Thank you very much for taking the time to review our manuscript. We appreciate your valuable comments and suggestions, and we have addressed each of your concerns in the revised version of manuscript and supplementary material. Please find our detailed response below.

Response to Reviewer 2

Response to Minor Review

Question 1:

It seems during this revision all the GEMS TCO data were updated to V2.0 from V1, and all of the figures were changed. Is the statement "GEMS solar irradiance is 20 % lower than the Dobber et al., (2008) reference spectrum, and shows distinct spatial and seasonal variability" (Lines 527 476, ATC1 version) still valid for V2.0 retrievals?

Answer 1:

The statement "GEMS solar irradiance is 20% lower than the Dobber et al., (2008) reference spectrum, and shows distinct spatial and seasonal variability" remains valid for GEMS V2.0 retrievals since GEMS V2.0 data continues to utilize the same GEMS solar irradiance as in GEMS V1.0.

Question 2:

Line 20: spell out DFS

Answer 2:

We have spelled out DFS as " Degree of freedom of the signal" in Line 18

Question 3:

Line 246: For the study period the ground pixel resolution is 3.5 km x 5.5 km (as mentioned in Line 550)?

Answer 3:

The correct ground pixel resolution for this study period is 3.5 km x 5.5 km, as stated in Line 550. We ensured to make the necessary correction in the revised manuscript by changing 3.5 km x 7 km to the correct value of 3.5 km x 5.5 km in Line 220.

Question 4:

For Pandora data usage, acknowledge statement guideline below is recommended to follow, specifying the location names and PIs (for those in Figure 3; Seoul_YSU, Seoul_SNU, Seosan, Tsukuba, Ulsan, Yokosuka, Busan and Bangkok), if not included in the authors. https://www.pandonia-global-network.org/home/documents/pgn-data-use-guidelines/The PI names are specified in all of the PGN-based output data files.

Answer 4:

We have made the suggested modification to the acknowledge statement regarding the usage of Pandora data. The revised statement now reads as follows:
"We thank the Principal Investigators (PIs) and staff for their effort in establishing and maintaining the Seoul_YSU, Seoul_SNU, Seosan, Tsukuba, Ulsan, Yokosuka, Busan, and Bangkok sites."

Response to Reviewer 3

Response to Minor Review
General comments

Question 1:
The description of the algorithm was not quite clear to me. Is the presented profile retrieval part of the total column algorithm or does it belong to the ozone profile product?

Answer 1:
The presented profile retrieval is part of the total column algorithm.

Question 2:
The comparison to PANDORA, TROPOMI, and OMPS include the period from August 2020 to December 2020. A full yearly cycle would give better picture of the indicated seasonal variability. With the half-year period shown in the paper a seasonal cycle can not be separated from a general degradation effect. Figure 2 shows example distributions from March 2021 so the data might be available.

Answer 2:
We agree with the reviewer's statement that showing the complete annual cycle can provide a better understanding of the displayed seasonal variability. However, as mentioned in the previous response letter, the GEMS dataset used in our paper has been updated from GEMS V1.0 to GEMS V2.0. Currently, NIER (National Institute of Environmental Research) is distributing GEMS V2.0 data from November 2021 onwards. Reproducing the 5-month period of GEMS V2.0 data used in this paper indeed required a substantial amount of time. Including 7 months of GEMS V2.0 data in this study would require an impractical amount of time, as it would involve reproducing the data. The 5-month period used in our study already includes the summer and winter seasons, during which the seasonal bias of GEMS is most pronounced. Therefore, we believe that the 5-month data used in our study is sufficient to demonstrate the bias we intend to show.

Question 3:
In section 3.3 validation of GEMS total ozone with other satellites I suggest to add a figure of the difference between GEMS and TROPOMI or OMPS.

Answer 3:
As suggested by the reviewer, we have added a figure in the revised manuscript (Figure 7) showing the difference between GEMS and TROPOMI or OMPS.

Question 4:
The cloud data are mentioned to have large impact on the total ozone columns. However only the OMPS cloud data are discussed briefly. A full satellite - satellite comparison of the cloud

data is certainly worth an extra paper but brief discussion of the GEMS and the TROPOMI cloud data and why the influence on total ozone is not as strong as for OMPS can be included.

