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Atmospheric Measurement Techniques Discussions

Interactive comment on "SO_2 Layer Height retrieval from Sentinel-5 Precursor/TROPOMI using FP_ILM" *by* Pascal Hedelt et al.

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First of all, many thanks for the detailed feedback and issues found. We provide feedback to each comment in the following:

One main concern, for the specific algorithm, is that it uses wavelengths as short as 310 nm from TROPOMI. While these wavelengths provide higher sensitivity to SO2 and SO2 plume height, straylight at these wavelengths also can impact the retrievals .I wonder how the authors address this in their training?

- It is correct that straylight can introduce spectral features that may lead to bias in the retrieved SO2 LH, but straylight in Band 3 of TROPOMI (i.e. around 310nm) is very small: According to Kleipool et al (2018), see https://www.atmos-meas-

tech.net/11/6439/2018/amt-11-6439-2018.html table 8 and figure 25, bottom left, the in-band straylight after correction is as low as 0,5% (and thus meets the instrument requirements). Also no evidence for out-of-band-straylight in the UVIS was found by the TROPOMI L1 team (pers. comm. Quintus Kleipool)

I'm not sure how the 2 km accuracy stated in the abstract is determined. I assume this is based on results in Figures 2-4? On the other hand, the temporal mismatch between TROPOMI and the primary validation dataset (IASI) makes it difficult to support this accuracy estimate. Also given the difference in TROPOMI and IASI overpass time, some sort of trajectory analysis may help to better link the two retrievals in the comparison.

- The 2km accuracy is determined by applying the FP_ILM to an independent test dataset with known SO2 LH. Du to missing independent plumeheight data (from ground or other satellites) at exactly the same time as the S5p overpass, no other way to determine the accuracy is possible

- Unfortunately we have only limited experience with trajectory analysis models, but we have performed simple particle trajectory analysis using HYSPLIT in which we have started particles at the IASI LH points and followed them until the S5P overpass time. Based on this 'forecast' we will make a collocation IASI-TROPOMI based on closest distance, and generate statistics (correlation, mean, std, ..) in the updated paper. This however works only for extended plumes, i.e. that of Sierra Negra and Ambae. For Sinabung, we are too close to the (active) source to perform a meaningful colocation.

For NRT applications, the algorithm would require input of O3 VCD? How much time is required to retrieve O3? Also can the authors discuss if the plume height algorithm will run all the time or just be triggered by eruptions?

- Yes, the O3 VCD is required to compensate for the strong spectral interference between SO2 and O3 in the spectral range used for the SO2 LH retrieval. The O3 VCD is an operational TROPOMI product and is also used as input for the operational SO2 VCD retrieval (needed to calculate AMFs). Hence no additional time to retrieve O3 would required in the operational TROPOMI L2 retrieval.

- The SO2 LH algorithm should be triggered by the operational SO2 VCD detection flag, which flags pixel showing an enhanced SO2 signal. This can of course be optimized to trigger the LH retrieval above a certain VCD threshold. We will add a paragraph, discussing the possible implementation in the operational TROPOMI retrieval

Page 1, Line 15: oxidation of SO2 also takes place in the troposphere.

- Indeed. We have corrected the sentence slightly

Page 3: Line 30: can the authors give some examples of the parameter grids determined by the smart sampling technique?

- We will add more information on the parameters grid. However, there was a detailed description in the previous paper from Efremenko et al. 2017

Page 4, Line 12: Maybe figure 6 should be Figure 1, since it is discussed before all other figures.

- You are right. We will show Figure 6 first before the other figures

Page 6, Line 10: is there a way to determine which rows should be used for training that would provide optimized retrievals? One would assume that pixels with large SO2 VCDs should be used?

- In principle, an inversion operator for each single row should be trained, since each row has it's own instrumental characteristic. For the detection of a volcanic SO2 plume, we don't know in advance in which detector row it will be detected, so we made the choice of interpolating the plume height results retrieved for every 50th row to the actual row where it was detected.

Figure 1: it is a bit surprising that the error can be larger for really high SO2 VCD (close to 1000 DU), do we know why?

- Note that the figure shows the results for random parameter choices. The large errors seen for really high SO2 VCD is related to a very high SZA in these cases

Figure 1: it is not very obvious from the figure that high albedo values have a negative impact on the height retrievals – why limit training to albedo < 0.5?

- The large ranges of albedo introduces large variations in the spectra (many refelctions from the surface). This additional variations correlate with the variations due to perturbations in the SO2 VCD and LH. Therefore, to make the algorithm more stable, we restrict the albedo range to the physically relevant cases

Figures 3 and 4: add shade to mark +/- 2 km from the "real" plume height.

- Very good suggestion! We will update the figure accordingly

Figure 7: plume height retrievals were also done for pixels with small amount of SO2?

- Yes, we have applied the FP_ILM to all pixels for which an enhanced SO2 signal was detected (there is a flag in the operational SO2 product) are, hence even for low SO2 VCDs with correspondingly lower SO2 LH accuracies. . .

Figure 8: would suggest to only plot TROPOMI retrievals with SO2 > 20 DU.

- We also thought about this, but then one would only see a few pixels and not the entire extend of the SO2 plume

Figure 9: how much can the âĹij30 km retrieved plume height be trusted, if the training data only go up to 20 km (Table 1)?

- It is correct that the any LH result exceeding the training range has probably a high uncertainty. These cases should be treated with different optimized retrieval operator in an operational environment. In this sense we propose a 2-step retrieval: Once extreme values are detected, we switch to a designated operator.

Figure 11: suggest to plot CALIPSO ground track on one of the maps.

- Good idea, we will overplot the CALIPSO ground track

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