Comments from Referee #2

This manuscript shows the results of combining 2 measurement profiles which cover different altitude ranges into a single profile, and then comparing the results to MLS. The primary interesting result is how the lower stratospheric RS data influences the SOMORA retrievals at higher altitudes, but this effect gets very little attention.

Author's answer to Referee #2

The main point of the publication is the description of a method to merge profiles measured by two different measurements techniques each of them presenting different performances and different vertical scales and ranges. Special attention is also paid to the characterization of the merged profile. It is mentioned that the lower stratospheric RS data influence the SOMORA retrievals at higher altitudes, this influence is shown on figures 6(a) and a tentative explanation is given on lines 2-5 p 3411.
The proposed explanation is qualitative and the authors propose to extend it in the revised manuscript.

Author's changes in manuscript

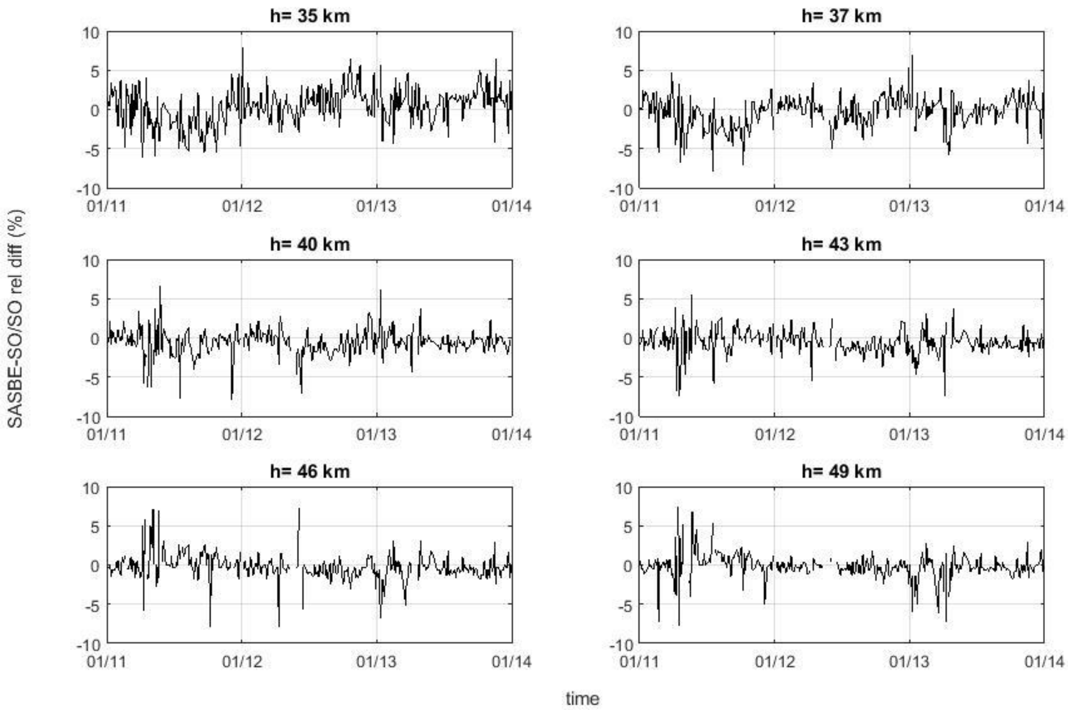
line 5 p 3411:
"This improvement is related to the fact that smaller a priori errors below 25 km are modifying the cost corresponding to the state vector and therefore influencing the retrieval well beyond the RS altitude range. As stable retrieval, the SOMORA retrieval is not drastically influenced by the a priori. However, in the case of the SASBE retrieval, the a priori errors are smaller below 25 km, the weight given to the a priori in the retrieval is then higher and the convergence point of the OEM retrieval has a high influence on the retrieval of the ozone profile. This is influencing the resulting profile over the RS altitude range as shown by the averaging kernels spread.
Moreover, the AVK of the SASBE retrieval and of the SOMORA retrieval above 25 km are similar but with a slightly smaller FWHM for the SASBE retrieval indicating a slightly better vertical resolution. The slight differences between the SOMORA and the SASBE ozone profiles above 25 km and the convolution of the MLS measurements with the AVK of the SOMORA or with the AVK of the SASBE could explain the differences observed in the comparisons with MLS."