Answer 4:

We have revised the manuscript in line 355 as follows: “The strong anti-correlation between total ozone and clouds can be attributed to the difference in cloud height estimation methods used by the OMPS algorithm compared to GEMS and TROPOMI. OMPS derives cloud height from cloud climatology (Joiner and Vasilkov, 2006) while GEMS and TROPOMI retrieve cloud information from real-time calculated cloud L2 products. The GEMS cloud retrieval algorithm employs the Differential Optical Absorption Spectroscopy (DOAS) method with the O2-O2 absorption band to retrieve effective cloud fraction, cloud centroid pressure, and cloud radiance fraction. On the other hand, TROPOMI utilizes two algorithms for cloud retrieval: OCRA (Optical Cloud Recognition Algorithm) and ROCINN (Retrieval of Cloud Information using Neural Networks) OCRA estimates cloud fraction by analyzing TROPOMI measurements in the ultraviolet and visible spectral regions, while ROCINN uses TROPOMI measurements within and around the oxygen A-band in the near infrared to retrieve cloud top height (pressure) and optical thickness (albedo). For more detailed information on these cloud algorithms, refer to NIER (2020a) and Loyola (2018). For more detailed information on these cloud algorithms, refer to NIER (2020a) and Loyola (2018).

Loyola, D. G., Gimeno García, S., Lutz, R., Argyrouli, A., Romahn, F., Spurr, R. J. D., Pedergnana, M., Doicu, A., Molina García, V., and Schüssler, O.: The operational cloud retrieval algorithms from TROPOMI on board Sentinel-5 Precursor, Atmos. Meas. Tech., 11, 409–427, https://doi.org/10.5194/amt-11-409-2018, 2018.

National Institute of Environmental Research (NIER): Geostationary Environment Monitoring Spectrometer (GEMS) Algorithm Theoretical Basis Document, Cloud Retrieval Algorithm. Incheon, Republic of Korea: Environmental Satellite Center. Available at: https://nesc.nier.go.kr/ko/html/satellite/doc/doc.do (Accessed 13 June 2023). 2020a.

Detailed comments

Question 1:
Check that the date / time format is in agreement with the Copernicus guidelines (also in the figures)

Answer 1:
We have checked the date/time format in both the text of the manuscript and the figures, and we can confirm that it is in agreement with the Copernicus guidelines

Question 2:
page 5 line 123: "treats surfaces, clouds,.. at surface pressure" does this mean you assume clouds to be at 1013 hPa?

Answer 2:
For more accurate descriptions, we have revised "at surface pressure" to "at terrain pressure". We assume cloud to be at terrain pressure, and the impact of clouds is adjusted in Step 3 of the algorithm.

Question 3:
p 5 l 133: "The models proceeds in three steps." i suggest to add something like. "Details of the individual steps are presented below." Like that it is obvious that an overview is given first.

Answer 3:
As suggested by the reviewer, we have revised "the models proceed in three steps" as "The models proceed in three steps. Details of the individual steps are presented below."

Question 4:
p 6 eq 1. λ_{340} instead of λ_{317} ? The description above indicates the wavelength is 340 nm.

Answer 4:
λ_{317} is correct in Equation (1). The reflectivity (R) at the ozone retrieval wavelength of 317 nm is calculated using the linear slope obtained from reflectivity at 340 nm and 380 nm.

Question 5:
p 6 l 161: capital S for "step 2" as for Step 1 and 3

Answer 5:
As suggested by the reviewer, we have revised "step 2" as "Step 2"

***Question 6**:*

p 6 l 174 "0.99 hPa to infinity" although it is clear what is meant here it might be misunderstood as the pressure range from 0.99 to infinity, this includes 1013 hPa and all levels in between. I suggest "all altitudes above the 0.99 pressure level".

Answer 6:

As suggested by the reviewer, we have revised "0.99 hPa to infinity" as "all altitudes above the 0.99 pressure level"

***Question 7**:*

p 6 l 175: the ozone climatology is different from the one in the forward model does this cause any inconsistencies?

