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 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 #1:

Question: The algorithm that has been developed for GEMS has not been published in the open literature. The algorithm description in the current paper leaves many aspects unanswered. Although it is based on a well-known total ozone algorithm, specific aspects import for a GEO instrument versus a LEO instrument are not addressed. I recommend significantly expanding section 2.2 to include the following aspects:

Question 1:

The algorithm uses a LUT based radiative transfer forward model. Provide an assessment of the error that this LUT based forward model makes wrt an online RTM (VLIDORT) and how this error propagates to total ozone.

Answer 1:

We have added a new supplementary section (Section S2) to the manuscript that provides an assessment of the error of the LUT-based radiative transfer forward model with respect to the online radiative transfer model (VLIDORT), and how this error propagates to total ozone. In section S2, we present the results of comparing the simulated radiances from the LUT-based and online models using a range of viewing geometries and solar zenith angles, which are shown in Figure S2. We also illustrate how interpolation errors may contribute to ozone retrieval errors in Figure S3.

Question 2:

Provide in a supplemental section a full description of the LUT RTM, its dimensions and methods used for interpolating this LUT. Also, I think this LUT and tools to interpolate it should be made available.

Answer 2:

We have included a new supplementary section (Section S1) to describe the process of generating the LUT and the interpolation methods in more detail. We have also included Table S1 to show the overall nodes of LUTs and Table S2 to summarize the variables and dimensions of the radiance and the Jacobian LUTs. Furthermore, we will provide the LUT and tools to interpolate it, which were used in this study, upon request. This provision will ensure reproducibility and facilitate further research.

Question 3:

A unique aspect of GEMS is the hourly observations. However, geometries vary strongly over the GEMS field-of-view. What is the expected effect of the viewing geometries on the vertical sensitivity of the ozone observations? How does the averaging kernel vary of the FOV and over time of the day? This is important information to understand the GEMS observations and the difference with LEO observations.

Answer 3:

Vertical sensitivity of the GEMS total ozone retrievals does indeed vary with viewing geometry as well as other factors such as surface reflectivity and slant-column ozone amount that change from scene to scene and throughout the day as observations in the GEMS region are made at different times, places, and sun-satellite geometry. The reviewer is correct to ask about the averaging kernel specifically since this provides information about the vertical sensitivity of the retrieval and the extent to which the retrieved ozone column depends on the a priori ozone assumptions. The GEMS total ozone algorithm calculates the averaging kernel accurately for each retrieval. The averaging kernel of the GEMS algorithm changes very rapidly at high SZA and similarly with VZA, though less strongly than on SZA. The reflectivity of the underlying surface, which is also retrieved by the algorithm, significantly affects the averaging kernel behavior in the troposphere. For high-reflectivity scenes, such as clouds, the vertical sensitivity in the troposphere is increased down to the pressure of the reflecting surface due to increased reflected radiation. However, sensitivity in the UV to ozone beneath the cloud is reduced, and the averaging kernel reflects this as well as a result of the cloud correction performed in the retrieval. However, vertical sensitivity is due to the fundamental physical limitations of backscatter UV retrieval algorithms in the troposphere, where Rayleigh scattering most significantly, the atmosphere restricts sensitivity. As larger angles of observation, Rayleigh scattering will additionally restrict vertical sensitivity to ozone in the lower atmosphere. The best way to see these effects is by examining the column weighting function, which is derived by summing the rows of the averaging kernel directly. We have included Figure 4S in Section S3 of the supplementary material to illustrate the changes in sensitivity with different observation conditions.

Question 4:

What is the impact of the choice of a-priori ozone profiles and the assumed a-priori errors? This especially important as you are fitting an ozone profile with 11 layers, using only 3 wavelengths. Hence the retrieval is heavily underdetermined and thus depending on a-prior information.

Answer 4:

The sensitivity of the retrieval to the a priori profile is an important consideration. We can directly examine this sensitivity using the column weighting function, which is derived by summing the rows of the averaging kernel. Although all three wavelengths are sensitive to total ozone under most viewing conditions, the shortest wavelength can be more sensitive to the profile and even lose total ozone sensitivity when the sun is low in the sky. The profile retrieval in 11 layers is underdetermined with broad layer averaging kernels. However, the sum of the layers in the retrieval results in an accurate total column amount with a DFS of at least 1 and is therefore not underdetermined. The coarse vertical resolution of the retrieval means that the profile is less accurate than other BUV profile retrievals, where the profile changes rapidly with altitude. However, as shown in our results, and also mathematically, the total column amount obtained by summing the layers of the coarse profile is accurate within the uncertainties reported by the retrieval and depends on a priori information about the same amount as total ozone retrieval techniques.

The influence of a priori on a specific total column retrieval is given by (1-W), where W is the column weighting function. Multiplying (1-$\boldsymbol{W}$) by x_a, the a priori profile gives the actual contribution of a priori to the retrieval, which, of course, depends on the vertical sensitivity of the retrieval provided via $\boldsymbol{W}$. Figure 5S shows a map of (1 - W) (in units of DU/DU) at (a) mid-day when the a priori influence is lowest, and (b) late in the afternoon when it is larger, to contrast the sensitivity at different times of the day.

Question 5:

The abstract leaves out important findings of the validation. Specifically, the time dependent drift and the latitudinal dependent errors shall be mentioned in the abstract.