Comments from Referee #2

The authors say that they have produced 3 profiles a week for the period 2011 to 2013, yet the only time series shown (Figure 5) is for May and June of an (I think) unidentified year. A 2-year timeseries of the differences between SOMORA and SASBE RS at a range of altitudes throughout the stratosphere should not be difficult to produce and would make this a much more interesting paper.

Author's answer to Referee #2

The interest of the publication is the description of the method producing a dataset of ozone profiles from ground up to 65 km. Figure 5 was intended to show part of the timeseries (2 months out of 3 years) in time but on the whole vertical range, in nbar scale, in order to illustrate the continuity in space and time and the conservation of the high vertical resolution introduced by the radiosonde in the SASBE RS data.. The statistical view of the dataset is given by figure 6. As below 25 km, the SASBE RS ozone profiles is the RS ozone profile, a timeseries of the difference between SOMORA and SASBE RS profiles between 0 and 30 km would be part of a study of the difference between SOMORA and RS which has been published in (Calisesi, 2003b) as mentioned in line 20 p 3405. This was not intended to be treated in this publication.
The figure below shows the 3-year timeseries of the difference between the SOMORA and the SASBE RS profiles above 25 km:



The authors found this picture of the temporal variation of the difference beeing advantageously replaced by a picture of the mean of the difference (Figure 6a) for purposes of the SASBE characterization. Figure 6a gives an idea of the amount of this difference when showing both SOMORA and SASBE RS mean difference to MLS.
The authors propose not to change figure 5, but will add an explanation on what is intended to show with this figure.

<u>Author's changes in manuscript</u>

Line 23 p 3409:
"(shown in nbar for 2 monthes of 2011 in Fig. 5)"

Line 26 p 3409:
"Figure 5 show then only partially the SASBE dataset in time (2 months) but the plotting of the profiles on the whole vertical range available allows to enhance the detailed structure of the lower part of the SASBE. A statistical view of the dataset is given in Figure 6."

<u>Comments from Referee #2</u>

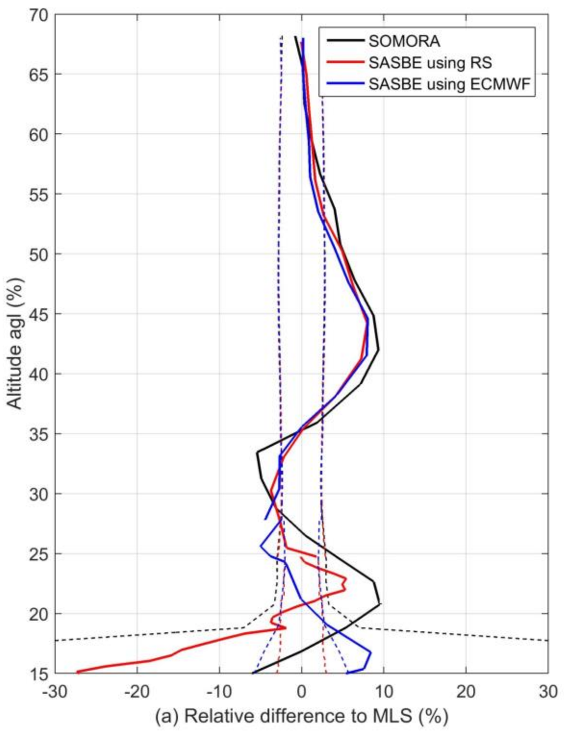
The primary interesting result in this paper is in Figure 6. The differences between the SASBE RS and SOMORA profiles at altitudes as high as 55km require some additional discussion. Given that the standard deviation between these profiles and the MLS profiles has not improved, and the difference is only ~2%, I would hesitate to categorize this as an "improvement", since neither SOMORA nor MLS have demonstrated an absolute accuracy to this level.

