Merged SAGE II / MIPAS / OMPS Ozone Data Record

Alexandra Laeng[1], Thomas von Clarmann[1], Gabriele Stiller[1], Natalia Kramarova[2], Kaley A. Walker[4], Joseph Zawodny[3], and Johannes Plieninger[1]

[1]Institut für Meteorologie und Klimaforschung, Karlsruhe Institute of Technology, Germany, alexandra.laeng@kit.edu
[2]Science Systems and Applications, Inc., Lanham, Maryland, USA
[3]NASA Langley Research Center, Hampton, USA
[4]University of Toronto, Canada

Correspondence to: A. Laeng
(alexandra.laeng@kit.edu)

1 Summary

The deseasonalized ozone anomalies from SAGE II, MIPAS and OMPS datasets are merged into one long record, using ACE-FTS instrument as transfer standard. The data are provided in 10° latitude bins, going from 60°N to 60°S for the period from October 1984 to March 2017.

The main differences to the merged SAGE II / Ozone_CCI / OMPS-Saskatoon dataset by Viktoria Sofieva are:
- the OMPS data are from the NASA processor
- the MIPAS 2002-2004 date are taken into the record
- ACE-FTS data are used as transfer standard.

The merging on overlapping periods is performed via weighted means, with weights inversely proportional to standard errors of the means (SEM) of corresponding monthly means. The dataset is provided along with uncertainty estimates.

2 Data description

The description of the parent datasets and transfer standard dataset are provided in the Table 1.

3 Merging approach

3.1 Motivation for using a transfer standard

To merge the different datasets, we use ACE-FTS time series as transfer standard; this is, before merging timeseries of parent instruments into one data set, we debias them by minimizing (on overlap with ACE) root mean square (RMS) of SEM^2-weighted differences of timeseries with ACE. This procedure allows to deal with following issues.

Vertical resolution discrepancies. The two measurement periods of MIPAS instrument should be treated as independent missions because of differences in the processing schemes and different vertical resolutions coming from different tangent altitude patterns. The vertical resolution of the 2002 period (in the following: HR) is lower than that of the 2005-2012 period (in the following: RR). This means that the ozone maximum is smeared out, i.e. the peak is lower and the flanks are higher. The clean way to handle the problem would be to use the averging kernels. This is a textbook illustration of a general problem of the merging: merging without adjustment of vertical resolution seems to be a sub-optimal approach.

Sampling issues. Both MIPAS and OMPS are dense samplers, with pole-to-pole coverage, providing more than 1000 profiles/day. SAGE II measured only two profiles per orbit, about 800 profiles per month, with some tropical and/or midlatitudes not sampled in the summer and winter months. Post-2000 SAGE II measured only one occultation per orbit.

Short overlap or no overlap. SAGE II / MIPAS HR overlap is of 3 years, SAGE II / MIPAS RR overlap is of 8 months, MIPAS / OMPS overlap : first 3 months of OMPS, which are not reliable, hence no overlap.

Hence there is a need for an independent measurement that did not change its characteristics over time, against which we could compare the parent datasets in order to derive absolute adjustments for non-atmospheric influences: a standard transfer. First, its use partially smoothes uneven sampling. Second, this allows to remove the bias between parent datasets which have no overlap period. Finally, this procedure at first order also removes altitude resolution issues. This is, because artefacts in the data due to a smoothing con-

Instrument	Processor	Time period	Vertical Resolution	Comment
SAGE II	NASA v7.0, original files	Oct 1984 - Aug 2005	1 km	
MIPAS HR	KIT IMK/IAA, V7H_O3_40	Jul 2002 - Mar 2004	3 km (at 20 km) - 6 km (at 50 km)	driftless
MIPAS RR	KIT IMK/IAA, V7R_O3_240	Jan 2005 - Apr 2012	2.4 km (at 20 km) - 3.5 km (at 50 km)	driftless
OMPS	NASA v2	Feb 2012 - Mar 2017	1.8-2 km	first three months of the mission are not used
ACE-FTS	V3.5/3.5, original files	Feb 2004 - Dec 2016	3.5-4 km	

Table 1. Datasets used in the merging

straint act in a systematic way, and the smoothing causes altitude depending biases. Since the use of a transfer standard is apt to remove biases between data sets, it will also remove those biases which result from different altitude resolutions or different content of prior information. The application of the averaging kernel is thus no longer needed in the averaging process.

We choose ACE-FTS as standard transfer instrument. Advantages and shortcomings of this choice are discussed in the Table 2.

3.2 Merging procedure

1. Calculate timeseries from all instruments. SAGE II: no sunset/sunrise bias removed, MIPAS : no day/night correction, because the final dataset is composed of anomalies and not of the time series themselves.

2. Calculate altitude- and latitude-dependent offset a^i with respect to ACE-FTS by minimizing (on overlap with ACE) RMS of SEM^2-weighted differences of timeseries with ACE:

$$\sum \left(\frac{M^i_{instr} - M^i_{ACE-FTS} + a^i}{(SEM^i_{instr})^2 + (SEM^i_{ACE-FTS})^2} \right)^2 \rightarrow min$$

3. Shift the parent instrument timeseries by the offset estimated above.

4. Calculate shifted seasonal cycles from parent instruments.

5. Calculate anomalies of parent datasets by removing shifted seasonal cycle of corresponding instrument from shifted timeseries of this instrument.

