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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Ozone trend profiles in the stratosphere: combining ground-based data over Central Europe to consider uncertainties" *by* Leonie Bernet et al.

Anonymous Referee #1

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This is the first review of the paper titled "Ozone trend profiles in the stratosphere: combining ground-based data over Central Europe to consider uncertainties" by Leonie Bernet et al. The paper describes effect of the sampling and instrumental artifacts on derived trends. Paper focuses on the Microwave time series from Bern, Switzerland and investigates step changes in the record due to modification to the instrument in 2009. The impact of step changes in the record on the trend and uncertainties is tested with the synthetic data record. The temporal sampling and time period selected for trend analyses are also tested by authors to determine uncertainties in the derived stratospheric ozone trends. Authors compare other ozone records from several local and regional NDACC stations with Bern Microwave ozone record and find pos-

itive trends in the upper stratosphere, consistent between ground-based instruments and satellite records (Aura MLS record). Derived trends in the upper stratosphere are similar to previously published analysis (i.e. WMO Ozone assessment, 2014; Steinbrecht et al, 2017; Petropavlovskikh et al , 2018). Larger differences in derived trends are found in the middle and lower stratosphere. Authors conclude that their proposed anomaly tool will help to improve trend estimates for ground-based stations.

This is a very well written paper. Analyses of ground-based data records for Europe are done with great detail to instrumental artifacts, sampling biases and trend model assessment to assess impact of anomalies on the trends and uncertainties. Comparisons with satellite overpass data help to identify differences in the considered ground-based records and suggest steps to improve homogenization of the GB records. The detailed comments are provided below.

p. 1 abstract, line 9 . "We compare our improved GROMOS trend estimates with results DERIVED from other ground-based station OZONE RECORDS () in Central Europe." Add " derived and "ozone records". You might also indicate that these are NDACC records. p. 1 line 20 "Antarctic ozone started " -> "stratosphere ozone over Antarctica started " p. 2 line1 "Outside of the polar vortex, however, increasing ozone is more difficult to detect" – why? I always thought that due to large dynamical variability in the vortex position over Antarctic (or Arctic) it is more difficult to detect a trend as compared to less variability observed over other locations, especially in the upper stratosphere. Are you discussing low stratosphere trends here? p. 2 line 28 "All of these studies" – I does not feel right to use "these studies" at the beginning of the paragraph. May be you can change it to the "As discussed above, several published studies found similar in magnitude trends in the corrected satellite records . . ." p. 3 line 23, "altitude information of the ozone molecules" -> "information about vertical distribution of ozone molecules"? p. 4 line 2, "subtracting mean bias" – was it annual mean or monthly mean bias? p. 4, line 16 (or line 18) "3-days moving window" (or 30-days moving window) – should it be "3-days moving average" ("30-days moving average")? p, 4, line 27 At the end of the

paragraph, please provide a brief description of main differences in the processing of these two station records (i.e different spectroscopic datasets, averaging time period of the measurements, different error estimates, vertical resolution, smoothing, external information used in retrieval such as temperature profiles), some information that will let reader know if there are differences between the two retrieval methods such that they would create differences in the processed data originating from the same measurement. p. 5, line 1 “influence” -> interference? p. 5 line 2 “averaged measurement error” – is it derived for one night of averaging or for the entire month? Is it standard deviation of averaged profiles or error propagation analyses? p. 5 line 5 “host” sounds like lidar is temporary located in France. Would “operated” be a better way to describe it? p. 5 line 18. Instead of “those” use Dobson . Also, at the end sentence add “for normalization”. p. 6 line 11 . “in the time period FROM Jan, 1995. . .” - add “from” p. 6, line 11.”The different GB instruments. . .” – add GB (ground-based). May be you can abbreviate ground based earlier in the text. p. 6, line 27. “We therefore interpolate all lidar and ozonesonde profiles . . .” Interpolation from altitude to pressure level requires knowledge of temperature . Temperature is typically available for ozonesondes from radiosonde measurement. But it is not always the case for the lidar (unless lidar also measures temperature). What temperature profiles is used to interpolate OHP and MOH lidar data from altitude to pressure level? Is it taken from reanalyses? ECMWF? p. 7, lines 26-27. “. . . was corrected by its mean relative difference to GROMOS” . Was the mean calculated over the entire period of the GROMOS/GB instrument time series? p. 7 line 29 “the respective month was identified as anomaly” Was anomaly identified in GROMOS data or in any of the compared instrumental records? p. 9 line 7 “the degrees of freedom of the trend fit” – can you please discuss this here – how you derive it. p. 9 line 21. “added to the corresponding part of covariance matrix” – can you provide more details? May be an example can be provided at this point to demonstrate the process? p. 9 line 33-34. “value of the corresponding dataset at each altitude” – did you already remove bias earlier in the process? And thus, this will be the same value for all datasets, yes? p. 11, line 15-17 “this can be explained by the low number of