<u>Author's answer to Referee #2</u>

The plotted standard deviation is the statistical standard deviation calculated on the 3 year timeseries of the differences between the AVK smoothed MLS ozone profiles and the SOMORA respectively SASBE ozone profiles. The standard deviation of the mean difference is calculated by dividing the statistical standard deviation by the square root of the sample number. The value is then reduced to 5 % and the observed difference can be considered as significative.
The authors propose to modify figure 6 in that sense.

Author's changes in manuscript

Figure 6:
Change of the statistical standard deviation of the differences to the standard deviation of the mean difference.



Comments from Referee #2

If the standard SOMORA a priori in the troposphere and lower stratosphere (i.e. altitudes where SOMORA is insensitive) is set to the average of the RS data does this difference go away?

Author's answer to Referee #2

In the case of the use of an average of the RS data as the a priori profile, the standard deviation of this dataset has to be considered for the covariance matrix of the a priori. The weight on the a priori in that case would be totally different from the weight used when merging one particular MWR profiles with its corresponding RS ozone profile. The covariance matrix of the a priori will be in that case more similar to the covariance matrix used for the SOMORA retrieval when a standard a priori is used. In both cases (average of RS and standard a priori), the a priori should not have a decisive influence on the retrieved profile. Therefore, the difference to MLS will probably be similar in both cases.
The key is not the a priori itself but the weight given to it in the retrieval and the stability that this is bringing to the retrieval.

Comments from Referee #2

Or is this difference caused primarily by a bias between SOMORA and the RS at altitudes where SOMORA measurements are influencing the retrievals?

Author's answer to Referee #2

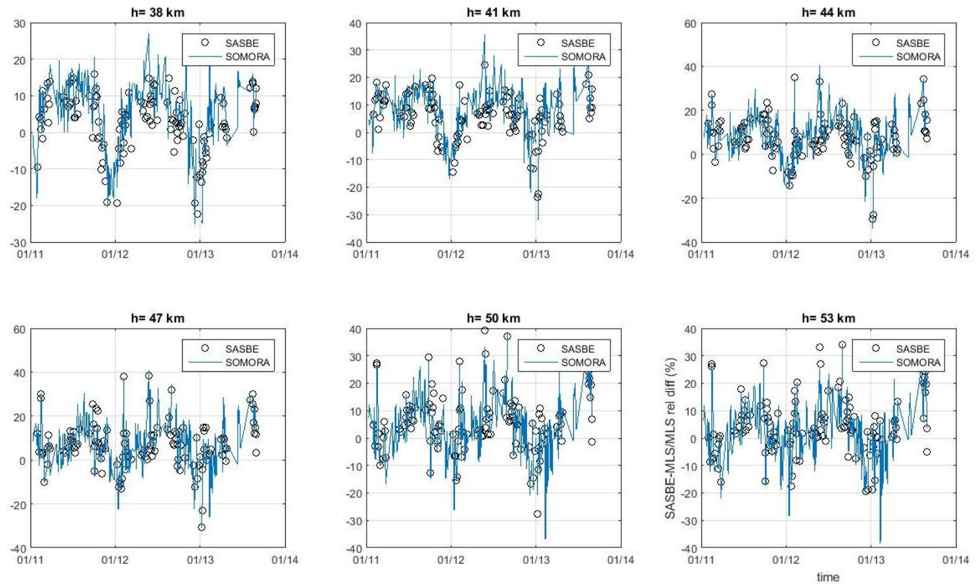
The bias between RS and SOMORA at 50 km is impossible to check because the vertical range of RS measurement over Payerne is 0-30 km.

