Thank you very much for taking the time to review our manuscript. During the review process, we have replaced the results analyzed from GEMS V1.0 with GEMS V2.0 data. We found that there were some errors in the LUT calculations used for ozone calculations in V1.0, which could affect the accuracy of the results. Therefore, we replaced all analysis data with V2.0 to prevent any such errors. As a result, GEMS V2.0 shows about a 2% lower ozone calculation result compared to V1.0, and all verification metrics of the analysis results have changed. We apologize in advance for any confusion this may cause.

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 Major Review

Question 1:

Though the authors state that retrieval of diurnal variation (line 15) and providing retrieval error information (line 17) are the features with GEMS, validation and comparisons are not given as a function of time of day and no discussion about the error of retrievals is made.

Answer 1:

We have added an analysis of the retrieval error information and its dependency on the time of day in the revised manuscript. This analysis can be found in lines 330-341 of the main text and in lines 119-142 of Section 3 in the supplementary material:

Question 2:

Only overall "positive" mean bias is mentioned in the abstract but in detail the bias is rather strong negative (up to -6%) for the mid/high latitudes. This is mentioned in conclusion but should be mentioned in Abstract as well.

Answer 2:

As suggested by the reviewer, we have included the negative bias results for mid/high latitudes in the abstract of the revised manuscript. It is located in lines 18-30 and reads as follows:

"To assess the performance of the GEMS algorithm, the hourly GEMS total ozone was compared with ground-based measurements from Pandora instruments and other satellite platforms from TROPOMI and OMPS. GEMS has a high correlation of 0.97 and small RMSE values compared to Pandora TCO at Busan and Seoul. It is notable that despite exhibiting seasonal dependence in the mean bias of GEMS with Pandora, GEMS is capable of observing daily variations in ozone that are highly consistent with

Pandora measurements, with a bias of approximately 1%. The comparison of GEMS TCO data with TROPOMI and OMPS TCO data shows a high correlation of 0.99 and low RMSE compared to TROPOMI and OMPS TCO data, but has a negative bias of -2.38% and -2.17% with standard deviations of 1.33% and 1.57%, respectively. Similar to OMPS, the influence of SO_2 from volcanic eruptions is not properly removed in some regions, leading to GEMS overestimating TCO in those areas. The mean biases of GEMS TCO data with TROPOMI and OMPS TCO are within ± 1% at low latitudes but become negative at mid-latitudes with an increasingly negative dependence on latitude. Furthermore, this dependence becomes more prominent from summer to winter. The empirical correction applied to the GEMS irradiance data improves the dependence of mean bias on season and latitude, but a consistent bias still remains, and a marginal positive trend was observed in December."

Question 3:

Algorithm versions or product names from TROPOMI, OMPS, and Pandora are lacking and thus the results are not traceable.

Answer 3:

"In response to the reviewer's suggestion, we have included Sections 2.3 and 2.4 in the revised manuscript (lines 208-226) to provide information on the algorithm versions and product names used."

2.3 Correlative Satellite Measurements

OMPS was launched in October 2011 on the Suomi National Polar-orbiting Partnership (SNPP) satellite and includes both nadir- and limb-viewing modules. OMPS NM total ozone data (OMPS NMTO3) were used in this study. The OMPS NM is a hyperspectral imaging push-broom sensor with a 110° cross-track field of view (FOV), and 35 cross-track positions. OMPS NM has a 50 × 50 km^2 spatial resolution at the nadir and measures solar backscattered ultraviolet radiation in the spectral range from 300 to 380 nm. The OMPS total ozone algorithm is based on the NASA version 8 total ozone algorithm (Bhartia and Wellemeyer, 2002). We used the operational OMPS-NM Level 2 (L2) version 2.1. As validated in McPeters et al. (2019), the maturity of this product is high with biases of less than 0.2 % when compared to ground-based instruments in the Northern Hemisphere.

TROPOMI was launched in October 2017 on the Sentinel-5 Precursor (S5P) satellite. TROPOMI aboard S5P is a nadir viewing spectrometer that provides measurements in the ultraviolet, visible, near-infrared, and shortwave infrared spectral bands. TROPOMI has a swath width of 2600 km (roughly 104° wide) with a ground pixel resolution of 3.5 km × 7 km (Veefkind et al., 2012). S5P/TROPOMI offline (OFFL) total ozone column products were used in this study which are obtained using the GODFIT version 4 retrieval (Lerot et al., 2021). The algorithm directly compares with simulated radiances through nonlinear least-squares inversion using the sun-normalized measured radiance from 325 to 335 nm. The modeled radiances and Jacobians are obtained with the RTM LIDORT (Spurr et al., 2018). A validation for S5P/TROPOMI OFFL TOC with global

ground-based measurements from April to November 2018 was found to be well within acceptable limits, with mean biases (MB) ranging from 0% to 1.5% and standard deviations between 2.5% and 4.5% for monthly mean co-locations (Garane et al., 2019).