OHP profiles. . .” – Why, if the two measurements sense the same ozone, there should be no large bias. Otherwise, what you are implying is that some large biases average out if one has a large number of coincident profiles. . .. I wonder if you should use coincident lidar measurements from OHP to evaluate if large biases between GROMOS and OHP sonds are indeed result of the spatial variability in ozone. Perhaps, you can plot PDF of subset of data (full or coincident) for both instruments to evaluate how they sample ozone variability over the same time-period. It will indicate if one instrument is not capable of obtaining low/high ozone, perhaps due to AK smoothing. . . p. 11, line 30-33. You indicated that positive anomalies in the middle and lower stratosphere in 2000 were confirmed through anomaly detection method. You also found positive bias in the upper stratosphere in 2000, although it was not confirmed by comparisons with other instruments (MLS and SOMORA). Would the middle and lower stratosphere biases suggests the instrumental anomaly in upper stratosphere in GROMOS as it seems to affect the entire profile? p. 12, line 21-22, why amplitude A is negative? Are coefficients in Eq (3) derived from observations? Why 0.1 ppm was selected for monthly uncertainty? Earlier you indicated that trend is 0.1 ppm per decade. What confidence level of the trend detection is expected in these time series? Also, please indicate the length of the artificial time series (yes, it can be deduced from Figure 5, but should be written in the first paragraph of section 4.1). p. 12, line 29. “($\sim$ 0.4 ppm) “ - should it be 0.35 or 0.36 based on a=7 ppm in Eq (3) and the rate of change in time series is very small (0.1/120 x 12 (month per year) x 20 (years) = 0.2 ppm) p. 13, line 4, you provide uncertainty now as 5 %? What is it in ppm? Is it still 0.35 ppm? Then 0.1 ppm uncertainty for series A was 1.4 %? It is a bit confusing to switch between % and ppm. Also, it is not clear what “corresponding months” means. Do you mean that uncertainties for JJA months in 2014, 2017 and 2017 were increased to 5 % while the rest of month in the entire time series has 0.1 ppm uncertainty? p. 13, line 12-13 you state that trend estimate improves “ the higher the uncertainties are chosen”. Did you test model with larger than 5 % uncertainties? Why 5 % was selected in the first place? p. 14 line 11-15, “GROMOS trend peak is observed as slightly

lower altitude". " We observe a slight shift in the peak" of AK. – what do you mean? Can you explain the shift and when it occurred in time series? Or you mean that the maximum weight in AK profile for layer 35-40 km is higher by 2-4 km than the assumed peak of the AK at the middle of that layer? Then, you also suggest that the full width of the AK is between 20 and 25 km. If it is centered at $\sim$ 36.5 km, then you have to assume that the averaged (AK weighted) trend is estimated between 26.5 – 46.5 km altitude range. Can you please provide AK example for the layer? If you apply the AK smoothing to the lidar profile and calculate trends. Would these trends be different from trends derived by integrating ozone profile between 35 and 40 km? p. 14, line 16-17. The harmonization of time series before/after 2009 (application of bias and seasonal cycle correction) does not necessarily means that the entire bias in the retrieved profiles will be removed. Say, the change in the instrument optical characterization would produce a shift in the vertical distribution of the AK weights, the upgraded instrument would start sampling at higher/lower altitudes. And since ozone trends can be different at higher/lower altitudes, it would affect the homogenized time series, even after you remove the step-change bias. Can you show the AK before and after 2009 (for approximately the same atmospheric conditions)? p. 15, line 1. Can the temporal sampling test be done on the artificial time series (change in sampling from 1hour to 3 minutes)? p. 15, line 15-16. It is confusing to show "ozonesonde" results at altitude above 30 km. May be you should stop test at 30 km. p. 16, line 17 – is it 45 km or 42 km? p. 16, line 22 "derive" – this sentence seems to have some missing text.... p. 16, line 30 – change "our" to "derived" or "estimated". Also "discrepant results" means "differences in derived trends"? Figures 6 b – add uncertainty bars to the results. .You can also add circle slightly shifted horizontally to show where they fall. 7 and 8 – please consider to change either green or blue colors – they are too close to be easily distinguished in the plot. Also, please consider to change uncertainty envelops from solid color to shaded or not even filled envelops – it is hard to distinguish between different instruments. 10. – the same comment as above – selection of distinct colors and reduction in envelopes. May be the plot can be separate in two plots to reduce overlapping information – one

for MOH and one for OHP.

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