Title: Improved retrieval of SO_2 from Ozone Monitoring Instrument: residual analysis and data noise correction

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We thank the reviewer #2 for carefully reading the manuscript and for providing constructive comments. Those comments are all valuable and very helpful for revising and improving our paper. All the comments are taken into account in the revised manuscript. We have attempted to address the comments below.

1. **Reviewer 2:** The introduction should focus more on the various correction approaches described in the literature. The current introduction is basically a list of paper related to SO_2 retrievals from BUV instruments.

   Authors: Yes, we agree with this comment. The descriptions of the various correction approaches were inappropriately placed in the section 2 of the discussion manuscript (p.984, lines 5–27). The text was moved to the section 1 (introduction) in the revised manuscript.

2. **Reviewer 2:** In this paper, the authors mentioned that they used TOMRAD to compute residuals at four wavelengths, and then perform the BRD retrievals to derive the SO_2. If the authors have done the TOMRAD computations, they need to provide more details. For instance, how ozone values are derived or which ozone values are used for both inside and outside of row anomaly areas? What cloud pressures, surface pressures (both terrain and clouds), and other needed parameters is obtained for the forward computation. Please clarify how and what has actually been done to obtain the residuals presented in this paper.

   Since the OMI SO_2 product (OMSO2) contains all the information needed to perform modified sliding median correction, the authors need to provide justification for going through the TOMRAD computation.

   Authors: We are very sorry for our negligence. More details about TOMRAD

computations were added in the revised manuscript. The added text is as follows (in red font):

The top-of-the-atmosphere (TOA) radiation was simulated by using TOMS forward model TOMRAD (Dave, 1964), in which the TOA radiation was dependent on the linear interpolation of radiation for eight solar zenith angles (15, 30, 45, 60, 70, 77, 84, and 88°), five viewing zenith angles (15, 30, 45, 60, and 70°), ten ozone profiles (125, 175, 225, 275, 325, 375, 425, 475, 525, and 575 DU) (DU = Dobson Units or milli atm cm, 1 DU = 2.69×10^{16} molecules/cm^2), three albedos (0.05, 0.3, 0.8), one surface pressure (1013.25 hPa); we calculated the residuals (residual = measured TOA radiation – simulated TOA radiation) at four wavelengths (310.8, 311.9, 313.2, and 314.4 nm) and assumed the air mass factor (AMF) value as a constant 0.36; we used the SO_2 absorption cross-section data at a constant temperature (273 K) (Bogumil et al., 2003).

The reason that we did the TOMRAD computations is to analyze the main noise sources which result in the obvious biases in the OMI level 2 SO_2 PBL product. Results show that the invalid value and noises in the irradiance data can result in the stripe biases of retrieved SO_2 columns. The row anomaly resulted from earth radiance can also result in the obvious biases in the OMI level 2 SO_2 PBL product. In practical work, we can use the residual information from the OMI SO_2 product (OMSO2) to perform modified sliding median correction.

3. **Reviewer 2:** The authors have confused ‘noise’ and ‘’bias in this paper. The sliding median correction method removes some biases (NOT noises) in the data.

   Authors: We are very sorry for our incorrect writing. Thanks for pointing this out. The manuscript was revised according to the comment.

4. **Reviewer 2:** Statistical analysis of the modified approach needs to be conducted for greater amount of data (at least one year worth of data) to evaluate its effectiveness.

   Authors: We agree with this comment. The statistical analysis of the modified

approach for greater amount of data was added in the revised manuscript. We use a large amount of data from January 2008 to May 2009 (more than one year) to evaluate its effectiveness. Table 1 was expanded for contained more statistical analysis results in the revised manuscript. One new figure named as Fig. 10 was added in the revised manuscript to clearly present the statistical comparison between the optimized results and OMI level 2 SO_2 PBL product from January 2008 to May 2009.

Please see the expanded Table 1 and the added Fig. 10 at the end of this document.

5. **Reviewer 2:** The English writing is poor and needs to be improved.

   Authors: We agree with this comment. The English writing is really hard to follow. We will take all necessary measures to improve English in the manuscript. Before final submission, we will send the manuscript to professional organization for English language check.

6. Other changes: In addition to the above changes, we have also made some additions and updates to the paper to improve clarity. These changes will not influence the content and framework of the paper. And here we list the primary changes in the revised manuscript. Please see the revised manuscript for the detailed changes.

   - One paragraph was added to the revised manuscript. The aim of this paragraph is to describe the structure of this article. The added paragraph is as follows (in red font):

     The paper is organized as follows: in section 2.1, the main noise in solar irradiance and earth radiance data is presented. In section 2.2, the different residual correction area is discussed, and an improved scheme for data biases correction is described. In section 3, the optimized results are compared with OMI level 2 SO_2 PBL product. In section 4, we summarize our findings.