Answer 7:

The reviewer does have a point. The issue is simply whether the Jacobians are accurate enough. We don't think this is a big issue, but we've also discussed it here. Ideally, one would iterate the Jacobian calculation like how Xiong's algorithm does. But the error introduced by not doing this is less serious for total ozone wavelengths, and the first guess we use is pretty accurate, to begin with. The one place where I have some concern is at high SZA where the algorithm is truly becoming a profile algorithm. This is an analysis of our long list of things to do.

***Question 8**:*

p 7 l 180 "... SNR corresponding to 320nm is 720." What is meant with 720? consider to skip the last two "words".

Answer 8

720 means that GEMS SNR requirement value for 320 nm. As suggested by the reviewer, we skip the last two "words".

***Question 9**:*

p 7 eq 4: this means the cloud fraction is not taken from the GEMS Cloud Product, why is that?

Answer 9

The cloud fraction in our current algorithm is inherently related to the cloud model we are using. That cloud model is different from what is used in the O2-O2 algorithm. he O2-O2 cloud model is MLER, the V9 model is not. It assumes clouds are non-opaque up to 40% reflectivity. The GEMS cloud fraction will not work in this algorithm.

***Question 10**:*

p 8 l 219: The resolution has been updated in August 2019 to 3.5 x 5.5 km. In the context of the GEMS validation, I would use 3.5 x 5.5 km.

Answer 10.

We utilize TROPOMI data, which has a spatial resolution of 3.5 x 5.5 km. We have revised the value from 3.5 x 7 km to 3.5 x 5.5 km in Line 219.

***Question 11**:*

p 8 l 221: Lerot et al 2021 is not listed in the references. Please also include the TROPOMI total ozone ATBD (https://sentinel.esa.int/web/sentinel/technical-guides/sentinel-5p/products-algorithms, June 2023)

Answer 11:

We have added two references in the revised manuscript as follows:

Lerot, C., Heue, K.-P., Romahn, F., Verhoelst, T., and Lambert, J.-C.: S5P Mission Performance Centre Readme OFFL Total Ozone, Tech. Rep., product version V02.04.01, issue 2.6, available at: [*https://sentinel.esa.int/web/sentinel/technical-guides/sentinel-5p/products-algorithms*] (last access: 13 June 2023), 2021

Spurr, R., Loyola Heue, K.-P, D., Van Roozendael, M. Lerot, C., and Xu, J.: ATBD for Total Ozone Column, S5P-L2-DLR-ATBD-400A, V2.4, issue 2.4, June, available at: [*https://sentinel.esa.int/web/sentinel/technical-guides/sentinel-5p/products-algorithms*] (last access: May 2022), 2022

***Question 12**:*

p 8 l 223: There has been a major update in TROPOMI level 1 data in August 2022. All the data presented here have been processed with the old level data.

Answer 12:

Thank you for the comment. In future GEMS validations, we will use the updated version of TROPOMI Level 2 data.

***Question 13**:*

p 9 l 249: one GEMS scan from the east to the west takes 30 minutes and is performed every 60 minutes, what happens in the 30 minutes between one scan and the next one?

Answer 13:

The GK-2B satellite is equipped with both the GEMS and the GOCI-2 sensor. GEMS and GOCI sensors divide the given 1-hour observation time into 30-minute intervals each. GEMS

scans the earth within 30 minutes from east to west to cover the full field of regard (FOR) of GEMS.

Question 14:

p 9 l 255: "It can also predict future development in the ozone states" I doubt that the GEMS total ozone algorithm can retrieve data from the future. Modify to: "It also gives essential information to models, that help us predicting the future development in the ozone state"

Answer 14:

