Comparison of ozone concentrations in the tropopause region as measured by ozone sondes and commercial airliners (MOZAIC)

Johannes Staufer¹, Johannes Staehelin¹, Thomas Peter¹, Fiona Tummon¹, Rene Stübi², Herman Smit³ and Valerie Thouret⁴

¹ IAC, ETHZ, Switzerland; ² Aerological Station Payemé, MeteoSwiss, Switzerland; ³ Research Centre Jülich GMBH, Germany; ⁴ CNRS - Laboratoire d’Aérologie Observatoire Midi-Pyrénées, Toulouse, France

Introduction
Ozone is a strong greenhouse gas with maximal radiative forcing at the tropopause. Few measurements exist to determine long-term changes in ozone at tropopause: (i) measurements from ozone sondes (the longest series started in the late 1960s) and (ii) data from regular aircraft. Recently, data quality of earlier (European) tropospheric Brewer Mast measurements was put into question (Logan et al. 2012; Schnadt Poberaj et al., 2009). In this study we systematically compare ozone measurements from ozone sondes with those of MOZAIC (Measurement of Ozone and Water Vapor by Airbus in Service Aircraft Program), available since 1994 (from up to 5 Airbus aircraft, see Fig. 1). We also include data from the NOXAR (Nitrogen Oxides and Ozone along Air Routes) project, with measurements from May 1995 - May 1996, and August-November 1997. We use trajectory analysis for air parcel matching to carry out sonde-aircraft comparison of long-term ozone trends in the upper-troposphere/lower-stratosphere (UTLS).

Method used (see Fig. 2)
Trajectory analysis: LAGRANTO using 6 hourly wind fields from the ERA-Interim reanalysis (1º; 61 hybrid vertical levels), including displaced trajectories (±0.5º in latitude and longitude); duration of trajectories: 144h. Trajectories were excluded if vertical movement exceeds 450 hPa (within 6 days) (6% of trajectories). Weighting of matches: Matches are weighted higher when the time between matches of ozone sondes and aircraft is shorter. Trajectories started from ozone sondes at UTLS: ± 125 hPa around local thermal tropopause (WMO definition). The matching criteria were carefully optimized resulting in: r: 50-100 km; ∆θ: 0.25-1 K. For further details see Staufer et al., 2013.

Results with ozone sondes measurements from Payemé (Switzerland)
Fig. 4 indicates that the agreement between ozone sondes and MOZAIC measurements in the UTLS is very good after 1998. The results also suggest that the change from Brewer Mast (BM) to EEC sensor, which occurred in 2002, did not lead to any break in the time series. The agreement for BM sondes is better without normalization (i.e. without applying the Correction Factor). Prior to 1998, for BM sondes normalization (CF) is better without correction factor. After 1998, the agreement is much worse. During this period (1994-1997) the agreement seems to be better with NOXAR ozonesonde measurements, suggesting that a slight shift in the MOZAIC calibration may have contributed to this inconsistency.

Conclusions
Our trajectory-based method is suitable for identification of the same air masses (also in the UTLS region). We analysed 14,859 balloon ascents and 129,340 independent trajectory matches with MOZAIC; self matches indicate that in the case of a large sample size, statistical uncertainty is on the order of ±2%.

Acknowledgements
J. Staufer’s work was funded by a GAW-CH grant 547 from MeteoSwiss. The authors thank the European Commission, Atmos. Meas. Tech. 6, 3393-3406, doi:10.5194/amt-6-3393-2013 (2013).

References

Figures
Figure 1: MOZAIC flight routes and ozone sondes used in the study.
Figure 2: a,c: Sonde profile – Payemé, 18 April 1995. b: Air parcel matching using trajectory analysis (LAGRANTO) (gray), MOZAIC flight tracks (blue).
Figure 3: Results of «self-matching» (see text). a,c: as a function of altitude; b,d: scaled by tropopause pressure. c,d: excluding first 24h. Numbers inside Figures: number of matches.
Figure 4: Comparison of ozone sonde measurements of Payemé (Switzerland) with MOZAIC. From left to right: with normalization (CF) and comparison with NOXAR.
Figure 5: Comparison of ozone sonde and MOZAIC measurements. Bold lines: time series of O₃ with (red) and without (blue) correction factors. Numbers at the bottom: number of sondes used for monthly mean differences. Shaded areas: standard error (68% confidence). Overlapping areas are displayed in violet (Staufer et al., 2014).