- For clarity, we divided the section 2 into two sub-section, section 2.1 and section 2.2.
- p.986, lines 4–18. For clarity, the structure of this paragraph was rearranged. These changes will not influence the content of the manuscript.
- p.986, lines 19–25. This paragraph was revised and added to the end of section 3 for the underestimation discussion of our optimized results.
- p.988, lines 18–27. p.989, lines 1–3. After serious consideration, we think that it is more appropriate to delete these sentences. Because these sentences have relatively weak correlation with the objective of our article.
- Three references were added in the revised manuscript. They are as follows (in red font):

  Dobber, M., Kleipool, Q., Dirksen, R., Levelt, P., Jaross, G., Taylor, S., Kelly, T., Flynn, L., Leppelmeier, G., and Rozemeijer, N.: Validation of ozone monitoring instrument level 1b data products, J. Geophys. Res., 113, D15S06, doi: 10.1029/2007JD008665, 2008.

  Eatough, D. J., Caka, F. M., and Farber, R. J.: The conversion of SO_2 to sulfate in the atmosphere. Israel Journal of Chemistry, 34(3-4), 301-314, 1994.

  Jaross, G., and Warner, J.: Use of Antarctica for validating reflected solar radiation measured by satellite sensors, J. Geophys. Res., 113, D16S34, doi:10.1029/2007JD008835, 2008.

The expanded Table 1 and the added Fig. 10 are as follows :

Table 1. Data precision of OMI level 2 SO_2 PBL column amount and modified SO_2 results in the North Pacific Ocean area (15–20 °N, 135–150 °E)

		OMI level 2 SO_2 PBL product		Modified SO_2 results	
Orbit number	Number of pixel[a]	Area-averaged SO_2 column amount (DU)	Standard deviation (DU)	Area-averaged SO_2 column amount (DU)	Standard deviation (DU)
Orbit 18507 (20080107)	1907	0.0595	1.2008	0.0620	0.9327
Orbit 18536 (20080109)	1953	-0.4852	1.4454	-0.2213	1.1461
Orbit 18638 (20080116)	1984	-0.0999	1.3149	0.3836	1.2998
Orbit 18740 (20080123)	1909	0.1880	1.0105	0.0398	0.8322
Orbit 18871 (20080201)	1933	0.7516	1.8377	0.4021	1.4690
Orbit 19104 (20080217)	1920	0.3567	1.5643	0.3261	1.2513
Orbit 19337 (20080304)	1922	0.4041	2.0318	0.2906	1.6425
Orbit 19439 (20080311)	1926	0.6060	2.1257	0.7389	1.7141
Orbit 19570 (20080320)	1919	0.0433	1.2365	-0.0058	1.0086
Orbit 19672 (20080327)	1936	0.1899	1.0301	0.2085	0.8319
Orbit 19905 (20080412)	1907	0.1667	0.9854	0.1870	0.7951
Orbit 20138 (20080428)	1920	-0.1806	1.0205	0.0719	0.8410
Orbit 20371 (20080514)	1922	-0.0423	1.0232	0.1111	0.8488
Orbit 20604 (20080530)	1916	-0.2976	1.4105	0.0350	0.9809
Orbit 20837 (20080615)	1913	-0.0399	1.2001	0.0261	0.9941
Orbit 21070 (20080701)	1910	-0.0794	1.3059	0.0135	1.0578
Orbit 21303 (20080717)	1908	-0.1780	1.3292	-0.0058	1.1230
Orbit 21536 (20080802)	1918	0.1112	1.8013	0.0113	1.2669
Orbit 21769 (20080818)	1926	-0.4309	1.7046	-0.1902	1.4375
Orbit 22002 (20080903)	1916	-0.0596	1.1503	0.0547	0.9344
Orbit 22104 (20080910)	1910	-0.4114	1.2626	0.0077	0.9859
Orbit 22133 (20080912)	1901	-0.7013	1.3775	-0.1409	1.1562
Orbit 22235 (20080919)	1937	-0.7516	1.6452	-0.1214	1.2066
Orbit 22468 (20081005)	1908	-0.3530	1.4373	-0.1714	1.1991
Orbit 22701 (20081021)	1918	-0.2325	1.1066	-0.0089	0.8928
Orbit 23167 (20081122)	1911	-0.0737	1.1845	-0.0562	0.8885
Orbit 23400 (20081208)	1907	-0.0696	1.1347	-0.0167	0.9328
Orbit 23866 (20090109)	1927	0.2881	1.7047	0.0943	0.9842
Orbit 24332 (20090210)	1921	0.8497	3.6913	0.0361	1.3513
Orbit 24798 (20090314)	1906	0.2798	1.5517	-0.0302	1.1520
Orbit 24929 (20090323)	1903	0.0915	1.4896	-0.3857	1.8019
Orbit 25497 (20090501)	1919	-0.5072	1.9516	-0.3021	1.5747

[a] Here we select those days with the number of pixel in the North Pacific Ocean area larger than 1900.

