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Interactive Comment

Interactive comment on "Retrieval of near-surface sulfur dioxide (SO_2) concentrations at a global scale using IASI satellite observations" *by* S. Bauduin et al.

Anonymous Referee #2

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This is a review of the paper titled, "Retrieval of near-surface sulfur dioxide (SO2) concentrations at a global scale using IASI satellite observations", by Bauduin et al. 2015. In general the paper is well written with a good description of the IASI SO2 retrieval methodology. One main comment that affects many parts of the analysis and interpretation of the new results is the lack of information on the detection limit and sensitivity of the IASI SO2 observations. This needs to be demonstrated and made more transparent in the paper.

Comments: 1) One main comment that would greatly benefit the SO2 research community in terms of using these SO2 IR observations would be to provide more insights on the sensitivity and information being provided by IASI on SO2. Some related questions and comments around this issue include:

a. What do these new IASI global SO2 satellite near surface (anthropogenic) observations provide that are not already being provided by UV/VIS (i.e. OMI, and it the future TropOMI and Tempo)? For example, if IASI is not as sensitive as UV/VIS satellite observations under most atmospheric conditions, however, under ideal IR viewing atmospheric conditions this new retrieval approach provides similar information this should be clearly stated in the paper. Also, is there anything that the IR can (or potentially can) provide that the UV/VIS cannot in terms of near-surface SO2 sensitivity?

b. The paper does state that IASI identifies only "dominant anthropogenic hotspot sources". Being a global scale paper it would be really nice to provide a better sense (or quantification) of this statement. Thus, given the general reduced sensitivity of the IR compared with UV/VIS one would assume IASI on a global scale would generally miss a lot of the near surface SO2 sources. Based on the sources that can be seen, what is an estimate of the detection limit both at a single observation level and on a more general emission source level? For example on a emission source level, the UV/VIS OMI instrument is sensitivity to SO2 sources emitting $> \sim 30$ kt/yr (Fioletov et al., 2015), which corresponds to about half of the global anthropogenic emissions of SO2. GOME2 and SCIAMACHY is estimate at 300 kt/yr (Fioletov et al., 2013). Using the sources shown in Figure 6 and contrasting those with Figure 7 of Fioletov et al., (2013), IASI would appear to more closely comparable to GOME2 or SCIAMACHY. Of the 12 sources described in this IASI SO2 paper, all appear to have emissions of at least 600 kt/yr suggesting this might be a reasonable IASI detection limit. Or, since you are already using the EDGAR emissions inventory, it would be very straightforward to compare the sources you are able to detect with value from EDGAR to estimate obtain a detection limit. That said, there are many large 1000+ kt/yr sources that IASI does not appear to able to detect. This should be mentioned explicitly as well. For example, there are many land-based volcanoes in Indonesia that emit over 1000 kt/yr that are not seen at all, in addition to sources in India and China (as pointed out by the authors).

c. The near surface IASI SO2 product is for a 0-4km layer. For air quality monitoring there is an important difference between being sensitive at 4-km and near the bottom of the boundary layer. It would be good to show from where in this layer the measurement information is coming. One suggestion might be to add a contour plot of the computed Jacobians as a function of height and wavenumber.

d. As this is a global scale analysis another metric to help gauge the sensitivity of IASI to near surface SO2 globally would be to provide the percentage of valid retrievals relative to the total number of global IASI observations from 2008-2014 (shown in Figure 6). Similar to what was shown in Figure 9 over China.

e. Again, the main focus of the paper is global scale near-surface SO2 from IASI. However, the presented detailed comparisons are shown over the highest global anthropogenic SO2 concentration region. To determine the utility of IASI SO2 observations globally it would be good to see the results presented more globally over many regions. For example, since both OMI (likely the current "gold standard" for global SO2 observations) and IASI provide global observations of SO2, why are there not more comparison performed from around the globe under varying conditions. For example, why not also perform the comparison over the Balkhash region shown in the paper?

f. Due to the large high bias in the IASI observations due to its apparent detection limit, the IASI average values are not very representative. One suggestion would be to show a regional spatial map of both OMI and IASI data over the China and Bakhash regions. This would provide the readers with a better sense of the IASI retrievals relative to OMI.

g. Page 11, lines 362-366. Along similar lines to the previous comment, according to Krotkov et al., 2015 there are many moderate to large SO2 sources seen by OMI in these regions (e.g. Figures 6 and 7), which is not consistent with the claims made it this statement. In contrast IASI sees virtually none of these sources (e.g., none in India). Maybe there is good agreement in the global distribution of some/most of the very large emission sources, but this should be clearly stated. The way it is currently written it gives the impression that both instruments have similar SO2 measurement capabilities, which is not the case.

h. Related to comment 1c), the IR and UV/VIS vertical sensitivity to total column SO2 is different. How might this difference in vertical sensitivity contribute to the differences seen in the IASI/OMI comparisons?

i. Pg. 12 lines 394: "It is clearly seen in Figure 8 that IASI is mostly not sensitive to surface SO2..." Maybe better to use "inferred from" instead of "clearly seen" as no information is provided in Figure 8 indicating where IASI is sensitive.

