## Response to Reviewer #3

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:

Including a discussion on the potential for validation the polarization correction with GEMS observational data would strengthen the discussion. For instance, would it be possible to compare the L1 data with and without corrections to other reference satellites? (Perhaps solar/view geometries could be chosen where the polarization effect is largest). Or could derived L2 products based on the corrected and uncorrected L1 could be compared with ground measurements.

→ Yes, verification of polarization correction is very difficult. We tried to find ways to utilize other reference satellites, as you suggested. We have tried to benchmark our method against GSICS method (of course, we don't think our criteria and method are perfect as GSICS), matching the geometry as much as possible and selecting cloud-free areas to compare with TROPOMI, etc. However, since polarization correction is not the only factor that determines the radiometric accuracy of GEMS, we could not conclude that the difference in radiance spectrum with the reference satellites is due to polarization correction. However, as you mentioned, it is necessary to continue to evaluate GEMS observation using other reference satellites.

Given the limitations in the pre-launch characterization, such as only measuring the center position, and other complexities, were L2-based correction methods considered?

→ A correction based on L2 has not yet been considered. As I mentioned at the end of the paper, I believe that algorithm testing of L2 with and without polarization correction would allow us to track spatial variation in polarization error (especially with products that can be strongly influenced by polarization spectrum feature).

Please clarify what was demonstrated with the actual GEMS data (see related specific comments below)

→ In my opinion, the information we were able to obtain from the actual GEMS data confirms the quantitative variation in polarization error that might have been taken for granted, and suggests that the increased polarization error at dawn and evenging may affect each product. Indeed, the impact of this variation in polarization on L2 needs to be analyzed in future studies, which we plan to do.

Please include more details on the reference frame transformation methodology (see below for detailed comments)

→ Revised. we described it more detail with additional figure for each coordinate in payload.

Specific comments:

35: “high peak of curvature of polarization error”: Do you mean in the spectral region with a sharp spectral feature in the polarization sensitivity? Please clarify.

→ Revised. We have corrected the sentence to make it a bit clearer that the peaks and curvature in the GEMS polarization coefficient cover the high wavelength region.

38: “diurnal variation for the spatial distribution of polarization error confirmed.” My understanding is that the diurnal variation is based on the calculated Stokes combined with the pre-launch measurement parameters, not the GEMS observations.

→ As you know, the polarization error is determined by the combination of the polarization state of the atmosphere and instrument. The DOLP of incident light on the GEMS get varied depends on the geometry at each observation, resulting in a spatiotemporal variation of the polarization error.

58: Could include the spectral sampling here (although I realize it is included in Table 1).

→ Revised. We have added “0.2 nm spectral sampling” to the GEMS spectral information description .

62: I think along with accuracy, stability should be emphasized as well, since, with a polarization-sensitive instrument, the diurnal signal can change as the solar/view angles change throughout the day.

→ Revised. As you suggest, we agree that the accuracy and stability of the observations are important factors in the output. We've added "stable" to the sentence.

93: This statement makes it sound like VLIDORT is the only RTM that can perform RTM in this spectral range. Perhaps more justification can be offered by citing some associated validation work for the model.

→ Revised. We cited references that did comparative verification work with VLIDORT (Escribano et al., 2019; Korkin et al., 2020). Further, we additionally cited the paper on VLIDORT's simulation uncertainty in the last discussion section (Castellanos et al., 2018).

131: Aside from a lower signal from off-nadir positions, could the polarization sensitivity vary as well depending on scan mirror angle?

→ Yes, it can also change according to the change of SMA. (For example, PF and PA can be slightly different for the E/W direction by changing the SMA. Although such a test was not performed in the polarization test of GEMS, according to the model result according to the angle change provided by BATC, the change according to E/W direction was very small even N/S direction were slight high; See below figure). But, the exact result is not known because it was only the result of the model and not the actual measurement result.

