The detection of ozone anomaly events and inhomogeneities in the ozonesonde time series of Uccle, Belgium, by comparison with the nearby station of De Bilt (Netherlands)

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1. Setting the stage

- The ozonesonde stations of Uccle (Brussels, 50°48'N, 4°21'E) and De Bilt (near Utrecht, 52°06N, 5°10E) are only **separated 175 km** from each other and hence offer a unique opportunity to assess the ozonesonde data quality of both stations.
- Although using different ozonesonde types (En-Sci vs. Science Pump resp.) and applying different correction strategies, **the Uccle and De Bilt ozonesonde time series are very identical** for the different parts of the atmosphere (boundary layer, free troposphere, stratosphere), see Figs. 1a to 1c.
- However, during a 2.5 year period (**mid 2007 – end 2009**), the **Uccle** station is **consistently measuring higher (free) tropospheric ozone** values then nearby De Bilt, but not in the boundary layer (see also Delcloo et al., 2011) or in the stratosphere!
- Logan et al. [2012] pointed similarly to anomalous high free tropospheric ozone values measured with the ozonesondes in Uccle, compared to other European ozonesonde stations and regulair aircraft (MOZAIC) O_3 measurements.

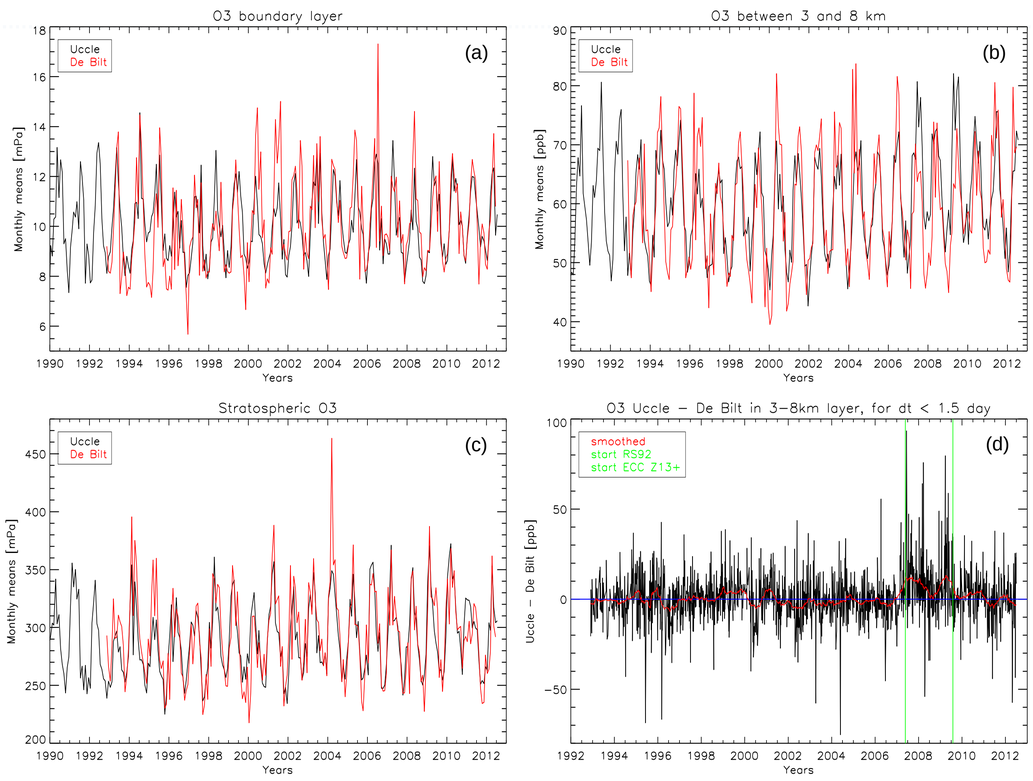

Fig. 1: Monthly mean comparison plots between integrated ozone amounts for the ozonesonde stations of Uccle (black) and De Bilt (red) for different parts in the atmosphere: (a) boundary layer (0-3 km), (b) free troposphere (3-8 km), (c) stratosphere (h > tropopause height). In (d), the deviations in integrated ozone amounts in the 3-8 km layer are shown, in black, for quasi-simultaneous (dt < 1.5 day) observations at Uccle and De Bilt. The red curve represents a smoothed version of these deviations.

- A direct comparison of the O_3 measurements of the MOZAIC mid-tropospheric and UTLS data above Brussels with the Uccle sondes, based on back trajectories, confirmed the discrepancies during the same period (J. Staufer, private communication).
- Clearly, there is an issue in the Uccle ozonesonde data from mid 2007 to end 2009. However, the only instrumental changes during this period are:
  i. the change of the Vaisala radiosounding equipment in the summer of 2007 (RS80 → RS92, interface change, sounding software change),
  ii. sounding software updates,
  iii. the yearly change of ozonesonde batches.