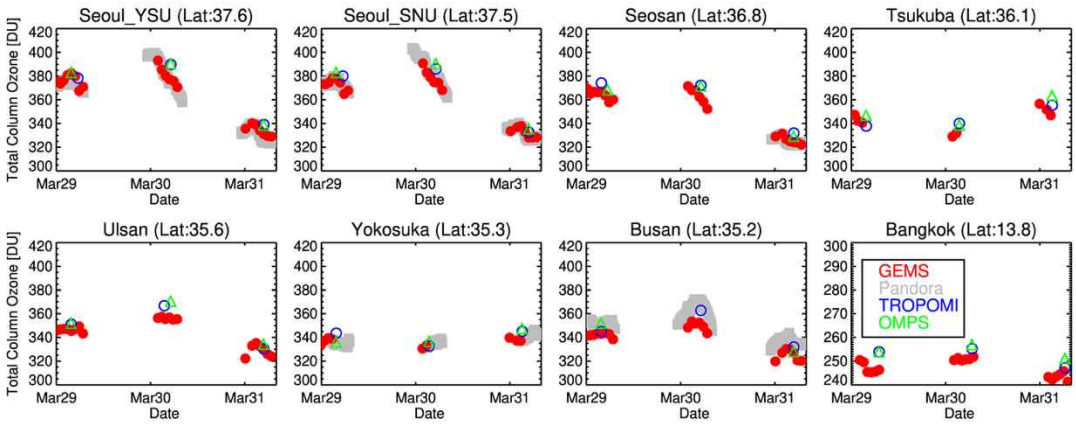
As suggested by the reviewer, we have revised the sentence "It can also predict future development in the ozone states" as follows: "It also provides essential information to models that help us predict the future development in the ozone state."

Question 15:

p 10 l 261 and figure 3: According to the text and the caption also OMPS and TROPOMOI data are include in figure 3 but they are not listed in the legend nor can I see them.

Answer 15:

We have revised Figure 3 to include the OMPS and TROPOMI data as mentioned in the text and caption. The updated figure is attached below.



Question 16:

p 11 table 1 is it worth including some validation results (slope, bias, R2) in the table?

Answer 16:

We have added Table 2 to present the validation results, as recommended by the reviewer.

Table 2. The statistical metrics, including correlation coefficient (R), root mean square error (RMSE), mean bias (MB), and mean standard deviation errors (MSE) comparing GEMS, TROPOMI, and OMPS with Pandora TCO at Busan, Seoul, Ulsan, and Yokosuka sites.

GEMS					
	N	R	RMSE [DU]	MB [%]	MSE [%]
Busan	169	0.97	1.34	0.38	1.25
Seoul	149	0.99	1.32	-1.36	1.08
Ulsan	96	0.9	1.77	0.76	2
TROPOMI					
	N	R	RMSE [DU]	MB [%]	MSE [%]
Busan	101	0.97	1.38	3.96	1.2
Seoul	95	0.98	1.47	2.81	1.34
Ulsan	54	0.9	1.68	3.64	1.97
Yokosuka	42	0.98	1.3	2.45	1.31
OMPS					
	N	R	RMSE [DU]	MB [%]	MSE [%]
Busan	99	0.95	1.34	4.24	1.68
Seoul	88	0.97	1.63	2.96	1.84
Ulsan	58	0.92	1.59	3.38	1.73
Yokosuka	45	0.93	1.8	3.32	2.34

Question 17

p 12 l 306: There seems to be an issue with the Pandora measurements at Ulsan - you state this somewhere later in the text, perhaps it might be worth including it here.

Answer 17:

As suggested by the reviewer, we have added the sentence 'There seems to be an issue with the Pandora measurements at Ulsan' to line 306 of the revised manuscript

Question 18

p 13 l 333: The bias to the PANDORA measurements in Busan differs from the one in Seoul. When looking at figure 5 it seems that the time range is different. Especially the higher values in August are missing in Seoul, does this have an impact on the mean bias?

Answer 18:

As suggested by the reviewer, the Pandora measurements in the Seoul area were first conducted after August 15th, resulting in a difference in the time range between Busan and Seoul. The mean bias between the Pandora data and GEMS for Busan is 3.5 + 1.3 [%]. However, when excluding the values before August 15th and comparing them with the

Pandora data, the mean bias decreases to 2.8 + 0.8 [%], indicating a reduction in bias. The overestimation observed in GEMS during early August is likely related to the volcanic eruption mentioned in the manuscript.