Comments from Referee #2

Is there a seasonal cycle?
Is it consistent from year-to-year?
Much of this could be answered with a timeseries plot.

Author's answer to Referee #2

Below you can find plots of the 3 years timeseries of the difference between convoluted MLS and SOMORA ozone profiles in blue and convoluted MLS and SASBE ozone profiles in black. Both differences are showing a seasonal cycle and seems consistent from year-to-year.



SASBE RS is closer to MLS especially in summer, the difference of the SOMORA and SASBE RS to MLS is small for the rest of the year. Note that the sampling is very poor when using seasonal partition of the data and probably questions a reasonable detection of the seasonal differences.
Discussing the details of a seasonal variation, real or not, of the difference to MLS is not part of the description of the merging method but could be part of a future study. That's why the authors propose not to include this timeseries in the revised manuscript. The stability of the SASBE retrieval is characterized by its small mean difference to MLS.

Comments from Referee #2

Page 3404 – "The off-diagonal elements are parameterized with an exponentially decaying correlation function using a correlation length of 3 km." This seems not unreasonable, but is there any particular reason for this choice?

Author's answer to Referee #2

The correlation length has been chosen to be half of the best vertical resolution.

Author's changes in manuscript

Line 27 p 3404:
"The off-diagonal elements are parameterized with an exponentially decaying correlation function using a correlation length of 3 km chosen to be half of the best vertical resolution ."

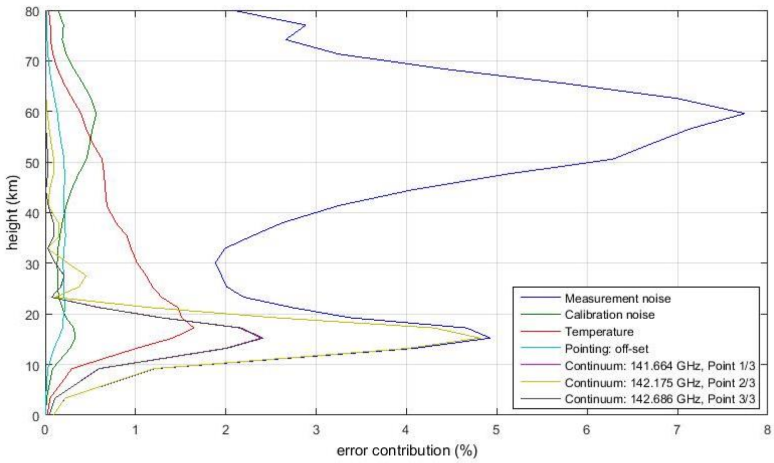
Comments from Referee #2

Page 3405 – The authors claim that the "observation error is to the greatest extent due to the thermal noise in the spectral data". Possibly this is the largest source purely random error, but there needs to be some discussion of the many other important sources of errors in 110 GHz O3 measurements – e.g. uncertainties in the tropospheric optical depth, baseline uncertainties, and uncertainties in the pointing.

Author's answer to Referee #2

SOMORA is measuring the O3 line at 142 GHz (line 15 p 3403)

Characterisation of the SOMORA microwave radiometer measurement has been performed and published in Rindlisbacher, 1999 and Calisesi 2003a and 2003b. The authors will add a reference to these work in the revised manuscript but, as the sources of uncertainties are the same for all retrievals, do not want to detail it here. However, you will find below a plot summarizing the different error contributions to the total error: calibration noise, temperature profile, pointing offset and tropospheric optical depth (continuum). The incertainties in the pointing are clearly negligible when compared to the other sources of errors, like the tropospheric optical depth and the baseline uncertainties. The main source of uncertainty is the thermal noise for all retrievals, i.e. SOMORA, SASBE RS and SASBE ECMWF.



Author's changes in manuscript

Line 13 p3405
Add: "A detailed analysis of the contributions to the observation error can be find in (Calisesi, 2000) and (Rindlisbacher, 1999)."

