Response to comments by the referee Mark Weber

We thank the referee for reading the manuscript so carefully and for his insightful comments. We have provided a detailed response below.

Referee: "The various data versions of the SBUV ozone data have not been well documented. The last peer review publication is the paper by Barthia et al. (2006) (sic) with respect to Version 6. Two major upgrades, Version 7 and 8, have not been described in detail so far. First, in the summary of the various data versions, the Version 7 data version is not described at all. Even though, there may be no algorithm changes in V7 few words should be mentioned here, e.g. the setting changes. A description (at least in brief) how the various data versions (V7, V8) improved SBUV ozone successively, should be given."

Response: We are sorry that the referee feels that we have not adequately documented various versions of the SBUV algorithm. In the past 3 decades there have been only two major SBUV algorithm versions. The V6 algorithm was developed in the mid 80s. It is described in detail by Bhartia et. al. (1996). It served as our official SBUV algorithm until we released data from the V8 algorithm at the 2000 Quadrennial Ozone Symposium in Greece. The details of the V8 algorithm were described in the CDs that were provided with the data. There are also documentation on V8 available from NOAA website. We have added the reference.

Though an attempt was made in the late 80s to develop a modified version of the V6 algorithm, to be labeled as V7, this algorithm was never finished. No data from V7 have ever been released. Differences between V6 and V8 are described in detail in this paper. Differences between V8 and V8.6 algorithm are relatively small. They have also been described in this paper.

In response to referee's comments we have added the following lines in the introduction: *The current version of the algorithm (V8.6) is a modified version of the algorithm (V8) that was developed in the late 90s. Data produced from V8 and the details of the algorithm were first released at the 2000 Quadrennial Ozone Symposium in Greece. This algorithm has been in use at NOAA ever since (Flynn, 2007). Differences between V8 and V8.6 are small. These differences and the differences between V6 and V8 are described in this paper. [The V7 algorithm, a modification of the V6 algorithm planned in the late 80s was never completed. Version 7 SBUV data referred to in the literature, e.g., Stolarski and Frith (2006) are for total ozone only which was produced using the TOMS Version 7 algorithm.]*

Referee: No quantitative evaluation is provided how the changes made in version 8.6. i.e. change of cross-section, new a priori ozone profile and cloud climatologies, improved the data set. The improvements over Version 8 needs to be well documented and quantified/demonstrated.

Response: In developing new versions of our algorithms it has been our policy to incorporate our best understanding of instrument behavior at the time of release, our evolving understanding of satellite retrieval algorithms and UV radiative transfer, and availability of better ancillary data, such as ozone absorption cross-section, ozone profiles needed to construct the *a priori* profiles, and cloud climatologies.

The primary motivation of going from V6 to V8 algorithm was to simplify the algorithm. By the mid 90s high quality stratospheric and lower mesospheric ozone profiles covering the entire globe had become available from SAGE II and UARS/MLS. So it was no longer necessary to generate *a priori* profiles using "c-sigma" and total ozone, as was done in V6. Moreover, construction of *a priori* profiles using the measured data themselves complicates the error analysis. Strictly speaking, they cannot even be called "*a priori*". Also, in the mid 90s, TOMS data revealed that two common types of aerosols (smoke and desert dust) have strong absorption in the UV. Since SBUV doesn't have the wavelengths even to detect such aerosols, much less to correct for them, we had to use a varying no of wavelengths in the algorithm to minimize the effects of these aerosols. We have described these and other changes from V6 to V8 in detail in this paper. By contrast, there has not been any change in the basic algorithm in going from V8 to V8.6. The V8.6 data released last year reflect our best understanding of instrument behavior and of ancillary (i.,e., external) data that go into the retrieval. The change in the instrument behavior and its impact on retrieved ozone is described by Deland et. al. (2012). This paper also compares V8 and V8.6 SBUV results with MLS data.

We have modified the abstract based on this comment. The modified text is: *The V8 algorithm was released more than a decade ago and has been in use since then at NOAA. The current algorithm (V8.6) is basically the same as V8, except for updates to instrument calibration, incorporation of new ozone absorption cross-sections, and new ozone and cloud height climatologies.*

We have also modified the text in section 3 as follows: *Changes from V8 and V8.6 algorithms include new ozone (McPeters and Labow, 2012) and cloud pressure (Haffner, 2011) climatologies, change in ozone absorption cross-section dataset, and updates to the calibration of several SBUV instruments. The cloud pressure climatology is based on Optical Centroid Pressure (OCP) derived from rotational Raman scattering using OMI data (Vasilkov et al., 2008). Vasilkov et al. (2004) show that OCP provides more reliable estimate of total ozone than that obtained using cloud-top pressure. For issues regarding ozone cross-sections see Liu et al. (2007). Figure 12 in DeLand et al. (2012) gives an example of how these changes have affected the ozone profiles retrieved from V8 and V8.6 algorithms.*

Referee: Large part of the paper is spent on the monthly mean ozone (MZM). On p. 5921, l. 23, the so-called "MZM retrieval" is mentioned that retrieves MZM ozone from monthly zonal mean radiances (or N-values) rather than averaging individual profiles. Although the connection between radiances and ozone is quite non-linear as the author states, the MZM retrieval has been optimised by providing (or constructing) a reasonable error matrices for the MZM retrieval. There is a very large description and discussion how to set up MZM error matrices. The most quantitative part of the paper deals with the MZM ozone, its retrieval setup and evaluation (comparison to MLS). This needs to be better reflected in the paper title and abstract.

