Response to Reviewer #4

We appreciate your very meaningful comments.

It gave us a deeper understanding of what we overlooked and didn't take into account, which enriched the manuscript.

General comments:

1. This paper discusses both atmospheric and instrumental polarizations, but some sentences are confusing. Please clarify throughout the paper.

   → Revised, we've clarified to avoid confusion.

2. This study used the pre-flight instrumental polarization sensitivity on the central point of the GEMS instrument. However, it is important to note that the polarization sensitivity can vary with different angles and over time due to different solar and viewing zenith angles. Although estimating the changes in the polarization sensitivity is challenging, it is important to assess whether the algorithm effectively corrects polarization effects on the radiance in real. If it is not easy to do so, it is recommended to provide quantitative values by showing the improvement of GEMS L1B and L2 products after polarization corrections or doing a sensitivity test. Additionally, the limitations of the algorithm should be discussed more when the algorithm is applied to real GEMS data.

   → Yes, that's right. The main purpose of this study is to define the polarization sensitivity of the GEMS in the prelaunch test (although limited information can be used), and to apply the polarization correction algorithm in near real time adopt that atmospheric polarization vary according to the observation geometry. Although the minimum quantitative value that can be polarization corrected was presented, there are still remained uncertainty sources. Therefore, the possibilities that could cause these errors were discussed together. I totally agree about the importance of looking at the impact on L2 product. However, it is hard to run L2 algorithms in the breadth of this study. We plan to analyze it with other L2 developers in the next phase of our future study.

3. The polarization correction algorithm utilizes spectra calculated by one of the radiative transfer models (RTMs), VLIDORT. Since a model is not perfect, it is important for the authors to ensure that VLIDORT simulates Stokes parameters well by providing references. To address this, the author should describe VLIDORT in an independent chapter of Section 3 or somewhere.

   → Revised, We cite references where VLIDORT has been benchmarked and studies that have tested its simulation performance against the GOME-2 PMD, and further describe VLIDORT in Section 3.

4. It is necessary to ensure that the sentences and terms are clear and unambiguous to avoid any confusion for the readers.

   → Revised, we've modified some ambiguous wording to improve clarity.

Specific comments:

Line 29: Is it the polarization axis, not angle?

→ Revised. Polarization axis is right expression.

47: Please provide specific a wavelength region to describe the polarization effects.

→ Revised. Polarization effects within UV-Vis regions.

48: Typo Mischenko -> Mishchenko. Please check all references.

→ Revised.

52: There are TROPOMI and OMPS nadir mappers with the same objectives.

→ Revised, we mentioned OMPS and TROPOMI, and added references.

62-78: Please clarify whether instrumental or atmospheric polarization is referred to here and throughout the paper. For example, the PMD is a device to measure instrumental polarization? However, the authors explained that GEMS does not have a PMD to measure atmospheric polarization states.

→ Revised. PMD measures the fractional polarization of the atmosphere. Wee clarified in the sentence.

126: What does SMA stand for? Regarding one of the general comments, polarization effects with different SMA angles should be discussed.

→ Revised, it denotes "Scan Mirror Assembly (SMA)". I wrote down the full word of the SMA acronym.

128: Please describe the physical meaning of PA like PF.

→ Revised, we explain the meaning of PF and PA.

150-154: Chi is the polarization axis, but chi_LMP is the polarization angle? Also, please explain how the polarization angle (chi_LMP) is calculated by Eq (2).

→ Sorry for the confusion. The description of definitions of ϕ and χ were reversed. ϕ is polarization axis, and χ is polarization angle via IRP.

175-185: Define all notations and their meanings. The quaternion matrix and multiplication might be unfamiliar to many readers. It would be helpful to provide an overall explanation of the quaternion matrix and multiplication in the Appendix.

→ Revised. As you pointed out, quaternions may be unfamiliar to others. We've added a more detailed explanation of what quaternions mean and what was lacking in that paragraph.

189: Figure 3 just shows the overall flow of processes from original GEMS L1B to corrected GEMS L1B, but it does not present the algorithm flow chart. It would be more helpful to show how parameters in Eq (1) are derived using input data in Figure 3. In addition, please provide the meanings of box shapes in Figure 3.

→ As you suggested, I thought deeply about showing how the parameters are derived using each variable, but I think it would be too complicated and confusing to implement it in the flow chart, such as each variable is directly entered into Eq. (1). We would like to keep the current structure. please, confirm. Instead, we modified the "polarization correction algorithm" that was stated in the small square to "polarization correction equation", as it could have been misleading since the whole flow chart means the flow of polarization correction algorithm. And We added the corresponding variable in Atmosphere and Instrument, which are colored red and blue. Perhaps the description of the box shapes you suggested was referring to the red and square boxes, rather than a description of what the shape of each part does in the process, so we added a caption explaining what each box means that related polarization parameters for atmosphere and instrument.

192: In the re-process, the authors use GEMS L2 products for polarization correction, but satellite products have large uncertainty. It is worth considering if the method of using GEMS L2 products can achieve the same performance compared to polarization correction using climatological data.

→ Yes, you are right. We also have a process of reprocessing using L2 output derived from the same pixel, rather than climate data. Although it was mentioned in the main text that this content is not dealt with in depth, as you said, the accuracy and uncertainty of the L2 output should be acquired. In particular, the performance of the L2 cloud will be the most influential during the reprocessing process. In particular, the performance of the L2 cloud will be the most influential during the reprocessing process. We tested using L2 Total Ozone, which has relatively stable and high performance. As already suggested in the text, the change in total ozone amount has little effect on polarization, and the distribution does not change significantly compared to climatology. So, the difference was very small between NRT and reprocess (almost same). Since L2 algorithms are still being improved by developers, it will be possible to improve the reprocessing process through continuous comparison/evaluation in the future.

