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Discussions

Interactive comment on "Probabilistic retrieval of volcanic SO$_2$ layer height and cumulative mass loading using the Cross-track Infrared Sounder (CrIS)" *by* David M. Hyman and Michael J. Pavolonis

Anonymous Referee #1

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The authors present a new technique to retrieve SO2 height from hyperspectral measurements from CrIS satellite instrument. Although the results of this study deserve publication in AMT, the paper leaves a poor impression, essentially because it is not written well. There are numbers of comments that should be addressed before the paper can be accepted for publication. I suggest the author improves the structure of the paper, remove unnecessary equations and terms and follow suggestions below.

Comments:

For a non-expert, the paper is very hard to read and does not follow a logical flow. Overall, the paper is written in a way that is not helping the reader. In many places, the text is unnecessary complicated and not concise enough. There are too many unnecessary equations and terminology. Section 2 is hard to digest, the same information can be better described with less words and equations. The probabilistic approach in particular is the novelty of the paper and should be understandable in a simpler way. It should be clear what SO2 height PDFs represent. Is it somehow a propagation of noise/error on the spectra? Is there atmospheric variability accounted also? How can this be linked to the covariance matrix used? This kind of considerations is not well explained and should be clarified. Consequently the added-value of the proposed approach is not obvious, and it is a pity: what sense has a PDF for a metric such as plume height which is in any case an effective estimate for a complex real SO2 vertical distribution? Without a clearer explanation of what this represents, it is hard to judge. This impression is also reinforced by the absence of estimates/discussion on the systematic sources of uncertainties on the retrievals.

-The CrIS instrument is not introduced. Therefore, it is not clear what CrIS is adding new to existing retrievals (from IASI). Basic information such as overpass time, spatial resolution, instrument performance, etc. would be very helpful. Similarly, a small section is needed on the data products used for comparison with CrIS (including references).

-I think Clarisse et al. (2014) is not using a Dirac delta, but rather a prescribed thickness for the SO2 layer. It is unclear at Eq. 3 point if it is what the author suggests. Later it is written that a 1km thickness is used. I find the text of p4 a bit hard to follow. It could be simpler and avoid introducing formulation and Dirac delta if not strictly needed.

-Section 2.2: What is kernel density estimation? The description is difficult to follow: On line 150, the author writes: "We impose a Gaussian prior with mean and variance given by MC sampling using the model columns that make up the Jacobian with noise added." A Gaussian for what? What noise? All information in one sentence is hard to

digest.

-Section 2.3: at l205, the reader discovers that background spectrum and covariance are interpolated spatially. The way section 2 is written is confusing for non experts and the text should be clearer and simpler.

-Section 2.5: here the covariance matrices and mean spectrum are calculated per season lat-lon boxes, etc. It is understood but how is the probabilistic approach implement for each of this season and box, it is unclear.

-Figure 4 is not needed for understanding the paper. Please consider skipping.

-Nothing is said about system uncertainties despite the fact that strong underestimation is found for Raikoke first overpass. Could volcanic ash produces such strong underestimation?

Section 3:

-l 246: the explanation for the lower SO2 columns due to incomplete coverage is very unlikely. Other instruments like TROPOMI have shown huge columns for an area much larger than the CrIS inter-pixels distance.

-Figure 7d,e: Regarding the red curves, "the high noise S-NPP CrIS FOV 7" has not been introduced before and is impossible to understand for someone not familiar with CrIS. Please clarify or skip.

Section 4: comparison with other data sets are shown but without explanation and references. I suggest to add a small section with a presentation of the data sets with necessary details, e.g. what is the overpass time relative to CrIS, spatial resolution, etc.

-Fig 9: TROPOMI is presented for three heights but it is not mentioned what they represent. The Fig 9 is too qualitative (also because of the log scale used). The least would be to show differences or ratios between the retrievals.

-Please use CALIOP throughout the text. Commuting between CALIOP and CALIPSO is confusing.

-On the bimodal PDF in Fig 10 and discussion on l345-355: this is interesting. The author gives two reasons (real feature/artefact of the method) but is not concluding. I wonder to what extend this bi-modal behavior applies to the full plume (not only over the CALIOP track). If this is a significant feature, it might be possible to know if it is real using forward trajectory calculations and CrIS measurements for the next overpass.

-In eq. 25 ".. of SO2 as a Riemann sum". First this equation is trivial, second, what is "Riemann sum" adding here? This paper will be read by scientists used to scientific notation. The paper is full of these and should be simpler.

-Section 4.2: equation 26 is not needed. On Fig 11, the author infer a total mass of 1 Tg while estimate from the VolRes initiative (based on multiple satellites) is of 1.5 Tg. Please explain the discrepancy. I don't understand what the results on e-folding really brings here, expect speculations.

Conclusions

It is written: "Because of the improved spatial resolution over IASI and the technique's sensitivity, we can resolve small clouds that are undetectable by other means ". I'm not convinced. This sentence is not well supported by the paper. First, the reader cannot judge whether CrIS has a superior spatial resolution than IASI because CrIS has not been presented in the paper. Second, it is unclear that the technique has a superior sensitivity than IASI. What would cause this presumable superior sensitivity ? A better instrument or a better retrieval technique? Please remove or elaborate further.

Typos

-l 26: Becasue -> Because

-l 233: the the -> the

-The use of "FOV" is misleading. FOV means field-of-view. Here it is used as satellite overpass or pixels?

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