6. On overlaps (SAGE/MIPAS HR and SAGE/MIPAS RR), the merging of anomalies is performed with weights inversely proportional to SEM^2:

$$A^i_{merged} = \frac{1}{\frac{1}{(SEM^i_{instr1})^2} + \frac{1}{(SEM^i_{instr2})^2}} \times \left(\frac{1}{(SEM^i_{instr1})^2} A^i_{instr1} + \frac{1}{(SEM^i_{instr2})^2} A^i_{instr2} \right)$$

7. Uncertainty estimates of merged anomalies are SEM's of corresponding timeseries in case of unique instrument, and weighted combination of corresponding SEM's on overlaps (square root of the variance of the weighted mean).

An example of obtained timeseries before shiftng are presented in the Figure 1. An example of obtained anomalies (from shifted timesereis and shifted seasonal cycle) is presented in the Figure 2, as well as the merged anomaly (black line).

4 Ozone trends

The merged SAGE/MIPAS/OMPS timeseries have been analysed by fitting the following regression function to the data:

$$O_3(t) = PWLT(t,t_0) + a_1 QBO_1(t) + a_2 QBO_2(t) + b F_{10.7}(t) + c ENSO(t) + \sum_{n=1}^{2} \left(d_n \sin \frac{2\pi t}{l_n} + e_n \cos \frac{2\pi t}{l_n} \right)$$

where t is time,

$PWLT(t,t_0)$ is a piecewise linear function, composed of 2 linear slices, with joint point in January 1997 (turnaround point).

$QBO_i(t)$ are quasi-biennial oscillation (QBO) terms, i.e., equatorial winds at 30 and 50 hPa
http://www.geo.fu-berlin.de/met/ag/strat/produkte/qbo/
$F_{10.7}(t)$ is the monthly average solar 10.7 cm radio flux
ftp://ftp.ngdc.noaa.gov/STP/space-weather/
$ENSO(t)$ is the 2-month lagged ENSO MEI index
https://www.esrl.noaa.gov/psd/enso/mei/table.html

The sum of 2 sin and 2 cos functions of the periods length l_n =12 and 6 months, respectively, represent the residual seasonal and the semi-annual cycle, which might have survived the deseasonalizing procedure, e.g. by alaising with the QBO or other quasi-periodic variation.

Values provided under “merged ozone anomaly uncertainty” were taken as uncertainties for the regression. Results with consideration of autocorrelation are presented at the Figure 3.

Pros	Cons
Due to reduced latitudinal coverage can not be used itself for global trend studies => new information for trends	Poor coverage in tropics
Stable within 2% / dec (in plus, part of the drift can come from sampling, so assume ACE stable is not a bad idea)	Overlap with MIPAS HR period is just 2 months (Feb-March 2004)
Errors are growing slowly with time	
Diff. ACE- MIPAS is constant over time	
Lat/lon distribution of errors is reasonnable	
In good agreement with all four parent datasets	

Table 2. Pros and cons of ACE-FTS as standard transfer dataset.

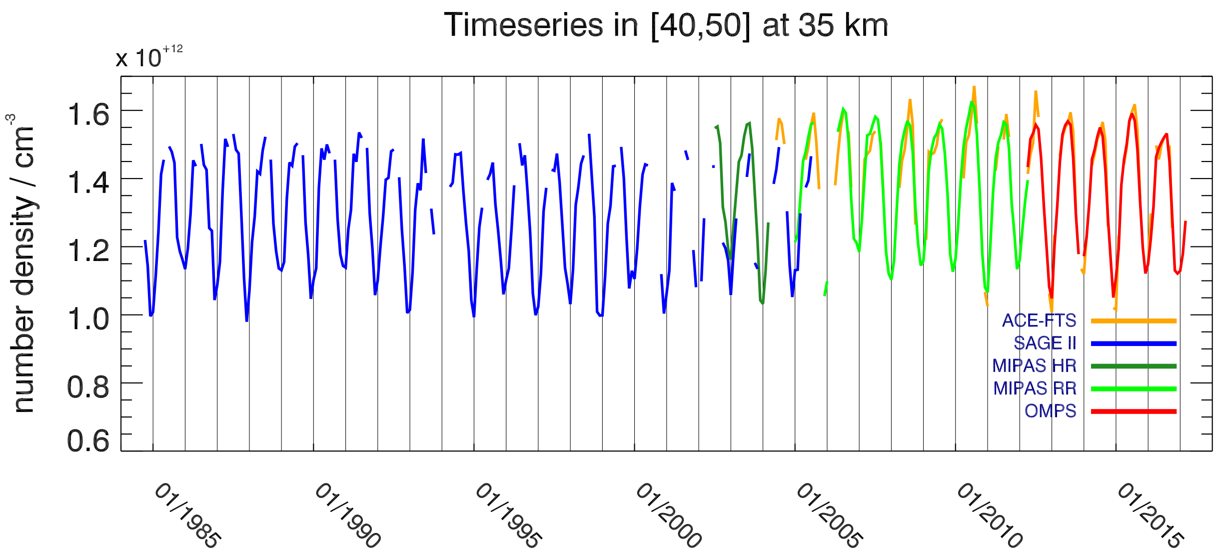

Figure 1. Timeseries of parent instruments and transfer standard instrument in 40°-50°N at 35 km.