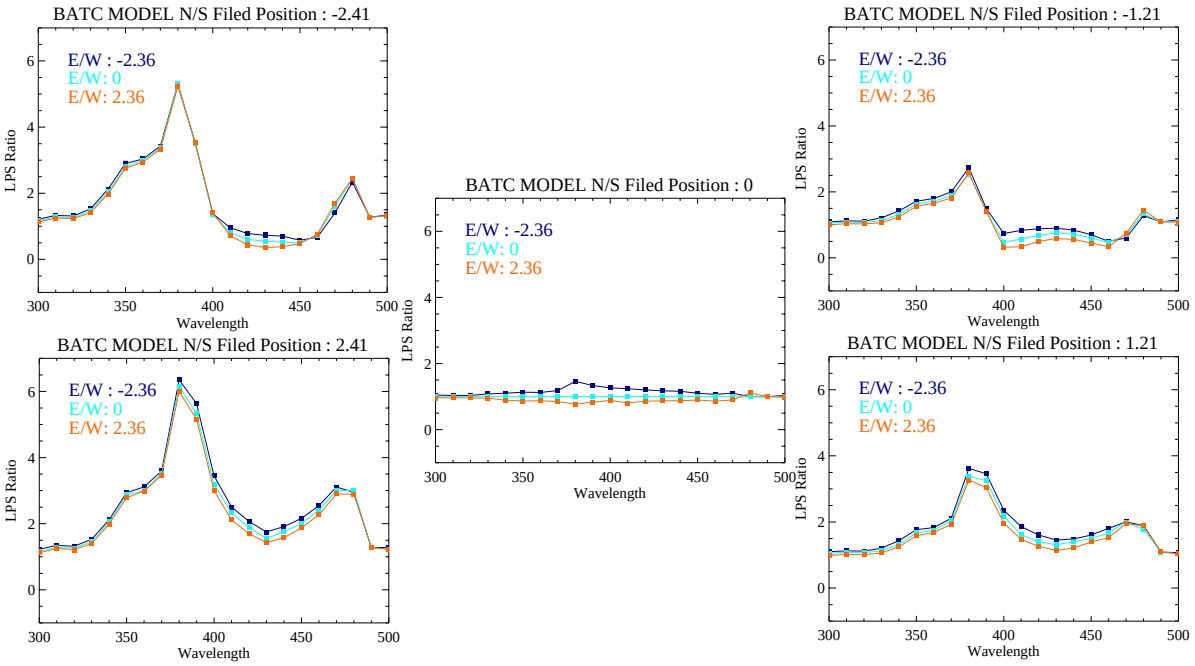


Fig. The variability of LPS(=PF) ratio with regards to E/W and N/S direction. The results are from BATC model. It didn't include in manuscript, but you can check it out for reference.

133: “ideal state” is a bit confusing. I recommend removing this sentence.

→ Revised. Yes, the expression “ideal” seems a bit confusing because it is a result measured under limited conditions. We removed that sentence.

160: Please provide more description on reference frame transformation methodology. For instance, it is not clear to me what the difference is between the instrument and boresight reference frame. Some suggestions:

A figure showing the geometry including definitions of the various reference frames. A working example (maybe as an appendix if the authors feel this breaks up the flow too much)

→ Revised. In the supplement, we have attached an image of the coordinate system that is transformed to define the reference frame in each part of the payload, even though the coordinate axis that defined the local meridian plane is not the same as the coordinate axis that defined the local meridian plane. (However, the details have been reinterpreted and simplified due to the confidential issues).

200: “with assumed cloud albedo to be 0.8” to “with an assumed cloud albedo of 0.8”

→ Revised.

Figure 3: spectral range is slightly different than the GEMS spectral range. Perhaps make them consistent or explain the discrepancy.

I think you meant Table 3. We simulated the RTM for LUTs with an additional 10 nm at each end of the GEMS spectral range. For consistency and to avoid confusion, we have noted it to 300-500, which corresponds to the GEMS spectral range as you suggested.

244: These statements are a bit confusing to me. In the previous section, the sensitivity of TOA radiance to ozone was shown to be smaller than the other parameters considered. Here, the authors state that polarization sensitivity plays a crucial role for ozone. Can you clarify?

→ Fig. 4 shows the effect of each parameter on polarization error change with both the polarization state of the atmosphere and instrument considered. This is not to say that ozone does not affect polarization (the change in DOLP with and without consideration of ozone in radiative transfer models is large and significant compared to other trace gases). Since polarization is primarily affected by scattering, the change in polarization error with ozone accounted for was relatively small compared to other variables such as geometry. This suggests that we may be able to reduce the dimensionality of the LUT (e.g. using fixed total ozone amount) in the future to improve the effectiveness of the calculation.

