Comparison of tropospheric ozone profiles at Brussels, measured with MOZAIC aircraft and ozonesondes

R. Van Malderen[1], N. Pateraki[2], H. De Backer[1], H. G. J. Smit[3], and V. Thouret[4,5]

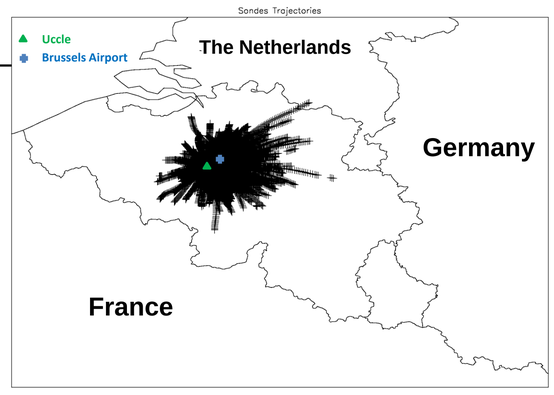
(1) Royal Meteorological Institute of Belgium, (2) University of Patras, Greece, (3) Forschungszentrum Jülich GmbH, Institut für Energie- und Klimaforschung, IEK-8 Troposphäre, Jülich, Germany, (4) Université Paul Sabatier de Toulouse, France, (5) CNRS - Laboratoire d'Aérologie UMR 5560, Toulouse, France

Mail to: Roeland.VanMalderen@meteo.be

1. Tropospheric ozone profile measurements at Brussels, Belgium

Ozonesondes

- ozonesonde launches **3 times a week** at Uccle (Brussels, 50°48'N, 4°21'E), around 11h30 UTC, since 1969 (since 1997: electrochemical concentration cell or ECC)
- ozonesondes are driven by the wind, we calculated their **trajectories** from the wind velocity and wind direction measurements.
- at Uccle, the relative uncertainty of tropospheric ozone measurements with ECC ozonesondes varies **between 5 and 6%** (Van Malderen et al., 2016)
- The in-flight response time of an ECC ozonesonde sensor is 20-30 s ➔ **vertical resolution of a few 100 m**



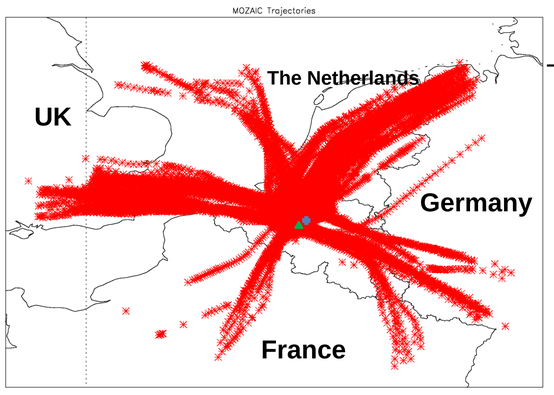


***Fig. 1**: Trajectories of the ozonesondes launched at Uccle (left) and the MOZAIC flights taking off and landing at Brussels Airport (right), both for the period 1997-2001.*

Mozaic

- = Measurement of Ozone and Water Vapour on Airbus in-service **Aircraft**
- in operation since August 1994
- measurements during take-off and landing **at Brussels Airport** in the period **1997-2001**, up to cruise alt. of 9-13 km
- the O_3 analyser is a dual beam UV absorption instrument with a detection limit of 2 ppbv and accuracy of **± 2%**
- The response time of the O_3 analyser is 4s ➔ (theoretical) **vertical resolution** of 30 m altitude ➔ in practical: **150 m**

a dataset of 594 simultaneous (= same day) tropospheric ozone profiles, with mean distances between 15 km (at ground) & almost 400 km (at cruise altitude/tropopause)

2. Examples

Good agreement

- sonde launch at 11h30, MOZAIC take-off at Brussels at **11h07**
- observations taken between Brussels and Paris (France, **280 km south** of Brussels)
- **low ozone** amounts (**winter**)

Bad agreement

- sonde launch at 11h29, MOZAIC landing at Brussels at **14h49**
- observations taken between Bremen (Germany, **380 km** to the **NE** of Brussels) and Brussels
- **higher ozone** amounts (**summer**)