Response: We have added a line in the abstract to better reflect our emphasis on monthly zonal means. The new line is: *Using MLS data we show that the V8 algorithm is best suited for estimating monthly ozone zonal means, rather than individual ozone profiles. Hence our emphasis in this paper is on characterizing the sources of errors that are relevant*

for deriving trends from monthly mean anomalies and for estimating biases between different types of ozone sensors.

Referee: Apart from the fairly detailed description the MZM retrieval, MZM ozone datasets and related "constructed" errors, the evaluation of physical errors, e.g. influence of aerosols, cloud, ozone, and temperature climatologies as well as cross-section choice is apart from naming the errors absent (see section 4). Since the SBUV algorithm is very fast, it would be very easy to make sensitivity tests on the error contribution.
The argument that "such complexity cannot be handled simply by providing accuracy and precision" is not convincing. A detailed error and data characterisation is essential when describing new data versions, be it the retrieval of individual profiles or the MZM retrieval.

Response: As we have emphasized in the paper, the primary value of SBUV data has been for studies of long-term changes that are usually derived from monthly zonal mean anomalies. Yet the error in retrieving this important quantity is rarely discussed in the literature. The primary value of our paper is that it does so, perhaps for the very first time for profiles retrieved from BUV type sensors. Errors in individual profiles are not random, so one cannot calculate errors in ensemble mean profiles simply by dividing by the square root of number of points averaged, as one typically does with in situ sensors. Therefore, in our opinion prescribing the former error in detail will not serve the need of most users of SBUV data. To keep the size of the paper to a manageable level, and to keep the emphasis on the zonal means, we decided not to discuss errors in individual profiles in this paper. Also, even for individual profiles the dominant error source for V8 is the smoothing error, rather than tropospheric aerosols, clouds and temperature variability. This is because we do not use the wavelengths that are strongly affected by them.

We have also added the following sentence in section 4.2 where systematic errors and bias errors are briefly discussed: *To estimate such errors quantitatively it is necessary to compare with sensors with higher accuracy than SBUV. Since Kramarova et al. (2013) discuss such comparisons, in this section will provide just an overview of the errors invloved.*

Response to "item by item" comments:

p. 5914, l. 22: There have been peer-review papers on BUV ozone that should be cited here.

Response: Recent papers on the buv profile algorithm have been designed to process data from hyperspectral instruments like GOME rather than from SBUV like instruments. Still, given referee's comment we have decided to include them. We have added the following text in the introduction: *Most of the recent work in this field has been focused on deriving improved ozone profiles in the lower stratosphere and troposphere by taking advantage of extra information, redundancy, and low noise characteristics of hyperspectral instruments, like GOME, SCIAMACHY and OMI (Hasekamp and Landgraf, 2001; Hoogen et al., 1999; Liu et al., 2005; Liu et al., 2010; Meijer et al., 2006; Munro et al., 1998; van der A et al., 2002)*

l. 23: The authors state "additional instruments of progressively improved design". Please provide a few sentences what the design improvements were.
We have described the major improvement that occurred between Nimbus-4 BUV and Nimbus-7

SBUV instruments. By comparison future improvements to the instruments have been small. We have added the following sentence in the text to clarify this and have added a new reference where some of the instrument changes are discussed: *Changes made to the instruments since then have been modest. They are described in Frederick et al. (1986).*

p. 5915, l 1.: "but only a few have been published". Only the paper by Barthia et al. (1996) is mentioned, so it would be better to say "only one has been published" or alternatively list the other papers as well.
We have changed the relevant text as follows: *Over the years several different algorithms have been applied to process these data, but only a few have been published in the open literature (Bhartia et al., 1996 and references therein).*

l. 3: please mention the data version released in 2004 (I guess it was V8)
The V8 data were released in 2000 QOS. This has been clarified.

l. 11: spell out numbers: "ten", "seven", and "three"
The scientific style manuals disagree on this issue. We will follow the advice of AMT editorial staff when we submit our final copy.

l. 25: To me the field of view seems to be very large, or is this the field of view related to the footprint after scanning thru the wavelengths in 18s and 24s, respectively.
We have clarified this issue by adding the following lines in the text: *All instruments view the earth in the nadir along the satellite track, with approximately 11.3˚ x 11.3˚ field-of-view, corresponding to approximately 170 km x 170 km at the surface for SBUV/2 (200 km x 200 km for SBUV).* We have also changed the following line: *The measurement sequence takes 24 s to step through all 12 wavelengths (18 s for Nimbus-7 SBUV), which extends the scanning region in the along-track direction to create an effective footprint of 170 km x 340 km (200 km x 330 km for Nimbus-7).*

p. 5917, l. 12: use the "citet" latex command for citing Twomey (1963).
Thanks for catching the mistake. We have fixed it.

