Response to review of "*Version 2 Ozone Monitoring Instrument SO_2 Product (OMSO2 V2): New Anthropogenic SO_2 Vertical Column Density Dataset*" (doi:10.5194/amt-2020-186)

Referees' comments in *Italic*, Responses in blue

Anonymous Referee #3

This paper provide an important documentation for a new global anthropogenic SO2 VCD dataset based on the OMI planetary boundary layer (PBL) SO2 product. It is useful for the air quality and environmental study. The paper described the principle component retrieval algorithm specific for the anthropogenic SO2 in the atmosphere. Conducted dataset quality assessment. Compared with several previous dataset versions. I would recommend that the paper be accept for publication. Following is my comments.

We thank the reviewer for the positive review and comments. We have revised our manuscript accordingly. Please find below our point-to-point response to specific comments.

Comments

1. For the abstract. Authors mentioned several versions of OMSO2. If there is a table in the content listing each versions' characterization that would be helpful?

Thank you for the suggestion. We have added a new table (Table 1) in the revised manuscript that summarizes the main features of different versions of OMSO2.

2. Line 32. It might be better for readers to have a reference about how anthropogenic so2 emission "have significant impacts on the environment".

To our knowledge, there has been a lack of comprehensive, recent reviews on the topic, and we have added a textbook (Seinfeld and Pandis, 2006) as a reference.

3. Line 73. Is it accurate to say the AMFs represent the sensitivity of radiances to SO2 VCD? Jacobians yes. But for AMF, is that just a factor between SCD and VCD? Although it can be affected by a lot of factors.

AMF (-dln(I)/dtau) and Jacobians (dln(I)/dSO2) are connected through SO_2 cross sections, and we can calculate one from the other. SCDs are determined by spectral structures in the radiance data, and they can be viewed as a quasi "measurement" quantity. Given the same VCDs (*i.e.*, identical amounts of SO_2), scenarios with larger AMFs (for example, due to more elevated SO_2 height) will have larger SCDs or equivalently more marked spectral structures in the measured radiances. Thus measurements will be more sensitive to SO_2 when the AMFs are larger, even if the absolute amounts (VCDs) are the same.

4. Line 83~84. Can I understand the new update in the version 2 is the improved anthropogenic SO2 product?

Yes, we have clarified this point in the revised manuscript and changed the sentence to "As compared with OMSO2 V1.3, the volcanic SO_2 dataset in OMSO2 V2 is largely unchanged,

while the anthropogenic SO_2 algorithm has seen some major updates and will be the focus of this paper."

5. Line 117, "SO2 light absorption". Is this a precise expression? I guess you want to say the light (radiance) being absorbed by SO2.

We have changed "SO_2 light absorption" to " the absorption of radiances by SO_2" in the revised manuscript.

6. Line 123, do you want to say SZA>75 degree?

We mean that retrievals are done for all pixels with SZA < 75 that are unaffected by the row anomaly, even if the pixels are flagged for SO_2 and excluded from PCA. We have clarified this in the revised manuscript.

7. Line 173, what does sun-normalized radiances (I) mean? Is that the ratio of the back scattered radiance and the solar irradiance? But in line 181, the "I" has been defined as "Backscattered TOA radiance).

Thank you for pointing this out. Yes, sun-normalized radiance I is the ratio between the measured back scattered radiance at TOA (I_{meas}) and solar irradiance (F), *i.e.*, $I = I_{meas}/F$. In line 181 of the original manuscript, I has the same definition. In the revised manuscript, we have made clarifications. We have also changed the symbol used following Eq. 1 to be more consistent with the rest of the paper.

8. Line 242, Are you saying "within the SAA region of 0-45°, 100°W-5°E"?

Yes. In the revised manuscript, we have changed the phrase to "within the SAA region (defined here as the domain 0-45°S, 100°W-5°E)".

9. Line 404 to 411. In this paragraph, are you comparing version 2 with snow/ice and without snow/ice? If yes, how do we evaluate the retrievals for the two case? By comparing the third party, you tell us, that SO2 retrieval over snow/ice covered surface might be more accurate than not be covered. How about the case of Norilsk in April and in July (starting from Line 394)? In that case, are you expressing that older version with constant Jacobian caused more seasonal change (snow cover and snow free)?

Yes, in line 404-411, we are comparing snow and snow-free retrievals in OMSO2 V2 over China. We have clarified this in the revised manuscript, adding " Both Fig. 7a and Fig. 7b show retrievals from OMSO2 V2, but Fig. 7a is for retrievals over snow-covered pixels and Fig. 7b is for those over snow-free pixels."

We agree that it is important to use third-party measurements to confirm that snow/ice retrievals in winter are indeed more sensitive to retrievals over snow-free areas. In the absence of such data, we have changed the last sentence in paragraph in the revised manuscript. The sentence now reads: "This appears to provide evidence that highly reflective snow/ice surfaces can

enhance OMI sensitivity to emission sources even at relatively large SZAs during wintertime, although a more thorough evaluation using other datasets such as those from ground monitors is necessary before a more definite conclusion can be drawn."

As for the Norilsk case, yes, the larger seasonal changes in OMSO2 V1.3 over the area are likely caused by snow/ice effects in April that are not accounted for with the constant Jacobians. In the revised manuscript, we have changed the second sentence of the paragraph to "The area is usually covered by snow/ice in April but not in July. As shown in Fig. 6c and 6d, there is a large seasonal change in SO_2 VCDs from the previous OMI PBL SO_2 dataset (OMSO2 V1.3), likely caused by snow/ice effects in April that were previously unaccounted for with the use of constant Jacobians."

10. Line 416, when you say the OMI rows, do you mean the cross track number?

Yes, in the revised manuscript, we have added that OMI rows are also referred to as cross-track positions at the first use of "OMI rows" (in section 2.1).

11. Why do you summing up the so2 mass for grid cells' VCD > 0.1? By what reason you selected two thresholds 0.5 and 0.1DU?

As SO_2 retrievals are still relatively noisy, for grid cells with VCDs below the threshold value, we assume that the actual SO_2 signal is too weak to be reliably detected by OMI, and thus we effectively treat them as if they contained no SO_2. This helps to reduce the effects of retrieval noise and small negative biases over certain areas.

To select the threshold value, we consider the typical retrieval noise for a PBL SO_2 profile (~0.5 DU, 1-sigma), and the number of measurements available for averaging each year (~50-100). Through data averaging, we can expect to reduce retrieval noise roughly by the square root of the number of measurements. So averaging 100 measurements would reduce the noise by roughly a factor of 10 (in an ideal case). As a result, we selected 0.1 DU as the threshold.

Since the selection of the VCD threshold is somewhat arbitrary, we also conducted sensitivity tests with different thresholds to see if the overall trends remain unchanged. We found that using a threshold of 0.05 DU did not qualitatively change our results.

We have added the above discussion to the revised manuscript.