202: How well does a radiative transfer model including VLIDORT simulate atmospheric polarization effects? Regarding the general comment, it would be helpful to provide a basic description of the model with references.

→ A previous study (Choi et al., 2020) showed good agreement between simulation by VLIDORT and GOME-2 PMD (especially for clear sky).

218: The light could be polarized by liquid water and water vapor, which are abundant in climate and weather conditions. Why are they not considered?

→ In the polarization correction algorithm, the polarization of the cloud area is also considered. While we haven't simulated mie clouds or ice particles, we do have a process for not incorrectly correcting cloud areas by assuming a clear sky. When tested in previous studies, the difference in the change in DOLP between Mie and Lambertian clouds was not significant. The figure below shows an example of a comparison between Mie and Lambertian clouds, along with the cloud height (COD), from Choi et al., 2020.

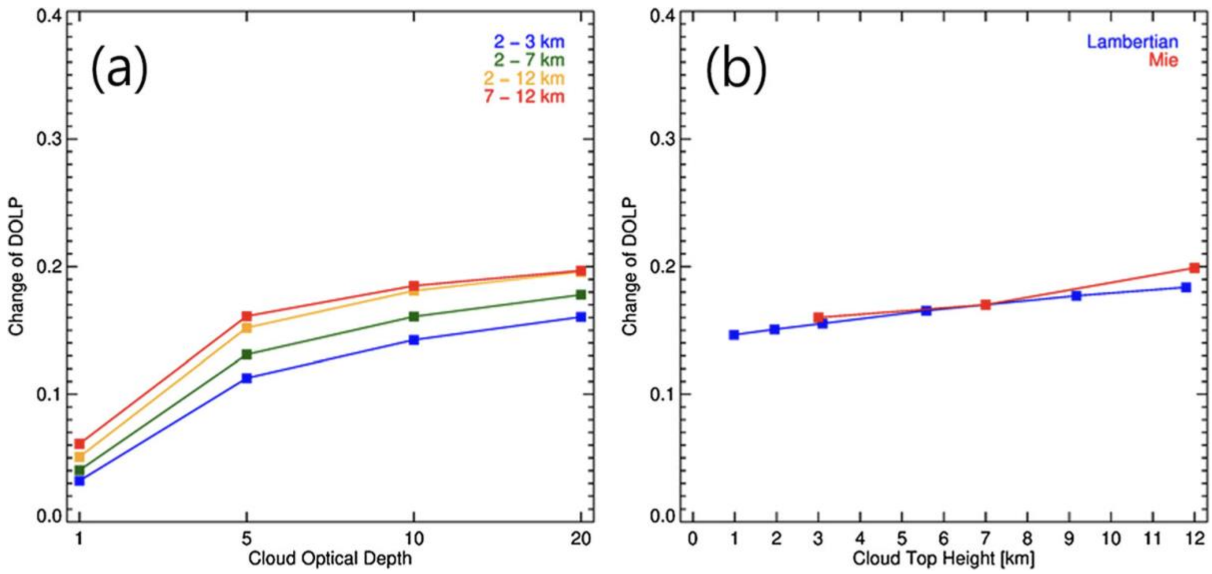

Fig. Average changes in the DOLP across the spectrum (a) for the various CODs and (b) calculated using Mie theory (red line) and the Lambertian top surface (blue line)

229: Can the GEMS slit function be assumed as a Gaussian function? Is there any error resulting from a different shape of the slit function?

→ The SRF of GEMS is close to the Gaussian function. The variation of SRF according to the change of wavelength is also very small. Therefore, the applied Gaussian function (FWHM 0.6nm) is similar to the actual SRF, and the error due to the shape of the slit function is small. Although, it is necessary to reconstruct by applying the actual GEMS SRF in the future.

233: Please define what I_obs and I_true represent.

→ Revised.

283: GOME-2 already has a coarse spatial pixel size of 80 km x 40 km, and it is difficult to achieve a finer resolution than its own spatial resolution. Therefore, despite interpolation to a finer spatial resolution, it does not make the surface LER more accurate.

→ Yes, you are right, as you said, the spatial resolution of GOME-2 is sparse, and even if interpolated to match the resolution of GEMS, it cannot accurately represent the reflectance of each GEMS pixel. In this study, we use climatological GOME-2 LER database as input, but if a GEMS-optimized surface reflectance database is created in the future, it would be good to use it. Thanks for your comment.

322 The normalized radiance is not shown anywhere in this paper, and Figure S2 seems to only show Q and U components without cloud. The authors should clarify a sentence and provide supporting figures.

→ We added the radiance spatial distribution map to Supplements Figure 5. Since we have added a figure for Radiance (I), we have changed in the manuscript from "normalized radiance" to "radiance".

327: It is difficult to distinguish clouds in the figures. Therefore, it is hard to understand cloud effects on polarization. It would be helpful to show clouds in figures.

→ Along the same line to the answer above, we have added an illustration of reflectivity in Supplementary Figure 5. We have defined the region with a reflectivity of 0.2 or less as the clear sky region, which is mentioned in the caption.

Figure 10: The difference is mainly related to interpolation? Rather than interpolation, it seems to be other reasons because the difference is too large.

→ Yes. The most dominant reason for the difference is the interpolation of the LUTs as shown in Fig. 10: the gaps look like a big, but it's actually a 4-digit decimal order difference. As we discuss in the Discussion, linear interpolation causes these small differences and is one of the sources for the residual polarization error.

372: Figure 5 just showed climatological ozone, not diurnal variation.

→ Sorry for confusing. Not Fig. 5, but Fig. 4. Corrected accordingly.

Table 1: Please correct a unit of the spatial resolution (not km).

→ Revised. We modified it to km^2.