Question 19

p 14 fig. 7 a) use GMT or KST for all plots, for a better comparison. 7b) and 7c) three orbits from TROPOMI or OMPS are shown. so there is certainly a significant time difference between the presented data.
Add the respective overpass times in the caption. Add a delta O3 picture here

Answer 19:

As suggested by the reviewer, the times have been converted to KST (Korean Standard Time), and the respective overpass times of TROPOMI or OMPS have been added to the caption. Additionally, the delta O3 picture has been included in Figure 7 as requested.

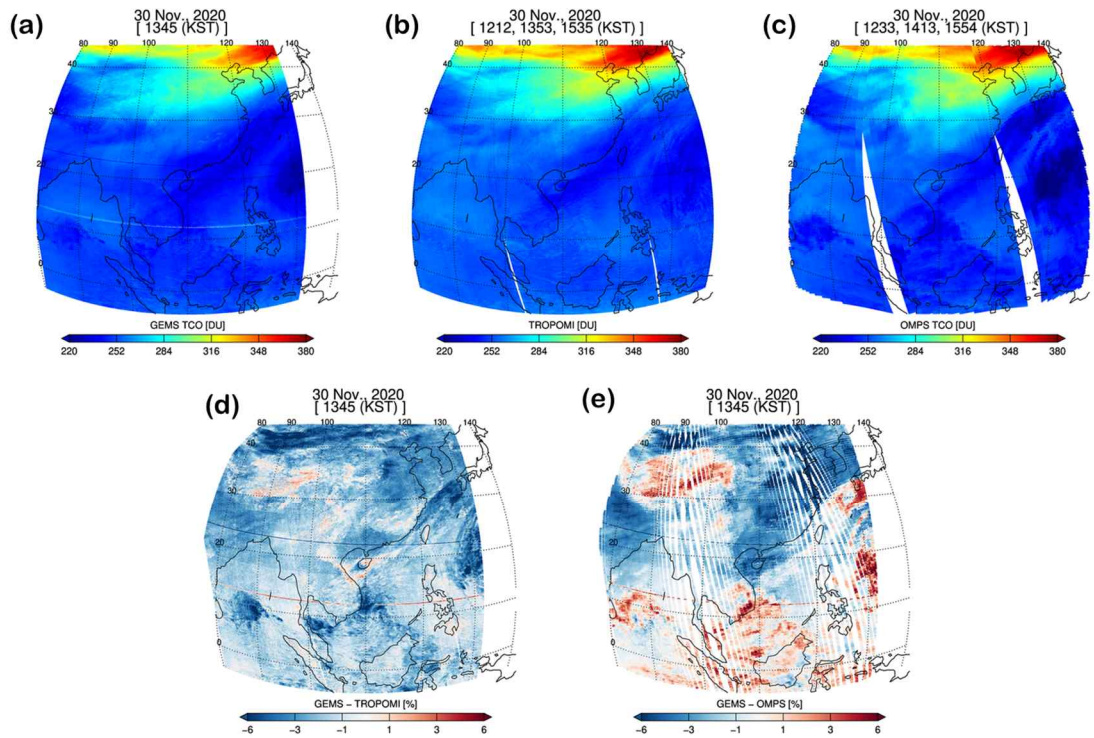


Figure 7. Total Column Ozone maps for 30 November 2020. (a) GEMS, (b) TROPOMI, (c) OMPS, (d) Percentage difference between GEMS and TROPOMI, (e) Percentage difference between GEMS and OMPS.

Question 20

p 15 l 358-360 "The UV measurements ... the cloudy scene." these two sentences contain the same information; one sentence might be skipped.

Answer 20

We remove The UV measurements over the cloudy scene can provide ozone information presented in the upper part of the cloud.

Question 21

p 15 fig 8: include similar cloud data for TROPOMI and GEMS as well, and add the respective references.

Answer 21:

As suggested by the reviewer, the cloud data comparison between GEMS and TROPOMI has been added to Figure 8 as requested.

