Responses to Reviewer # 1

The authors thank the referee for providing the constructive comments on our paper.

General comments:

In this paper, the authors need to provide more discussions about the possible impacts of cross-section change. Ground-based Brewer measurements are employed to characterize the accuracy of the ozone retrieval algorithms. However Brewer data are retrieved using Bass and Paur (1985) ozone cross-sections, which are also used by the OMI TOMS algorithm, but are different from the BDM cross-sections used by the SOE, the KOE, and the OMI DOAS algorithms. It is mentioned in this paper that Brewer retrieved ozone columns would be significantly different if the BDM cross-sections are used instead of Bass and Paur (page 4059, lines 5 – 8). Furthermore, the temperature dependence of these two ozone cross-sections are different, indicating that switching one with the other would not be a simple bias in the Brewer data, but more complex differences that depend on the observing conditions. It is therefore important for the authors to expand the discussion about the impacts of Brewer errors on the evaluation of algorithm performances, whether smaller differences between OMI and Brewer columns would signify more accurate retrievals, and if the scatter would be changed.

Response:
According to recent studies by Fragkos et al. (2013) and Redonas et al. (2014), switching from BP cross section will reduce the total ozone by ~3.2%. In addition, current Brewer total ozone does not consider temperature variation and uses a fixed temperature of -45°, and therefore does not consider the temperature dependence of ozone cross sections. Switching from BP to BDM and considering the effect of temperature variation and the temperature dependence of the retrievals, the Brewer total ozone at Thessaloniki, Greece, will be reduced from -2.8% to -4.5% as a function of time (with a seasonal variation of ~0.8%) compared to the original Brewer retrieval with of 0.2%/decade (Fragkos et al., 2013).

In 2009, WMO/GAC-IO3C has established the ACSO (Absorption Cross Sections of Ozone, http://igaco-o3.fmi.fi/ACSO/) Committee to review the current ozone cross sections and determine the impacts of changing ozone cross sections on retrievals from different instruments (both ground-based and satellite). According to the activities from ASCO members, switching from BP to BDM has different impacts on retrievals from different instruments/retrieval algorithms due to the use of different wavelengths/spectral regions and the quality of ozone cross sections in the used wavelengths/spectral regions. For example, the switch from BP to BDM will typically increase our SOE total ozone by ~1% (Figure 1) with a standard deviation of approximately of 0.6 %(also see C. Liu et al., 2013) for solar zenith angle less than ~70°. The change in Brewer total ozone is -3.2% (Redonas et al., 2014; Fragkos et al., 2013). The OMTO3 would increase by ~1.5% (Bhartia et al., 2013; http://igaco-o3.fmi.fi/ACSO/presentations_2013/satellite/WS_2013_Bhartia.pdf). The Dobson total ozone is insensitive to the use of current high-resolution ozone cross sections (Redonas et al., 2013). The mean changes on KOE, OMDOAS total ozone are -0.9 and -0.5 DU, respectively (Veefkind et al., 2010, http://igaco-o3.fmi.fi/ACSO/presentations_2010/satellite/OTM_2010_Veefkind.pdf). The change in WFDOAS total ozone is typically within 0.5% (Weber et a., 2013, http://igaco-

o3.fmi.fi/ACSO/presentations_2013/satellite/WS_2013_Weber.pdf). The change in GDOAS total ozone is within 1% from GOME, SCIAMACHY, and GOME-2 (Lerot et al., 2010, http://igaco-o3.fmi.fi/ACSO/presentations_2010/satellite/OTM_2010_Lerot.pdf). The BDM cross section dataset is recommended for use in our ozone profile retrieval algorithm (Liu et al., 2007; C. Liu et al., 2013). But the ozone cross section dataset by Institute of Environmental Physics, Bremen University (IUP dataset, Gorshelev et al., 2014; Serdyuchenko et al., 2014) is recommended for ground-based Dobson and Brewer measurements, because using this dataset reduces the Dobson/Brewer difference to within 1% and the seasonality of the differences; the use of BDM cross section dataset also removes the seasonality of the Dobson/Brewer differences, but causes ~2-3% Dobson/Brewer differences (Redonas et al., 2014; Fragkos et al., 2013).

If the Brewer retrieval algorithm uses the recommended IUP cross section dataset and accounts for the temperature dependence of the retrievals, then the retrieved total ozone is slightly reduced by -0.5% with a very small seasonal dependence of ~0.2% (as the Brewer wavelengths have been chosen to minimize the effects of temperature changes on retrievals) and a very small change in the trend on the order of 0.05% per decade, compared to the current Brewer total ozone (Fragkos et al., 2013; Redonas et al., 2014). So using improved Brewer retrieval would slightly change the biases between various satellite retrievals and Brewer data by ~0.5%, but pose very small changes to the seasonal variation (also in Kerr, 2002; Weber et al., 2005; Vanicek et al., 2006) and the long-term trend. In summary, the Brewer results using the best ozone cross sections (IUP cross section) and accounting for temperature dependence is very close to the current Brewer data, so the main conclusions of our studies are not affected much.