2) Section 3.4.1 on the LUT comparison with an optimal estimation retrieval scheme. Is this section needed? I do see some motivation for comparing a new method with a specific previous one. Provided are the differences between the LUT stated in this paper and the specific OE as implemented and reported by Bauduin et al., 2014. However, to make general statements on the LUT providing better results than OE for low SO2 signals would require more in-depth information. Fundamentally for any SO2 retrieval method the measurement information from the satellite is coming from the same spectra, thus in theory the physical optimal estimation retrieval should be able to provide the same information/sensitivity as LUT. Thus, it is likely that the differences between the methodologies can be attributed to the specific user selected input/assumptions rather than general methodology differences. If the LUT method shows measurement sensitivity under higher water vapour loading conditions, then a well-designed OE retrieval state should also provide this information and not fall back to the apriori. For example, maybe the OE retrieval is over constrained, etc.? One way to help provide additional insight would be to show the resulting spectral residuals for these cases before and after they have been minimized by the OE retrieval. This would show that: (i) there was information in the spectra to begin with, and (ii) the retrievals reduced them down to the noise level.

AMTD
8, C4040–C4045, 2015

3) Page 14, lines 460. less than 20-25% cloud fraction. The cloud fraction is not likely a great indicator in-and-of-itself for species with limited information, the cloud optical depth is more important. For example, 25% pixel fraction from a cumulus cloud might have a large impact on SO2 retrieval. There will also be a dependence on the height of the clouds. Have sensitivity tests been performed to show that a 25% cloud fraction is a good assumption for global IASI SO2 retrievals that have limited information?

4) Pg. 14, line 464-466. For the algorithm comparison it appears the cases selected for the comparison were based on the quality of the LUT retrievals. Does one get difference results if the cases were selected based on quality OE retrievals instead?

5) I am just curious if it would be more precise to attribute the water vapour impacts on the SO2 retrievals to the water vapour continuum rather than just humidity amounts? I would think that it is not likely the interfering water vapour lines, but rather the more broad water vapour continuum that is of more concern from a radiometric perspective for the SO2 retrievals.

6) Section 2.3.2: line 193: In the previous response it was mentioned that comparing a constant and spectral varying emissivity for specified regions are on the order of 0.1K (noise level of the instrument). Since this is a global retrieval, and infrared surface emissivity can vary significantly from the assumed 0.98 value for various surface types, please provide more details on how this is handled in the retrievals. For example, what is the impact of assuming a constant emissivity of 0.98 over different surface types (i.e. desert, water, snow (in winter), etc.)? a. On a related note, on page 11, line 340-345 there is a hot spot 13 over the desert in China. Could this a result of difference in assumed surface emissivity? Why would the plumes only be visible over the desert and not up/downwind of the desert? There is no good reason why OMI would not see this, as OMI is able to see SO2 over the desert (see Figure 7 from Krotkov et al., 2015).

7) It would be good to provide the correlation coefficient for the IASI/OMI time series in Figure 11.

8) Page 16, lines 543-545. To be complete in terms of the trade-offs between the two retrieval approaches some of the main benefits of a OE retrievals should also be noted. For example, robust straight-forward error estimates, direct method for accounting for apriori information in comparisons, sensitivity and information content provided for each retrieval via averaging kernels, straight-forward computation of observation operators for the direct inclusion of satellite retrievals in chemical model assimilations/inversions, etc.

References:

Fioletov et al., 2013, Application of OMI, SCIAMACHY, and GOME-2 satellite SO2 retrievals for detection of large emission sources, JGR, 118, 19, 11399–11418, doi: 10.1002/jgrd.50826.

Fioletov et al., 2015, Lifetimes and emissions of SO2 from point sources estimated from OMI, GRL, 42, 6, 1969-1976, doi:10.1002/2015GL063148

Krotkov et al., 2015, Aura OMI observations of regional SO@ and NO2 pollution changes from 2005 to 2014. Atmos. Chem. Phys. Discuss., 15, 26555–26607, 2015, www.atmos-chem-phys-discuss.net/15/26555/2015/doi:10.5194/acpd-15-26555-2015

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