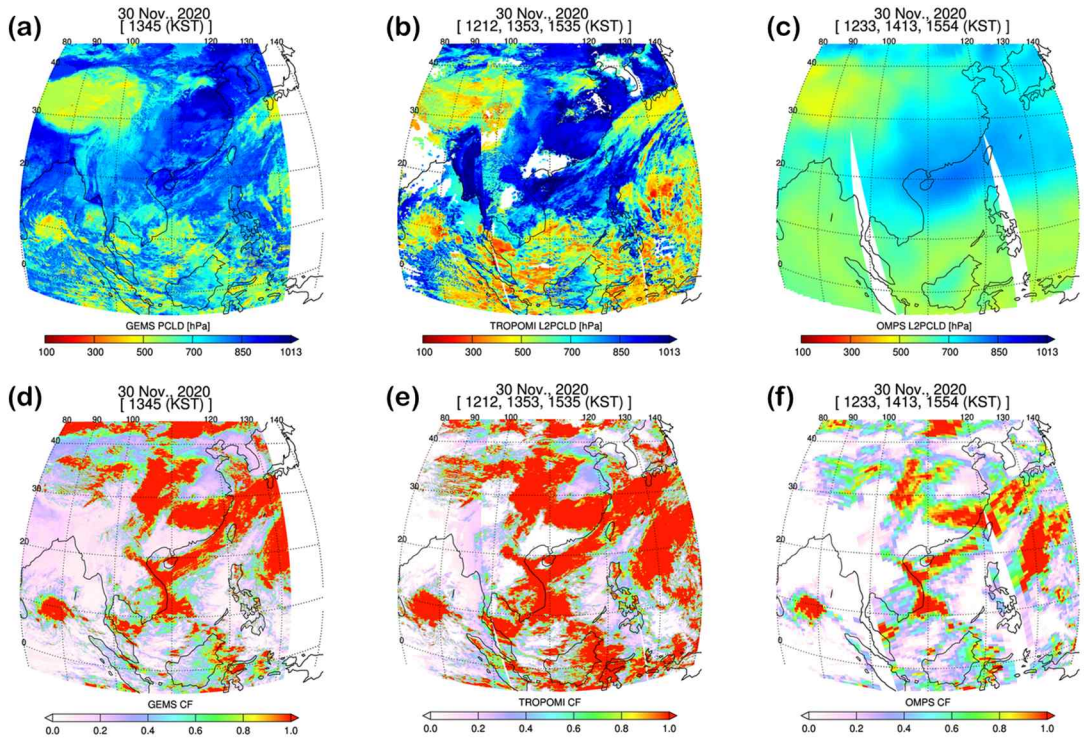


Figure 1 The spatial distribution of cloud pressure and cloud fraction obtained from GEMS, TROPOMI, and OMPS satellite observations on 30 November 2020. Panels (a), (b), and (c) display the maps of cloud pressure derived from GEMS, TROPOMI, and OMPS, respectively. Similarly, panels (d), (e), and (f) show the maps of cloud fraction obtained from GEMS, TROPOMI, and OMPS, respectively.

Question 22

p 17 table 2: the time collocation criteria for TROPOMI and OMPS differ from each other, Is this correct and if so, why?

Answer 22:

The actual collocation criteria used in our analysis is 30 minutes. Initially, a collocation

criterion of 10 minutes was used for TROPOMI due to its higher spatial resolution compared to OMPS. However, it was found that there were fewer matched data between TROPOMI and GEMS covering the GEMS region than anticipated. Therefore, the collocation criteria for TROPOMI was adjusted to 30 minutes, the same as OMPS. The time in the table has been updated to 30 minutes.

Question 23

p 17 figure 10.: when discussing figure 5, a seasonality in the bias was mentioned, in how far is figure 10 affected. Maybe you could generate similar plots for each season and mention the results briefly in the text. Is it useful to show the plots?

Answer 23:

As suggested by the reviewer, generating similar plots for each season in Figure 10 to investigate the seasonality of bias between GEMS and other satellites is indeed valuable. However, in our study, we have already analyzed the bias between GEMS and other satellites based on latitude and season in Figure 12. Considering that we have already addressed the seasonality of bias in terms of latitude and season, we believe that showing additional plots for bias seasonality in Figure 10 may not provide significant additional insights and may result in redundancy.

Question 24

p 18 l 413: perhaps replace by: "Moreover, the dependency increases from August to December"

Answer 24:

Accept

Question 25

p18 l 415: "-1% in August"

Answer 25:

Accept