2. Instrumental causes?

Radiosounding equipment change

- At Uccle, the ozone profiles are now calculated from the raw data (electric currents), so that we are **independent of the sounding software**.
- This is necessary, because in some versions of the sounding software, e.g. bugs in the background current subtraction were present.
- The radiosonde change RS80 → RS90 has a small effect on ozone and temperature above 25 km (mainly due to the better RS92 pressure sensor, Steinbrecht et al., 2008), but also more directly influences the whole ozone profile due to the **differences** recorded **in the pump temperatures between the two different types of interfaces**, see Fig. 2 at the 700hPa level (but present at all pressure levels).
- To conclude, the **radiosonde equipment change in mid 2007 cannot be the only cause for the recorded high tropospheric ozone values at Uccle**.

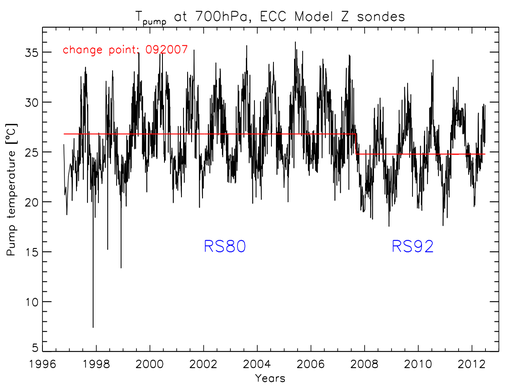

Fig. 2: Time series of pump temperatures at 700hPa for the ECC model Z sondes at Uccle. A statistically significant change point in the mean is found around September 2007, when the definite changeover from RS80 to RS92 was made.

Ozonesonde batch properties

(a)	MEAN	STDEV	n
overall	0.89	13.71	1685
good period	-0.37	12.32	1458
bad period	8.97	18.57	227
Znr < 10000	-1.68	11.73	115
Znr = 10xxx	9.40	18.80	98
Znr = 11xxx	6.00	17.33	103
Znr = 12xxx	8.35	15.79	79
Znr = 13xxx	0.06	9.97	49
Znr > 13000	-1.34	11.79	113
Znr > 14000	-2.42	12.98	64

(b)	GOOD PERIOD			BAD PERIOD		
	MEAN	STDEV	n	MEAN	STDEV	n
Znr < 10000	-1.68	11.80	107	-1.63	11.52	8
Znrs = 10xxx,11xxx,12xxx	2.61	10.47	62	9.35	18.72	218
Znr = 10xxx	3.71	7.53	8	9.91	19.43	90
Znr = 11xxx	2.58	11.87	20	6.83	18.36	83
Znr = 12xxx	2.37	10.45	34	12.87	17.65	45

Table 1: Statistical properties (mean, standard deviation, number) of the deviations in integrated ozone amounts in the 3-8 km layer for quasi-simultaneous observations at Uccle and De Bilt (see Fig. 1d), but now calculated for different batches of model Z ECC ozonesondes (Znr) and for different periods. The bad period is defined from March, 1, 2007 (start of use of Z10xxx) to August, 1, 2009 (start of use of Z13xxx or Z14xxx), the good period is then outside this period.

- From Table 1a, we are tempted to conclude that 3 different "bad" batches of model Z ozonesondes (with numbers Z10xxx, Z11xxx, Z12xxx) cause the anomalous behaviour in 2007-2009.
- However, Table 1b shows that these batches behave differently between mid 2007- end 2009 at one hand, and outside this period at the other hand, so that the **high tropospheric O_3 values are not related to the ozonesonde batch**.
- Some of our Z12xxx sondes were used in the most recent JOSIE intercomparison campaign and did not lead to any observed discrepancies in these vacuum chamber tests (H. Smit, private communication).

Ozonesonde properties

- As the deviations only occur in the free troposphere, where the absolute ozone amount is minimal, the background current of the ozone sensor is an obvious candidate to be responsible for the anomalous behaviour.
- However, from Fig 3a, it can be seen that the **background current is very constant and low** (± 0.02 μA) during the anomalous 2007-2009 period.
- On the other hand, the **ground calibration factors**, obtained at the laboratory before launch by applying ozone containing air (about 320 μg/m³ at room conditions) from a calibrated ozone source to the running sensor during 10 minutes, **are at the high end** from mid 2007 to end 2009. This means that at the time of the measurement, the ozonesondes are measuring too small ozone amounts.
- However, when imposing a value equal to unity for the calibration factors during this period, the comparison with the quasi-simultaneous De Bilt ozone profiles only improves slightly.