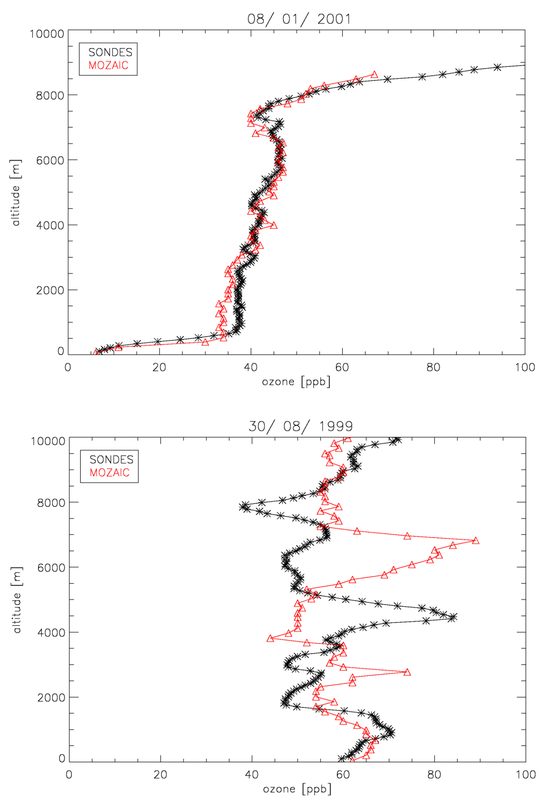


***Fig. 2**: Comparison of simultaneous ozone profiles measured by sondes and MOZAIC for 2 different days*

3. Motivation

What is the impact of different criteria (distance, time separation, altitude, ozone amount) on the agreement between ozonesonde and MOZAIC profiles?

And how to quantify this agreement?

4. 1D Statistics (~~altitude~~)

- We calculated **simple statistics**, like absolute/relative bias, RMS, scatter plot properties (R^2, slope), accumulative relative/absolute differences, etc. that average out/sum up the vertical levels.

Accumulative Relative Differences: $ARD = \frac{1}{n}\sum_{k=0}^{k=n}\frac{sondes[k]-MOZAIC[k]}{MOZAIC[k]}$

Mean Differences: $meandif = \sum sondes[k] - MOZAIC[k]$

Root Mean Square: $RMS = \frac{1}{n}\sum[(sondes - MOZAIC)^2]$

where n is the total elements of the different altitude levels per day and k is every altitude level in that day

- We looked at the relationship of those statistics with mean distance between the observations, the time separation and the mean ozone amount in the measurements.

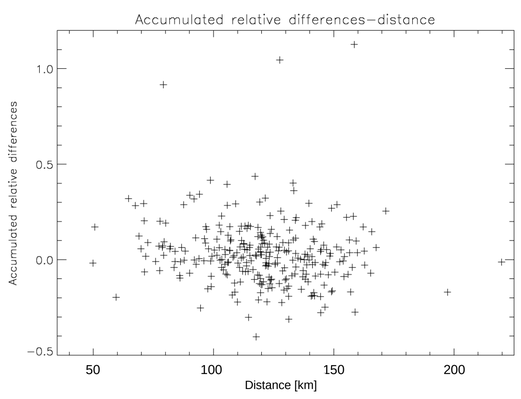


***Fig. 3**: The accumulated relative differences, calculated for the 594 simultaneous ozonesonde-MOZAIC profiles, as a function of the mean distance between the two measurements.*

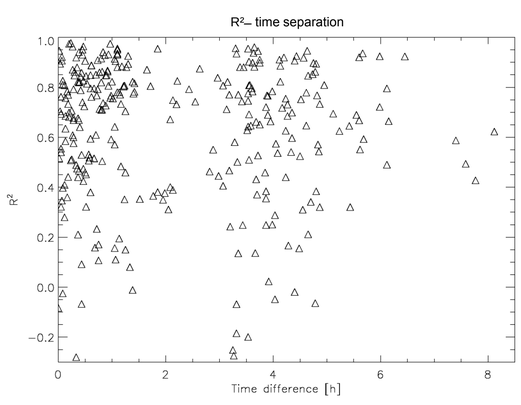


***Fig. 4**: Linear correlation coefficients between the ozonesonde and MOZAIC ozone profiles, as a function of the difference in observation time between the two measurements.*

➢ We **did not find any impact** of the mean distance, time separation and mean ozone amounts on those 1D statistics of the profile agreement!

5. 2D Statistics (vertical differences)

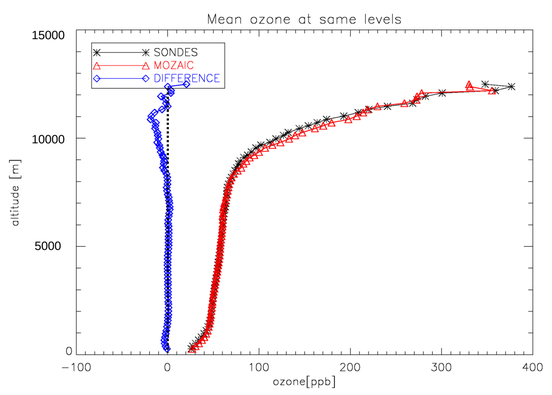


***Fig. 5**: Average O_3 profiles calculated at the same altitude levels for the simultaneous ozonesonde and MOZAIC measurements at Brussels. The difference shown here is SONDE – MOZAIC.*