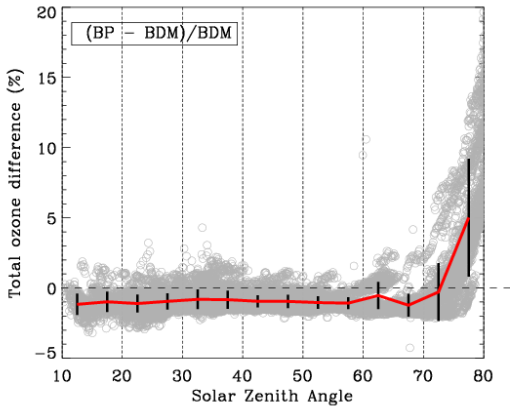

Figure 1. Relative differences between retrieved SOE total column ozone using BDM and Bass-Paur (BP) cross sections as a function of Solar Zenith angle for the NH of orbit 15876 on July 10, 2007. The red line and vertical bars indicate the mean biases and 1- σ standard deviations in bins of 5 °.

In revised manuscript, this discussion has been added in Section 6 (Conclusions and Discussions).

Specific comments:

Comment #1: Page 4059, line 9, “can be a problem”. Perhaps re-phrase this sentence, and specify the problem.

Response #1: We have mentioned in the response to general comment that the current Brewer wavelengths have been chosen to minimize the effects of temperature changes on retrievals. Switching from BP to BDM and considering the effect of temperature variation and the temperature dependence of the retrievals, the Brewer total ozone at Thessaloniki, Greece, will be reduced from -2.8% to -4.5% as a function of time, but with a small seasonal variation of ~0.8% and with a small long-term variation of 0.2%/decade, compared to the original Brewer retrieval (Fragkos et al., 2013).

The associated sentence has been revised for more clarification.

- **Section 2.2:** Absorption cross coefficients based on Bass and Paur (1985) data are used in Brewer operation algorithms. There could be a systematic bias in total ozone calculations due to switching to other cross sections from Bass-Paur cross section; for example, this may have an impact as large as -3.2 % if the BDM cross-sections are used [Redondas et al., 2013]. In addition, current Brewer total ozone does not consider the temperature dependence of ozone cross sections and use a fixed temperature of – 45℃ as the Brewer wavelengths have been chosen to minimize the effects of temperature changes on retrievals. According to a recent study by Fragkos et al. (2013), switching from BP to BDM and considering the effect of temperature variation and the temperature dependence of the retrievals, the Brewer total ozone at Thessaloniki, Greece, will be reduced from – 2.8 % to – 4.5 % as a function of a time with a small seasonal (long-term) variation of ~ 0.8 % (0.2 %/decade) compared to the original Brewer retrieval. Therefore, the impact of Brewer error due to the temperature dependence on evaluation of satellite algorithm performances is expected to be very small.

Comment # 2: Page 4057, line 13, “soft calibration” for TOMS needs to be characterized, similar to that for SOE, page 4056, lines 8 – 10.

Response #2: In response to the reviewer’s comments, we have summarized the OMTO3 soft-calibration in Section 2.1 and added references for the reader.

- **Section 2.1**: OMTO3 total ozone measurements are tied closely to OMI's pre-launch radiometric calibration at nadir, described by Dobber et al. (2006) and validated by Jaross and Warner (2008). Small residual errors in the Collection 3 radiances (Dobber et al., 2008) are further reduced using soft-calibration techniques. Biases and irregularities that vary with viewing angle and wavelength are estimated and removed relative to nadir by comparing the measured radiances with theoretical forward model calculations. This is done only when the variability in ozone or reflectivity is low and the radiances can be modeled reliably.

Comment # 3: Page 4054, lines 18 – 20, “Both OMTO3 and OMDOAO3 were validated previously by several groups using various reference data (e.g., Balis et al., 2007; Kroon et al., 2008; McPeters et al., 2008; Antón and Loyola, 2011)”. Need to describe somewhere in this paper if the findings of this work are consistent with those of previous comparisons.

Response #3: According to the review’s comments, we have revised the manuscript and added some

sentence in revised manuscript.

- **Section 3.1:** The larger biases and less scatter in TOMS comparison relative to the DOAS comparison has been reported in the validation work of Anton et al., [2011] and Koukouli et al., [2013]. In a recent comparison [Koukouli et al., 2013], TOMS-Brewer is -1.0 ± 2.1 % over mid-latitudes and DOAS-Brewer is -1.02 ± 2.9 %.

- **Section 3.2:** The DOAS differences show obvious dependence ranging from -2.2% at SZA 22.5° to -0.6 at SZA 77.5° (i.e., bias change by 1.6 % or 5.3 DU), but the SZA dependence of this product processed with v 1.2.3.1 of the DOAS algorithm from collection 3 OMI level-1b data is significantly improved over the previous data version. For example, increasing mean biases of more than 2% due to SZA were found in OMDOAO3 (v 1.0.5, collection 3) - Brewer data [Koukouli et al., 2012] and the OMDOAO3 collection 2 product showed a much stronger SZA dependence by ~ 4% [Balis et al., 2007; McPeters et al., 2008].

- **Section 3.3:** Similar results were reported in Anton et al., 2009, where they showed little swath dependence in either the TOMS or DOAS algorithms, but variability in the DOAS mean biases.

- **Section 3.6:** This seasonal dependent pattern agrees well with the comparison of the Brewer data from Hradec Kralove as presented in Vanicek [2006], which showed -2 % difference during winter and -1 % difference in summer.