2.4 Correlative Ground-based Measurements

The Pandora TCO retrieval algorithm utilizes a modified version of the Differential Optical Absorption Spectroscopy (DOAS) technique to determine the concentration of atmospheric constituents. In the case of TCO, the DOAS method compares direct solar spectra measured by the Pandora spectrometer to an independent extraterrestrial reference spectrum, which represents the expected solar spectrum in the absence of atmospheric absorption. Through spectral analysis of the measured and reference spectra within the 305 to 328.6 nm wavelength range, the Pandora algorithm retrieves TCO values using a spectral fitting approach, wherein fitting parameters are optimized to minimize the difference between the measured and modeled spectra. Additionally, the Pandora algorithm accounts for the effects of Rayleigh scattering and atmospheric absorption species such as NO_2 and O_4. Technical details about the retrieval algorithm and configuration settings are available in the software manual (Cede 2017). The TCO used in this study was processed and retrieved by using Blick software Suite (version 1.7).

Response to Minor Review

Comment 1:

Line 16. Be clear in which aspect the GEMS retrieval is advanced. Maybe those listed in lines 60-61. Mention them in short here.

Answer 1:

We have clarified the aspects in which the GEMS retrieval is advanced and briefly mentioned them in lines 14-17 of the abstract as follows:

"The algorithm used for GEMS is a more advanced version of its predecessor, the TOMS-V8, that incorporates several improvements, including a new look-up table, a simple Lambert equivalent reflectivity model, and a spectral dependence correction. The GEMS algorithm also uses the optimal estimation method (OEM) to make error analysis more accessible and robust."

Comment 2:

Lines 15 and 17. Results of the retrieval error information should be discussed in the main text. Biases should be analyzed and depicted as a function of time of day, as the diurnal observation capability is highlighted.

Answer 2:

As the reviewer suggested, we have added the validation results of GEMS with Pandora, and the analysis of retrieval error as a function of time of day to account for the diurnal

observation capability of GEMS. These findings can be found in lines 330-341 of the main text, and in lines 119-142 of Section 3 in the supplementary material.

Comment 3:

Lines 21 and 27. Small positive biases and "very well agreement" are mentioned but in reality negative biases for mid/latitudes are found against satellites and Pandora. This should be described with a good balance.

Answer 3:

As the reviewer suggested, we included the result of negative bias for mid/high latitudes in lines 28-31 of the abstract in the revised manuscript as follows:

"To assess the performance of the GEMS algorithm, the hourly GEMS total ozone was compared with ground-based measurements from Pandora instruments and other satellite platforms from TROPOMI and OMPS. GEMS has a high correlation of 0.97 and small RMSE values compared to Pandora TCO at Busan and Seoul. It is notable that despite exhibiting seasonal dependence in the mean bias of GEMS with Pandora, GEMS is capable of observing daily variations in ozone that are highly consistent with Pandora measurements, with a bias of approximately 1%. The comparison of GEMS TCO data with TROPOMI and OMPS TCO data shows a high correlation of 0.99 and low RMSE compared to TROPOMI and OMPS TCO data, but has a negative bias of -2.38% and -2.17% with standard deviations of 1.33% and 1.57%, respectively. Similar to OMPS, the influence of SO_2 from volcanic eruptions is not properly removed in some regions, leading to GEMS overestimating TCO in those areas. The mean biases of GEMS TCO data with TROPOMI and OMPS TCO are within ± 1% at low latitudes but become negative at mid-latitudes with an increasingly negative dependence on latitude. Furthermore, this dependence becomes more prominent from summer to winter. The empirical correction applied to the GEMS irradiance data improves the dependence of mean bias on season and latitude, but a consistent bias still remains, and a marginal positive trend was observed in December"

Comment 4:

Line 115, 21 ozone profiles are mentioned but how this is applied is not very clear, particularly with the statement of "three to ten ozone profiles" in line 152.

Answer 4:

We have clarified how the ozone profiles are used in our analysis and have rephrased the relevant text for clarity as follows:

Lines 117-120 "The pre-calculated radiances are obtained at different solar zenith angles, satellite viewing angles, and reflecting surface conditions (land/ocean, clouds, and aerosols) for TOMS standard ozone profiles that vary with latitude band and total ozone amount (Bhartia and Wellemeyer, 2002, Wellemeyer et al., 1997). Because

GEMS observes only low and mid-latitude regions, a reduced set of 11 ozone profiles of the 21 TOMS standard profiles in our radiance calculations.

Lines 127-129 “Supplementary sections provide an elaborate account of the radiance lookup tables (LUTs) used in the GEMS-O3T algorithm, as well as an evaluation of the errors that arise during LUTs interpolation.”

Comment 5:

Section 2.2.2 and Figure 1. Step 1, 2, and 3 should be mentioned in Figure 1 caption. Maybe red, green and blue parts are the steps, individually.

Answer 5:

As suggested by the reviewer, the caption of Figure 1 was modified as follows:
“Figure1. Flowchart of GEMS-O3T retrieval algorithm, consisting of a forward model for TOA radiance calculation and an inverse model for total ozone derivation. Steps 1-3 are highlighted with pink, green, and blue colors, respectively.”