Add a reference:
Rindlisbacher T., SOMORA: ein Mikowellen-radiometer für das Monitoring von stratospherischem Ozon, Diplomarbeit, Philosophisch-Naturwissenschaftliche Fakultät, Universität Bern, Bern, Switzerland, 175 pp., available at: http://www.iap.unibe.ch/publications (last access: 11.06.2015), 1999.

Comments from Referee #2

Page 3406 - "uncertainty of the ozone measurement is of the order of 5–10% depending on the altitude". Is this systematic error, random error, or some combination thereof.

Author's answer to Referee #2

This is an estimation of a combination of systematic and random error.

Author's changes in manuscript

Line 6 p 3506:
"The vertical resolution is 150 m and the uncertainty of the ozone measurement accounting for both systematic and random errors is of the order of 5-10% depending on the altitude (Stübi, 2008; Dabberdt, 2003)."

Comments from Referee #2

Page 3407 – "The off-diagonal elements are parameterized with an exponentially decaying correlation function using a correlation length of 150m below 25 km which corresponds to the vertical resolution of the RS ozone profile." Given that the grid spacing is 500m, this means that the off-diagonal elements are nearly zero, correct? This should be made clear.

Author's answer to Referee #2

Yes, it is correct. 150 m is the vertical resolution of the RS profile.

Author's changes in manuscript

Line 21 p 3407:
"As the grid spacing below 25 km is 500m, the off-diagonal elements are then close to zero."

Comments from Referee #2

Page 3410 – The abbreviation 'resp.' is unusual.

Author's answer to Referee #2

Thank you for the remark. "resp" has been changed to "or" in the subscripts of equations 4 and 5
and to "respectively" in the text.

Author's changes in manuscript

"resp." has been replaced by "respectively" in the manuscript.

Comments from Referee #2

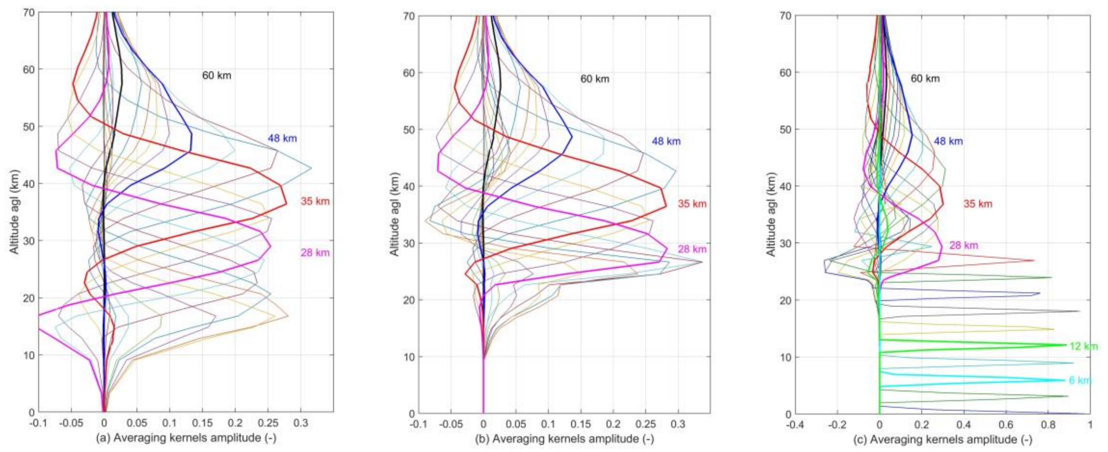
Figure 2 – At least a few of the curves need to be labeled to show what altitude they represent. Also, are they shown for every km? Every 2 km?

Author's answer to Referee #2

Thank you for the suggestion. The 28, 35, 48 and 60 km labelling of the AVKs have been added to figure 2.