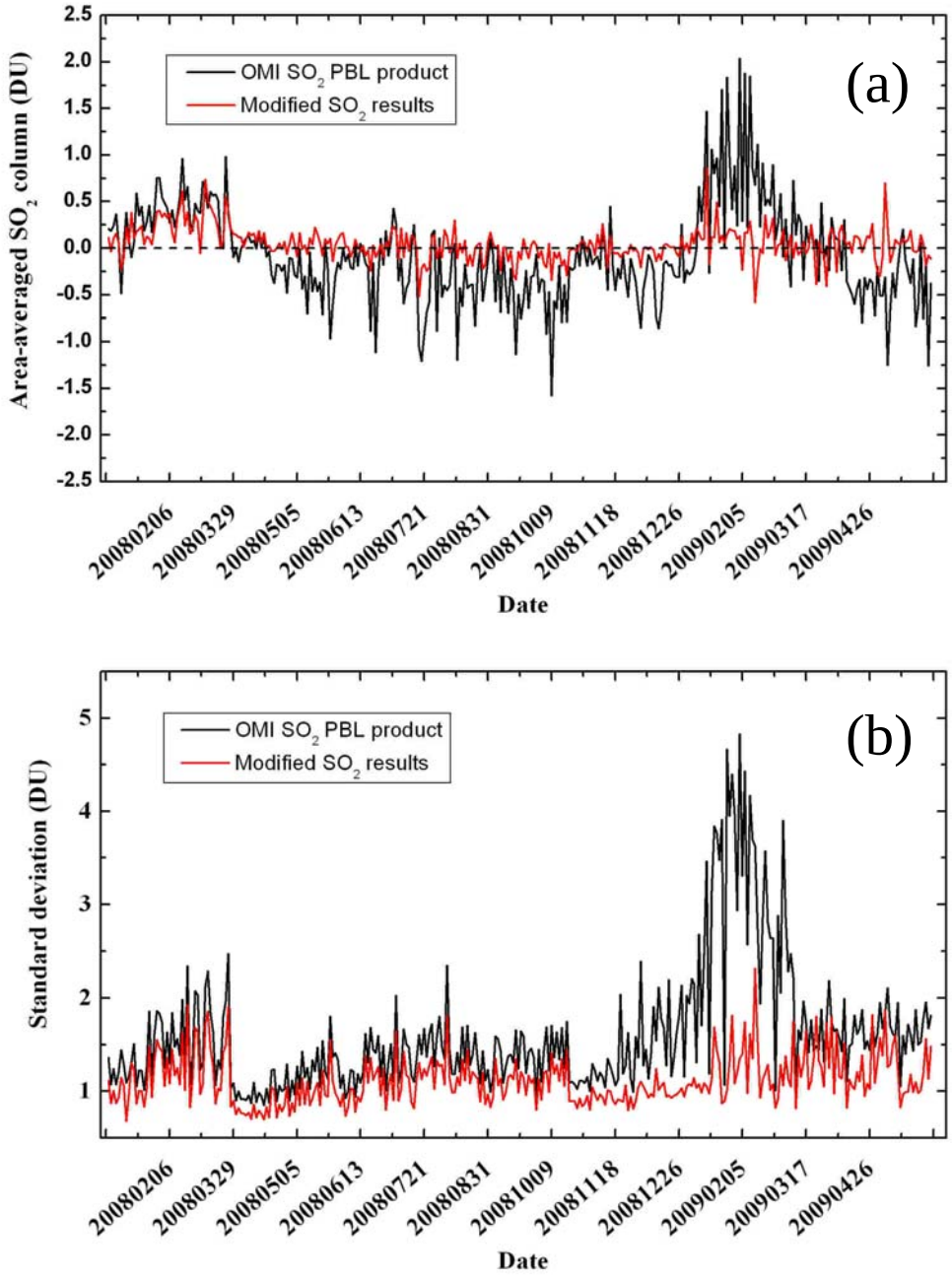

Fig. 10. Comparisons between SO_2 columns from OMI level 2 SO_2 PBL data versus those from the optimized results in the North Pacific Ocean area (15–20 °N, 135–150 °E): (a) Area-averaged SO_2 column amount from January 2008 to May 2009; (b) Standard deviation of selected pixels from January 2008 to May 2009. We select those days with the number of pixel larger than 1000 in the North Pacific Ocean area. The dashed line in (a) represents the Y=0 line.