l. 18: What about V7 (see major comments)?
Clarified.

p. 5918, l. 3: What effect has the change in cross-section? The effect on the ozone shall be shown. Similarly what are the effective changes due to the new O3 and cloud height climatologies! (see also major comments).
As discussed above. the changes are minor compared to errors in deriving monthly zonal means. These changes were made based on recommendations from the OMI team that has studied these issues in some detail. We have added references to the papers where these issues have been discussed.

p. 5919, l. 11: change "R & f_c" to "R and f_c".
Fixed.

p. 5921, l. 17: How MZM retrievals distinguish from averaging individual profiles. Some figures showing such a comparison should be provided and errors associated with MZM retrieval discussed (somewhere in the paper).

As described, we retrieve individual profiles not the monthly zonal means. However, the algorithm has been optimized for the retrieval of monthly zonal means by constructing an appropriate a priori error covariance matrix. We have modified the text in several places to make it clear that the monthly zonal means are derived (i.e., not retrieved directly) by averaging individual profiles.

l. 27: When "constructing the S matrix" for the MZM retrieval, the systematic errors can not be completely neglected (even if related systematic biases are not relevant for long-term trends). A discussion and evaluation of possible systematic errors (for individual and MZM retrievals) should be provided.
As mentioned, the key quantity for the retrieval is gamma. The value of gamma is usually selected by trial and error rather than by careful analysis of various errors involved. Changing gamma by a factor of 2 or even 4 has virtually no effect on the retrieval. We discuss the effects of systematic errors in Section 4.

p. 5923, l. 18: spell out MR: mixing ratio
Fixed.

p. 5924, l, 11: "SBUV documents" are mentioned. Please provide citations for the SBUV documents.
We have added the reference: Flynn, 2007.

l. 18: You probably show MZM W (missing overbar).
Fixed.

p. 5928, l. 20ff: aerosols may be important for MZM since Pinatubo falls in the period where stratospheric halogen was close to the peak. As argued earlier a more thorough and quantitative assessment of this error is needed here.
We discuss this issue at the end of section 4.2. We provide a reference to an earlier paper that examined the effect of stratospheric aerosols on the V6 algorithm. We are currently working on updating that study for V8.6. However, we do not expect any major change in the conclusion, except perhaps for total column ozone.

p. 5929, l. 19: mesospheric daytime variations have been discussed in Dikty et al., ACP, 2010 as well, however, the authors are correct that little is known on upper stratospheric daytime variation.
There are several groups around the world looking at this issue using new data. We expect more definitive papers to come out soon.

Table 1: all details from the table are not discussed in the main text. How is the ozonesensitivity weighted effective temperature calculated (which temperature and ozone profiles are assumed). Please indicate which ozone cross-sections are used (guess C2710 Malicet).
We have added the following text: *Table 1 provides wavelengths and the spectroscopic parameters for NOAA-17 SBUV/2 instrument. The ozone sensitivity-weighted temperature was calculated using a climatological mean mid latitude temperature profile weighted by the ozone sensitivity of the wavelength as a function of height at 45˚ solar zenith angle. The ozone absorption coefficient is based on data from Malicet et al. (1995).*

Units for T_{eff} is missing.
We truly appreciate the diligence of the reviewer in catching this omission. Fixed.

Figure 6 caption: change "theToms" to "the TOMS"
Thanks again. Fixed**.**

Response to comments by Referee #2

We thank the referee for reading the paper so carefully. We have fixed the typos caught by the referee. Our response to the other comments are given below.

Referee: There are many acronyms used in this paper and they are not always defined. Please define all acronyms at the first occurrence.
Response: We haven't spelled commonly used acronyms such as NASA, NOAA, GOME , SCIAMACHY. Since they are better known by their acronyms rather than their expanded form, we feel that these acronyms do not need to be defined. However, if the AMT editorial staff recommends otherwise we will fix them in the final copy.

Page 2, line 20: Why are the AE-E BUV data not available for your use?
Response: The data were deleted from the archives because of lack of demand. We have modified the text to read: *Data from the AE-E BUV instrument (launched in November 1975) are no longer available from the NASA archives.*

Page 12, line 2: It is not clear to me what the 'it' refers to in 'have corrected it'.
Response: Changed the text. It now read: *Of course, if one knew ε_N one would have corrected the N-values.*

Page 14, line 19: What does 'quite well' mean? This will likely mean different things to different people.
Response. We have deleted the sentence. The text now reads: *we will limit our discussion of the SBUV results to just the NOAA 17 SBUV/2 instrument that had good overlap with Aura/MLS. Aura/MLS has provided one of the most comprehensive datasets of ozone profiles available to compare with SBUV (Froidevaux et al., 2008). Most importantly, MLS profiles are provided in pressure vs. MR coordinate, which can be converted to SBUV layer ozone without using temperature profiles.*