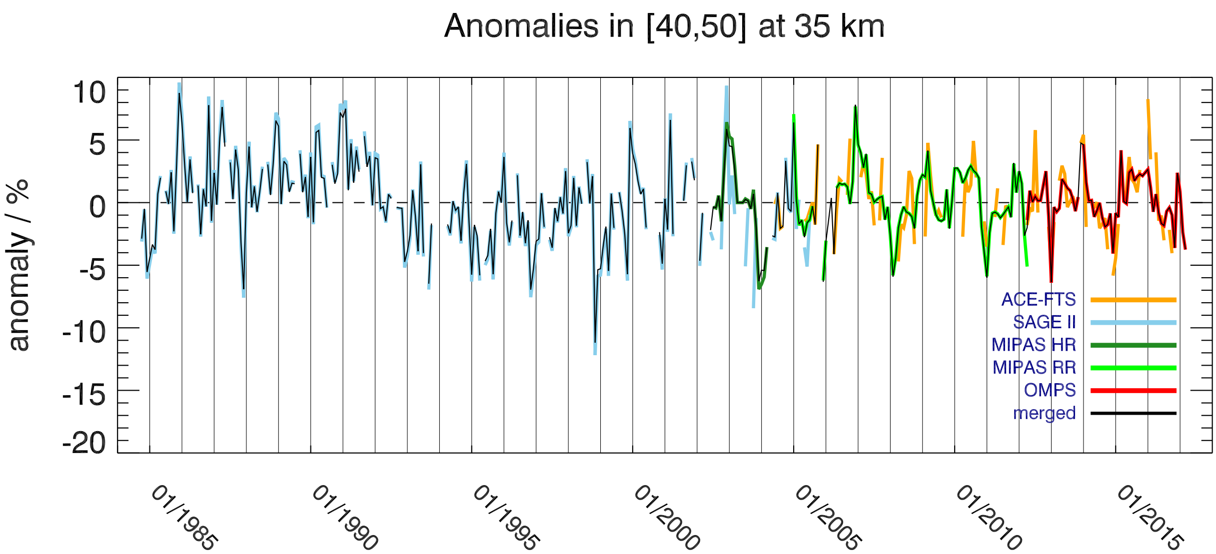

Figure 2. Anomalies of parent datasets, teansfer standard instrument datasets, and merged anomalies in 40°-50°N at 35 km.

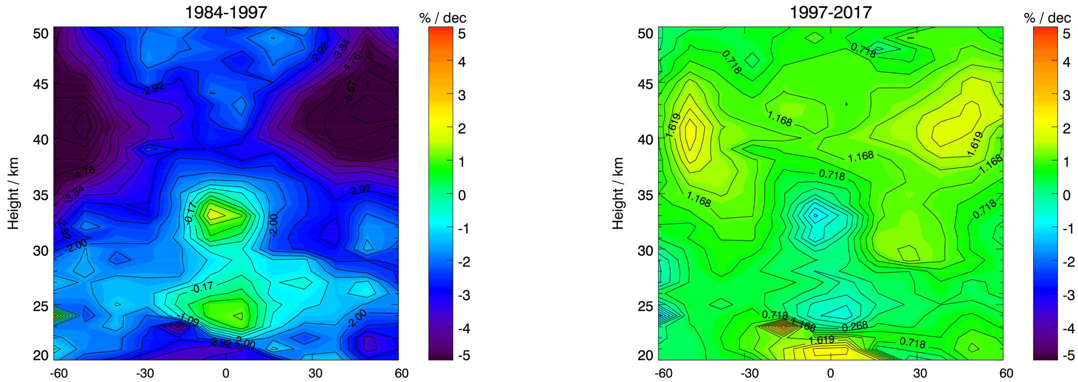

Figure 3. Ozone trend in % per decade as function of latitude and height for 1984–1997 (left) and 1997–2017 (right).

Parameter	Unit	Size
time	days since 1984-01-01	$N_{date} \times 1$
latitude_centers	degrees north	$N_{lat} \times 1$
altitude	km	$N_{alt} \times 1$
merged_ozone_anomaly	%	$N_{date} \times N_{alt} \times N_{lat}$
merged_ozone_anomaly_uncertainty	%	$N_{date} \times N_{alt} \times N_{lat}$

Table 3. Fields of NetCDF file.

5 File format

The merged SAGE II / MIPAS / OMPS NASA data product is available at LOTUS ftp server in NetCDF-4 format. The main fields are described in the Table 3.