Author's changes in manuscript

Figure 2: labelling of AVKs



Comments from Referee #2

Figure 5 – The text indicates that the x-axis on this plot represents both time and ozone concentration, but there is no labeling for the latter. On this very compressed scale there is no point in showing results above 30km.
It is impossible to tell from Figure 5 whether there is any correlation between SOMORA measurements in the lower stratosphere and the RS measurements (after convolution with the SOMORA averaging kernels). This information would certainly be of interest.

Author's answer to Referee #2

The purpose of Figure 5 is to illustrate the continuity of the dataset in space and in time enhancing on one hand the detailed structure of the lower part of the merged profiles when compared to the SOMORA profiles and on the other hand the vertical range going up to 60 km. The authors agree that this figure is only qualitative but feel that it is the best way to give the reader an idea of how the combined retrievals perform on a profile per profile basis and to show the differences between SASBE RS, SASBE ECMWF and SOMORA.

The nbar scale labelling is the same as in figure 4 (and in line 23 p 3409). The authors will add a reference to this figure when describing the ozone content scale of figure 5.

Author's changes in manuscript

A reference to figure 4 horizontal scale has been added in the legend of figure 5:
"Time serie of ozone profile in nbar (same horizontal scale as in figure 4, maximum of 180 nbar around 20 km height) over Payerne for 2 months…"

Comments from Referee #2

I am disappointed that the RS data was not used more directly to calculate a baseline term for the SOMORA data which could have been applied to the SOMORA forward model to reduce the biases between SOMORA and the RS in the lower stratosphere. Assuming such a baseline is constant over some period (which it well may be), this would allow for SOMORA measurements to lower altitudes during periods when RS data is unavailable. Hopefully such work will be presented in a future manuscript. I would welcome any thoughts from the authors as to the feasibility of such an approach.

Author's answer to Referee #2

In the SOMORA and SASBE retrievals, a polynomial of degree 1 is used as a model for the baseline where all coefficients are retrieval parameters. Hence, no specific baseline model is used. There is no physical way to derive a baseline model from the RS. The only way the authors see, and this may be what the reviewer suggests, is to develop detailed model for the instrument baseline (with sinusoids of given frequencies and amplitudes derived from FFT analysis of the residuals) minimizing the differences between the retrievals and the RS. This method has the potential to improve the lower levels of the SOMORA retrieval. However, the authors know from personal experience, that this process is extremely laborious and while the retrieval may be slightly improved, the uncertainties of the lowest retrieval levels remain relatively large. Therefore, the authors do currently not envisage such a development. Moreover, if this approach can improve the retrieval of the SOMORA profiles, it cannot be considered as a method for combination of 2 profiles. In this manuscript, the authors intend to merge 2 profiles keeping the specificities of each of them in the resulting profile (vertical resolution and measurement errors). At our knowledge, there are 3 approaches available for merging two types of profiles using OEM retrieval:

1) One of the two profiles is considered as the a priori in the retrieval of the other.
2) One instrument provide directly a profile while the second one is providing a Brightness Temperature spectrum. 2 different forward models are used in the OEM retrieval (the forward model for the observed profile being identity). Different weights on the data are considered in the OEM retrieval.
   This approach has been used for the combination of LIDAR and HATPRO Temperature and Humidity profiles and has been published very recently in AMTD:

   Barrera-Verdejo, M., Crewell, S., Löhnert, U., Orlandi, E., and Di Girolamo, P. : Ground based lidar and microwave radiometry synergy for high vertically resolved thermodynamic profiling, Atmos. Meas. Tech. Discuss., 8, 5467-5509, 2015, doi:10.5194/amtd-8-5467-2015.

3) The OEM retrieval is performed on the spectra combining the 2 instruments. One single forward model is used to simulate the measurement of both instruments.

The approach described in our manuscript could be considered as the easiest of the three. The resulting profiles should certainly be compared to the profiles obtained by the others methods when available.