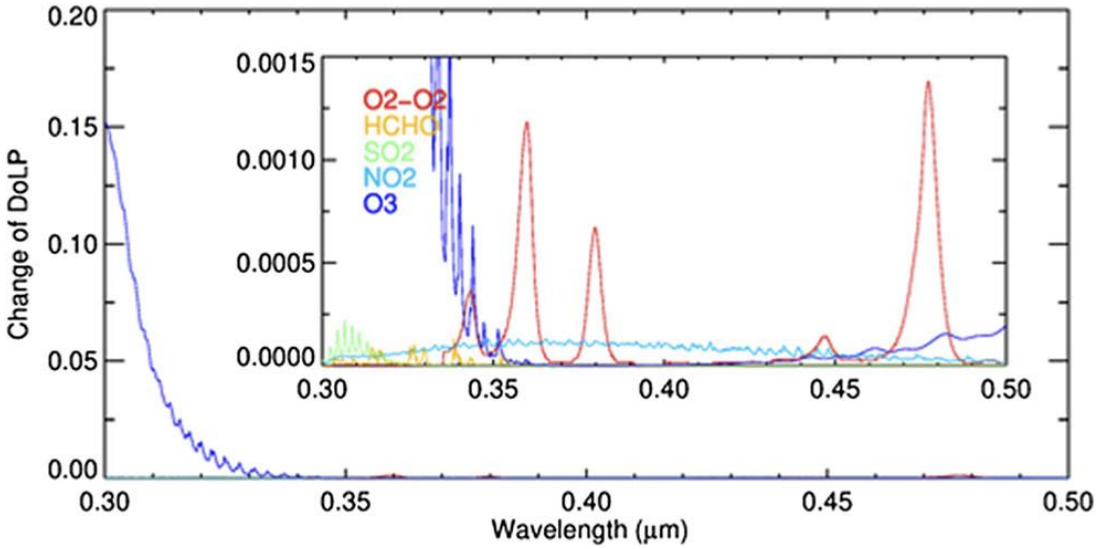


Fig. The changes in the DOLP simulated for the molecular atmosphere when each ofO3, SO2, NO2, HCHO, and O2-O2 is individually neglected.

276: Perhaps change “ideal” to “complete” or “comprehensive”

→ Revised

322: Figure S1 and S2 seem to be missing.

→ Figure S1 and S2 are presented in ‘Supplement file’. Since another figure was added, it is moved to Fig. S3 and S4.

Fig. 6: The degree of linear polarization used seems low. Was the solar geometry limited to around noon? Please add more details about the times of day/solar angle ranges, since this would greatly impact these values.

→ Yes, the synthetic data was simulated for the January 15, 2016 at 03:00 UTC. It is the noon time zone at Seoul. We have also specified the time information in Figure 6.

323: What RTM input parameters were used to simulate the clouds?

→ Clouds were simulated assuming a Mixed Lambertian cloud rather than a Mie cloud. OMI LER was applied for surface reflectivity, and GEOS-CHEM simulations were used for trace gases (O3, NO2, SO2, HCHO).

330: "exhibit sharp curvature in PF." Can you explain the significance of your choice of wavelengths. Do you expect larger errors due to the instrument's spectral sampling over these features?

→ As shown in Fig 9, the sharply increasing polarization error near certain wavelengths (349.6, 432.0, 454.6, and 494.8 nm) is reflected in the shape of the overall observed radiance spectrum, which can affect the results of retrieval using those wavelengths. In particular, errors in the radiance spectrum can be more significant when using the specific wavelength bins presented rather than utilizing a broader range of spectra. We believe that the sampling interval (0.2 nm of GEMS) allows polarization errors due to variations in these wavelength-dependent polarization errors to be more finely reflected in the observed spectrum.

354: What are "dump points"?

→ We agree that "dump point" is not a common phrase. We changed the wording to "raggedness points".

358: It would be interesting to understand the impact of the pre-launch measurement uncertainty on the polarization correction. Perhaps the authors could mention that this was not considered or that it will be considered in the future if that is the case.

→ Prelaunch measurement uncertainty has not been considered, so this may be a future consideration. The paragraph was unnecessarily descriptive and somewhat confusing, so we have added to future considerations in the Discussion.

Fig. 11, 365: Perhaps it would be helpful to clarify that you are plotting the ratio in Eq 1 as a percent difference (if that is the case).

→ Revised, we clarified that polarization error is Percent difference.

Technical corrections

358: typo: change "shist" to "shift"

→ Revised.

91: Recommend changing "comprised" to "included"

→ Revised.