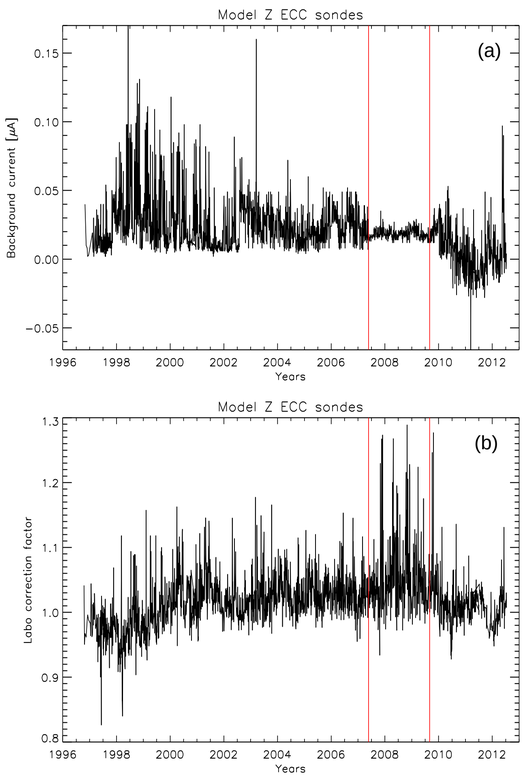

Fig. 3: Time series of the measured background currents (a) and ground calibration factors (b) for the ECC model Z sondes at Uccle. The red vertical lines denote the beginning and end of the period of anomalous high tropospheric ozone values in the Uccle soundings.

Ozonesonde descent data

- When we calculate the monthly means for the total amount of ozone in the 3-8 km layer from the sounding's **descent data**, a **better similarity with the De Bilt values** is obtained (see Fig 4.) throughout the mid 2007 – end 2009 period.
- Comparing the ascent and descent ozone profiles of some individual soundings (see e.g. Fig. 5), the higher tropospheric ozone values for the ascent data are obvious.
- Because the **descent data** are gathered at locations of about 100 km from Uccle (most of the time to the NE), they **might trace other free tropospheric layers** (more identical to those measured at De Bilt) than in the direct surroundings at Uccle, which is in an urban environment.

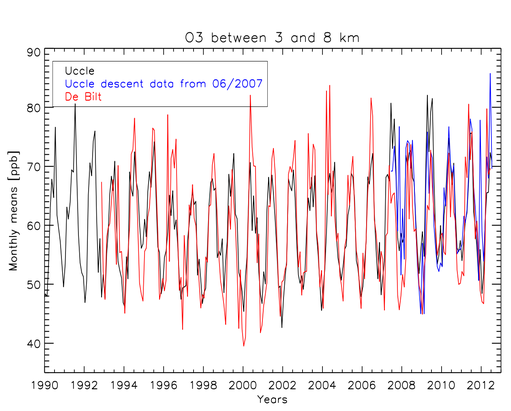

Fig. 4: Same as Fig 1b, but now also calculated from the Uccle ozonesonde descent data from June 2007 onwards (in blue) .

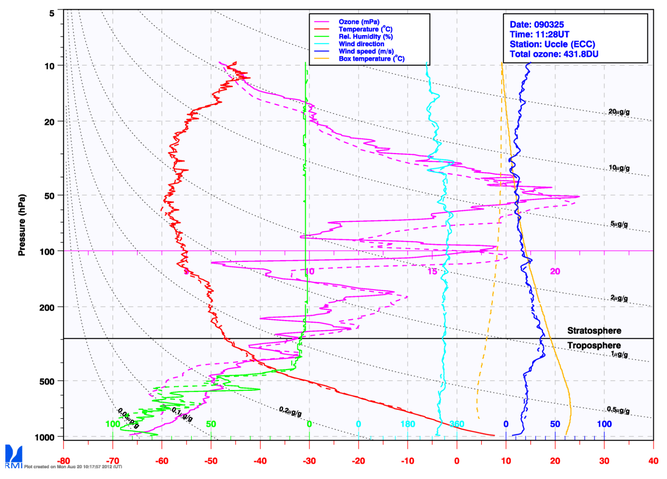

Fig. 5: Vertical profiles of all measured atmospheric variables for the sounding launched at 25/03/2009 .

3. Conclusions and Perspectives

- Until now, **we do not find any instrumental cause** of the observed high tropospheric ozone values in the period mid 2007 – end 2009 by the Uccle ozone soundings.
- There is a **small probability** that there might have been a **problem in the ozonesonde quality** in this period, but without decisive answer. In any case, the manufacturer is not aware of a problem in the production process during that time (W. Komhyr, private communication).
- As demonstrated by the analysis of the descent data, **we still cannot rule out any physical or environmental origin** of the discrepancies observed in the near surroundings of Uccle. Therefore, a 3D backward trajectories clusters and trends analysis similar as in Delcloo and De Backer [2008] could be undertaken for the free troposphere.
- Clearly, **the anomalous period lies behind us**, so that it will not affect any trend analysis based on the Uccle ozone sounding data.
- A more thorough comparison of the Uccle and De Bilt ozone soundings is being set up, focusing on the impact of the different correction strategies on the intermediate and resulting O_3 profiles!

References and Acknowledgements

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