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Comment on acp-2021-936

Anonymous Referee #2

Referee comment on "Volcanic SO_2 layer height by TROPOMI/S5P: evaluation against IASI/MetOp and CALIOP/CALIPSO observations" by Maria-Elissavet Koukouli et al., Atmos. Chem. Phys. Discuss., https://doi.org/10.5194/acp-2021-936-RC1, 2022

This paper examines volcanic SO_2 layer height retrievals from TROPOMI using a machine learning algorithm. The authors compared TROPOMI SO_2 height retrievals with co-located SO_2 height retrievals from the thermal IR IASI instruments, as well as the aerosol heights from CALIPSO lidar measurements. Data from several recent volcanic eruptions were examined, including the 2019 Raikoke eruption. The authors found generally good agreement between TROPOMI and other satellite datasets. In addition, TROPOMI SO_2 layer height retrievals were assimilated into the CAMS model, leading to better agreement between CAMS simulations and IASI retrievals, as compared with the baseline CAMS simulation without assimilating TROPOMI data. Overall, this paper provides useful information on the quality of TROPOMI SO_2 layer height retrievals, a new product that can be potentially useful for both aviation safety and research on the climate impact of volcanic eruptions. The topic should be of interest to some readers of Atmos. Chem. Phys. The paper is mostly well organized and the quality of figures is generally good. However, the presentation quality needs to be improved. The paper also lacks in-depth analyses on the causes for the differences revealed in the comparisons. I would recommend major revisions before the paper can be considered for publication in ACP.

Specific comments:

Title: The IASI retrievals are also uncertain and quite different between the two products. Also the CALIPSO aerosol heights may or may not have the same vertical distribution as SO_2. Given the uncertainties in these independent datasets, one may argue that the study here is more of a "comparison" rather than a "validation".

Lines 151-154: With the different overpass times between IASI and TROPOMI, why not use trajectory model to match measurements between different sensors?

Figure 2: Are the integrated profiles based on the same grid cells (i.e., for grid cells that have both valid TROPOMI and IASI height retrievals)? Or is the mass difference between

IASI/AOPP and TROPOMI due to different pixels being integrated? What could be the reason for different SO_2 mass estimates between TROPOMI and IASI/AOPP? Please clarify.

Figures 2 and 3: The distribution of TROPOMI retrievals is more spread-out - do we know why?

Lines 324-325: The comparison sample is dominated by Raikoke - can the authors elaborate how this affects the comparison (for example, correlation coefficient)?

Figure 6: Please specify the thresholds used to filter out CALIPSO weighted extinction height data (clouds?)

Also Figure 6: Are stripes in TROPOMI SO_2 heights due to retrievals or gridding?

Figure 7: Can the authors use different colors for the data points in the right panel based on SO_2 amount?

Figure 8: Can the authors comment on the low correlation between CALIPSO and TROPOMI? Is the correlation coefficient a function of time since the main eruption? Based on Figure 6 and Figure 8, can we draw the conclusion that individual TROPOMI retrievals are not so well-correlated with CALIPSO measurements?

Section 4.2.2 focuses on Sinabung but the discussion (lines 397-405) appears to indicate that the eruption is not an ideal case for validation/comparison using CALIPSO?

Minor comments:

Line 26: What does "3 and 4±3km" mean?

Line 27: Correlation coefficients?

Lines 50-52: The sentence is too long and difficult to follow. There are several other places where shorter sentences may help the readers.

Line 59: What do you mean by "direct validation"?

Line 79: "has been kicked-off" should be "was kicked off".

Line 98: " By thus" should be "By"?

Line 179: These are the conditions under which a retrieval would be considered valid for comparison? Please clarify.

Line 189: what are the "three modules"? Please specify or remove the statement, otherwise it could be confusing.

Line 284: "a kilometre high" refers to the height or thickness of the ash plume?

Line 370 (also lines 380-382): "satisfactory" - means the difference is within the expected uncertainty range of TROPOMI retrievals?

Line 388: "a heights" should be "heights" or "altitudes".

Lines 403-405: Perhaps briefly explain the physical processes that cause the bias in TROPOMI retrievals? I assume retrievals are possible with thin clouds above or below the volcanic plume, but only possible with bright clouds below the plume?

Figure 11: Perhaps indicate in the figure caption that middle panels are for CAMS without assimilating TROPOMI retrievals and lower panels are with assimilation.