Comment 6:

Line 216. What is the "situation"?

Answer 6:

We have clarified the situation being referred to in line 254-255.
“The GEMS hourly ozone monitoring system provides continuous updates on stratospheric ozone and its associated atmospheric changes. It can also predict future developments in the ozone state.”

Comment 7:

Line 223. TROPOM

Answer 7:

Accepted.

Comment 8:

Section 3.2. Need to mention algorithm versions or product names for Pandora, TROPOMI, and OMPS. Acknowledgments to the PIs need to be included.

Answer 8:

We have added sections 2.3 and 2.4 in the revised manuscript (lines 208-226) to provide

information on the algorithm versions or product names of the materials used and have acknowledged the relevant PIs in the revised manuscript.

Comment 9:
Table 1. Slash characters are required to separate month and day at several positions.

Answer 9:
We have added slash characters to separate month and day in Table 1.

Comment 10:
Line 251. Remove "However,"

Answer 10:
As the reviewer suggested, we have removed the word "However" from line 251.

Comment 11:
Line 255. This decrease (likely the one shown in Figure 5 and 11) could be seasonal (as mentioned in conclusion) or long-term degrading trend (as implied here)?
(255 Overall, it is important to note that the GEMS TCO decreases markedly over time)

Answer 11:
The use of BTDF-corrected irradiance data has been shown to significantly improve negative seasonal and latitude bias, suggesting that issues with GEMS Irradiance may be the cause of this decrease.

Comment 12:
Line 271. The statement that Pandora uses a fixed-temperature ozone absorption coefficient needs to be checked. In the recent algorithm version 1.8, the products "out2" for example considers the temperature dependence as climatology. For this perspective, mentioning algorithm version/product name is necessary for the traceability.

Answer 12:
We have added sections 2.4 in the revised manuscript (lines 227-235) to provide information on the algorithm versions or product names of Pandora used

Comment 13:
Line 297. Rewrite the sentence starting with "These bad pixels ..."

Answer 13:
We have rewritten the sentence pointed out by the reviewer as follows in lines 353-354. "These bad pixels are expected to be removed properly in the future by using an improved bad pixel mask variable in the GEMS level 1C data"

Comment 14:
Line 332. Are the -0.14 +/- 2.00 % and +0.10+/-2.31% mean biases?

Answer 14:
To clarify the meaning, the sentence was modified in manuscript (388-390) as follows: "Compared to TROPOMI and OMPS, GEMS shows underestimation with a negative bias of -2.38% (6.5 DU) and a standard deviation of 1.33%, and a negative bias of -2.17% (6 DU) and a standard deviation of 1.57%, respectively. It shows that the GEMS TCO agrees very well with the TROPOMI and OMPS TCO."

Comment 15:
Line 344. Perhaps Nishinoshima?

Answer 15:
Accept.

Comment 16:
Line 364. Are the distinct spatial and seasonal variability relevant to the features of the bias discussed here?

Answer 16:
The GEMS irradiance was 20 % smaller than that of the reference spectrum and showed distinct spatial and seasonal variability. The use of BTDF-corrected irradiance data has been shown to significantly improve negative seasonal and latitude bias shown in Figure 12 (The figure number has been updated from 12 to 13), suggesting that issues with GEMS irradiance may be the cause of this decrease.

Comment 17:
Figure 12. No difference is found with Figure 11.

Answer 17:
We apologize for the error in the manuscript. Figure 11 and 12 were identical, and Figure 12 has been replaced with the correct figure (presented below) in the revised

manuscript. The figure number has been updated from 12 to 13 due to the addition of a new figure, Figure 6, in the main text.

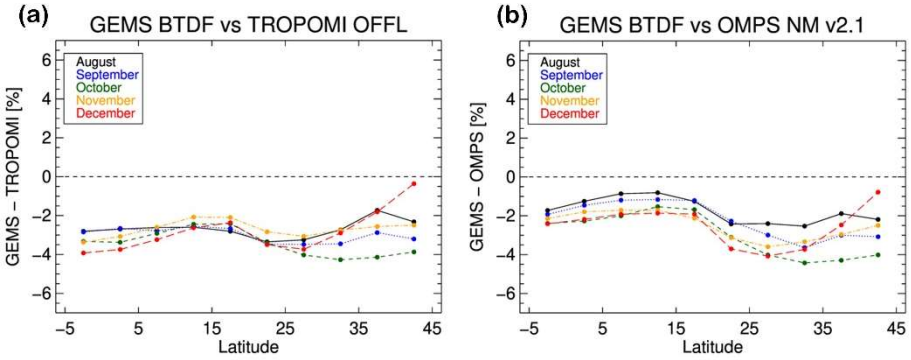

Figure 13. Mean Bias in TCO between GEMS applied BTDF correction and TROPOMI (left), and GEMS and OMPS as a function of latitude and months from August 2020 to December 2020. GEMS retrieval with the algorithm flag equal to 0 or 1, both SZA and VZA <70°.