtops #5375 seems not to have changed much since at least 2012, and that its readings can be used with some confidence as a possible supplement to those of the much more expensive Brewer instrument (see for instance **[ref.4]**).

Using channel 1 (O3(1/2)) might give a smaller difference, but this choice ignores the causes why the developers of the Microtops instrument choose to compute TOC from the attenuations given by 3 different wavelengths i.e. correction for stray light and particle scattering.

7. References

1. http://www.woudc.org/data/explore.php
Uccle: choose Total Ozone, daily observations, station 053, year 2017; Diekirch: choose Total Ozone, daily observations, station 412, year 2017

2. Data archive of meteoLCD: http://meteo.lcd.lu/data/index.html

3. http://meteo.lcd.lu/data/dobson/2016/UCCLE/intercomparison_Uccle_Diekirch_2016.pdf (link)

4. D.H.Holdren, R.O.Olsen, F.J. Schmidlin: Comparison of Total Ozone Overburden from Handheld Photometers with the Wallops Island Dobson Spectrophotometer. GRL, vol.20, no.20, pages 3589-3862, Oct.15, 2001 (link)

5. J.L. Gomez-Amo et al.: Operational considerations to improve total ozone measurements with a Microtops II . Atmos. Meas. Tech., 5, 759-769, 2012 (link)

6. Z. Podrascanin et al.: A Comparison of Microtops II and OMI Satellite Ozone Measurements in Novi Sad from 2007 to 2015. Pure Appl. Geophys.,174 (2017), 4489-4499. (Springerlink, pay-walled)
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An Excel file with all relevant data can be found at http://meteo.lcd.lu/data/dobson/2017/UCCLE/uccle_woudc_Diekirch_2017.xls