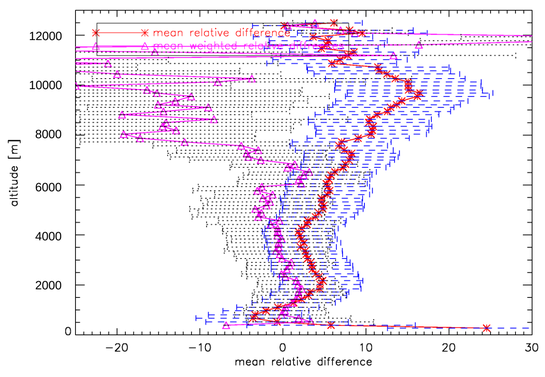


***Fig. 6**: The mean of the relative vertical differences between the individual sonde and MOZAIC ozone profiles, defined as MEAN[sonde – MOZAIC/ MOZAIC)*100] (in **red**), with 1σ error bars. In **magenta**: a (normalized) weighted mean of the relative differences, with weights equal to the inverse distances between the individual MOZAIC and ozonesonde measurements.*

Average O_3 profiles

- The average O_3 profile measured by the **MOZAIC** instrument has **higher ozone** concentrations at almost all altitudes than the ozonesonde average profile.
- The **absolute differences** in the average profiles are **largest** in the **upper troposphere**.

Vertical relative differences

- The **relative differences** between the ozonesonde and MOZAIC ozone profiles vary between **-5 and +15%.**
- Roughly, the relative differences **increase with increasing altitude**, to about 10000 m. Also the 1σ uncertainties increase with altitude. Both are probably related with the increasing distances between the observations with altitude.
- Indeed, if we put the **inverse distances** as **weights** in the relative differences calculation, the mean relative differences are **reduced** (→ 0) **up to about 7 km**.
- Reducing our sample of simultaneous observations by selecting only those measurements **within 2h** time delay and/or **within 100 km** distance, had **no large effect** on the mean vertical relative differences.

6. Conclusions

- This is a **first quick analysis** of the impact of different criteria (distance, time separation, altitude, ozone amount) on the agreement between ozonesonde and MOZAIC profiles at Brussels. The influence of the weather conditions was not studied.
- Using a **1D statistic** to quantify the profile agreement, we did **not** find any **impact**.
- The **time separation and distance** between the measurements might be still **too small** to detect an impact for especially the upper tropospheric layers, since the typical horizontal ozone correlation length is about 500 km in the troposphere (Liu et al., 2013) and timescales of autocorrelation vary between about 1.5 and 3.5 days in the troposphere (Liu et al., 2009).
- The **relative differences** found here vary between **-5 to 15%**, and between -5 to 10% for the layers below 8 km. These numbers are **substantially higher** than found by Tanimoto et al. (2015) for the same dataset (between -1 and 2%), but there were differences in the calculation.
- For the vertical relative differences (**2D statistic**), we can see that the **distance** between the 2 different measurements has an impact. At first sight, the time separation does not seem to have.
- Using **trajectory calculation** to match the European MOZAIC measurements with the Uccle ozonesondes in the period 1997-2004, Staufer et al. (2014) found relative **differences within ±5%** for the UTLS. This is a very promising approach.

Acknowledgements and References

Solar-Terrestrial Centre of Excellence

Both R. Van Malderen and the ozone sounding program in Uccle are funded by the Solar-Terrestrial Centre of Excellence (STCE), a research collaboration established by the Belgian Federal Government through the action plan for reinforcement of the federal scientific institutes.

References:

- Liu, G., Tarasick, D. W., Fioletov, V. E., Sioris, C. E., and Rochon, Y. J.: Ozone correlation lengths and measurement uncertainties from analysis of historical ozonesonde data in North America and Europe, J. Geophys. Res.-Atmos., 114, D04112, doi:10.1029/2008JD010576, 2009.
- Liu, G., Liu, J., Tarasick, D. W., Fioletov, V. E., Jin, J. J., Moeini, O., Liu, X., Sioris, C. E., and Osman, M.: A global tropospheric ozone climatology from trajectory-mapped ozone soundings, Atmos. Chem. Phys., 13, 10659–10675, doi:10.5194/acp-13-10659-2013, 2013.
- Staufer, J., Staehelin, J., Stübi, R., Peter, T., Tummon, F., and Thouret, V.: Trajectory matching of ozonesondes and MOZAIC measurements in the UTLS – Part 2: Application to the global ozonesonde network, Atmos. Meas. Tech., 7, 241-266, doi:10.5194/amt-7-241-2014, 2014.
- Tanimoto H., R. M. Zbinden, V. Thouret, P. Nédélec, Consistency of tropospheric ozone observations made by different platforms and techniques in the global datasets, Tellus B 2015, 67, 27073, http://dx.doi.org/10.3402/tellusb.v67.27073
- Van Malderen, R., Allaart, M. A. F., De Backer, H., Smit, H. G. J., and De Muer, D.: On instrumental errors and related correction strategies of ozonesondes: possible effect on calculated ozone trends for the nearby sites Uccle and De Bilt, Atmos. Meas. Tech., 9, 3793-3816, doi:10.5194/amt-9-3793-2016, 2016