Answer 5:

We have revised the abstract to include the time-dependent drift and the latitudinal-dependent as follows:

Lines 18-30 "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. Therefore, further investigation into correction methods is needed."

Response to Minor Review

Question 1:

In figure 4 comparisons are shown for GEMS, TROPOMI and OMPS. I propose to include in the figure (or in a supplemental figure) the results of the GEMS-Pandora comparison at the mean overpass time of TROPOMI/OMPS. In this way potential errors that very over the day are not folded into this comparison, and the comparison with TROPOMI and OMPS is much cleaner.

Answer 1:

We have revised the manuscript to include a figure 4 that shows the comparison results of GEMS-Pandora using only the data corresponding to overpass time of TROPOMI/OMPS.

Question 2:

What is the status of the GEMS data set? Is produced by the operational processor and available for users?

Answer 2:

The GEMS V2.0 data used in our study. At present, the NIER website (https://nesc.nier.go.kr/product/). only provides GEMS V2.0 data from November 2021 onwards. However, data production for the period prior to that is expected to be reproduced and made available soon. In the meantime, if you request GEMS V2.0 data for the period August 2020 to December 2020, we can provide it to you personally.

Question 3:

For all datasets (GEMS, OMPS, TROPOMI, Pandora), the version used in work should be clearly documented. When available, the DOI of the dataset should be used.

Answer 3:

We have added sections 2.3 and 2.4 in the revised manuscript (lines 208-226) to provide information on the versions of all datasets used in this study. The DOI of each dataset is also provided in the revised manuscript as follows:

- GEMS data are available through the GEMS Users Data Hub (https://nesc.nier.go.kr/product/), Accessed: [last access: 5 February 2023].

- Copernicus Sentinel data processed by ESA, German Aerospace Center (DLR) (2020), Sentinel-5P TROPOMI Total Ozone Column 1-Orbit L2 5.5km x 3.5km, Greenbelt, MD, USA, Goddard Earth Sciences Data and Information Services Center (GES DISC), Accessed: [last access: 5 February 2023], 10.5270/S5P-ft13p57.

- Richard McPeters (2017), OMPS-NPP NMTO3 L2 V2.1, Greenbelt, MD, USA, Goddard Earth Sciences Data and Information Services Center (GES DISC), Accessed [last access: 5 February 2023], doi: 10.5067/0WF4HAAZ0VHK.

-Pandora data are available through the website http://data.pandonia-global-network.org/, Accessed [last access: 5 February 2023].

Question 4:

Figure 11 and 12 appear exactly the same to me. Is by mistake the wrong figure used in the manuscript?

Answer 4:

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.

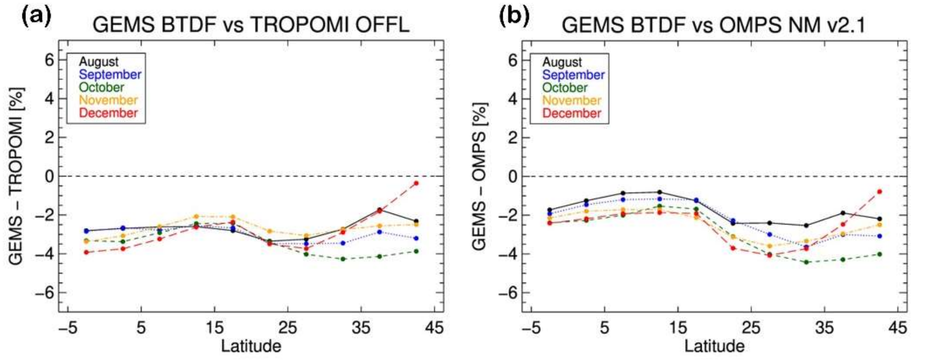

Figure 13. Mean Bias in TCO between GEMS applied BTDF correction and TROPOMI (left), and GEMS applied BTDF correction and OMPS as a function of latitude and months from August 2020 to December 2020. GEMS retrieval with the algorithm flag equal to 0 or 1, both SZA and VZA <70°.

Question 5:

*To overcome issues with the calibration of the solar spectrum, I would suggest processing (part of) the GEMS data with **a fixed solar spectrum**. What is the impact on the seasonality if this?*

Answer 5:

Thank you for the suggestion. We have performed an additional analysis by processing GEMS data with a fixed solar spectrum obtained by convolving the TSIS-1 high solar irradiance spectrum with the GEMS SRF data, and compared the results with TROPOMI and OMPS. The results showed that the negative bias increases similarly to the case of applying BTDF correction. However, a clear positive bias in December was observed in the case of using a fixed solar spectrum, which could be due to the limitations of convolving the TSIS-1 high solar irradiance spectrum with GEMS SRF data. Therefore, we acknowledge the need for further investigation into correction methods for GEMS irradiance.

Question 6:

In the conclusions, the authors mention that the ozone data is expected to improve by improving the GEMS characterization. What is the timeline for this? How is this coupled to public data release and/or version of the GEMS data?

Answer 6:

The timeline for improving the GEMS characterization has yet to be determined, as it is an ongoing effort. We will continue to update the GEMS data as we make improvements. Any updates to the GEMS data will be publicly released with an updated version number and will include a description of changes made. The responsibility for data distribution and version control lies with the National Institute of Environmental Research (NIER), so it should be subject to NIER's decision

Thank you again for your time and effort in reviewing our manuscript.

Sincerely,