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Atmospheric Measurement Techniques Discussions

Interactive comment on “Evaluation of ozone profile and tropospheric ozone retrievals from GEMS and OMI spectra” *by* J. Bak et al.

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Response to General Comments

The manuscript “Evaluation of ozone proïňĄle and tropospheric ozone retrievals from GEMS and OMI spectra” by Bak et al simulates measurements for the proposed Geostationary Environment Monitoring Satellite instrument from OMI level 1b measurements in order to analyse ozone retrieved from them. GEMS is expected to measure earthshine radiance from 300-500nm, whereas OMI currently measures between 270-500nm. The manuscript assesses the impact of this shorter wavelength range (and other sub-ranges) on the retrieval of ozone in the troposphere and stratosphere. It would be expected from ïňĄrst principles that without the spectral information from the

Hartley Bands <300nm information about stratospheric ozone would be reduced. The authors use properties of the averaging kernels (AKs), a measure of information content and retrieval error to demonstrate how the retrieval is affected. They then evaluate the retrievals against MLS ozone proïňĄles in the stratosphere. The impact of the restricted wavelength range of GEMS on ozone proïňĄle retrieval is very important to establish, both for satisfying the mission requirements and for future reference. It is anticipated that there will be extensive comparison to other satellite products that are scheduled to be operational at the same time as GEMS (not least those from MetOp and Sentinel 5 Precursor/Tropomi). Overall the manuscript satisïňĄes its objectives, and the study of how a change in wavelength range affects the retrieved ozone proïňĄle for this type of instrument is a useful one beyond just GEMS. \

Comment: it is important to clearly distinguish whether ‘tropospheric ozone retrievals’ (used frequently) are tropospheric column retrievals or tropospheric profile retrievals, i.e. what is the final product that is compared. Based on the AKs shown in Figure 2 it is apparent that a proïňĄle is retrieved in the troposphere, and yet a tropospheric column or just tropospheric ozone is referred to in the text. More clarity is needed so that conclusions drawn in the manuscript about comparative tropospheric ozone for GEMS and OMI are more meaningful.

Response: According to reviewer’s suggestion, we have revised the text to usage of the tropospheric ozone and profile retrievals for clarity.

Revised Text (p. 6734, line14): both tropospheric ozone profile and column retrievals Revised Text (p. 6741, line32): tropospheric column ozone retrievals Revised Text (p. 6747, line2): this exclusion makes little difference in both retrieval sensitivity and the retrieval error for the tropospheric ozone profile/column retrieval.

Comment: It is stated that tropospheric retrievals are no worse than OMI for the curtailed wavelength range, but it would be an improvement to give an indication to the reader of what OMI is capable of in terms of retrieval of ozone in the troposphere. This would entail at the very least a reference to a paper that evaluates tropospheric ozone derived from OMI measurements.

Response: In Fig. 1, we actually showed the capability of OMI retrievals (270-330 nm) in terms of DFS in the troposphere and stratosphere and retrieval errors in tropospheric/tropospheric ozone columns. In Fig. 2, we showed two examples of OMI retrieval averaging kernels with the spectral range of 270-330 nm. In the revised text, we have added some descriptions about the ability of OMI to provide the tropospheric ozone information in the section of introduction for the readers

Added text (p.6736, line 12) Liu et al. (2010a), for example, demonstrated that OMI measurements contain up to ∼1.5 degrees of freedom for signal in the troposphere, and the retrieval error of the tropospheric column ozone is normally within 2-5 DU (5-20%).

Comment: For example, the last line of section 3 (ending in 'OMI experience') does not indicate whether fitting to 3% is good or bad. For example, is it larger or smaller than the standard deviation of the ïňĄt residuals? In general I would not think it sufficient to state that something is as good as OMI in some way but not even indicate how good OMI is.

Response: The "3%" was misprinted and should be "3" as the unit of fitting residuals defined here is dimensionless. The fitting residual is defined as the root mean square of fitting residual relative to measurement error and we changed the terminology to "fitting RMS". An ideal fitting RMS is around 1 assuming the used OMI measurement error is correct. But it can be less than 1 if the measurement error is overestimated or greater than 1 if the measurement error is underestimated (often at high solar zenith angles) or if the fitting is not good. We tried to remove those retrievals with fitting RMS greater than 3.

Revised text (p. 6740, line 5): We limit our study to solar zenith angles less than 85°N and retrievals with fitting RMS (i.e., root mean square of fitting residuals relative to

measurement error) less than 3.

Response to Specific Comments

Comment #1: It would have been clearer to indicate in the title the fact that GEMS is a mission in preparation or that these retrievals do not represent a final or real product from GEMS and some assumptions or approximations have been used to simulate them. It is a minor editorial point though, as it is soon evident from the abstract that this is the case, and may be superseded by the need for brevity. Response #1: GEMS is the name of an instrument to be launched on board the GeoKOMPSAT (Geostationary Korea Multi-Purpose SATellite) in 2018. We prefer to keep the present title as we mentioned it in the first sentence of the abstract. We have changed the first sentence of the abstract to: Korea is planning to launch the GEMS (Geostationary Environment Monitoring Spectrometer) instrument into the GeoKOMPSAT (Geostationary Korea Multi-Purpose SATellite) platform in 2018 to monitor tropospheric air pollutants on an hourly basis over East Asia.

Comment #2: Page 6742 line 13 it is stated that the errors increase by 1-2% for most of the stratosphere and 3-4% above 40km, compared to OMI. This is an ambiguous statement, as it implies that this percentage change is the change based on the OMI retrieved error. Figure 2 shows that in absolute terms the retrieved error actually doubles above 3hPa compared to OMI.

Revised text (Page 6742 line 13): The GEMS profile retrieval errors increase by ∼ 1-2% (from 2% to 4%) for most of the stratosphere and by 3–4% (from 3-4 % to 6-8 %) above 40 km. Above 30 km, the error increase is significant as the retrieval error almost doubles.

Comment #3: In the abstract (page 6734 line 16) and section 4 (page 6740 line 18), the information content is defined as the degrees of freedom for signal, derived from summing along the diagonal of the averaging kernel (although this is not the only measure of information content). In addition to the measurement vector, the DFS is also heavily dependent on the prior covariance (and the state itself), and while these are accepted as being the same for the OMI and GEMS retrievals for this simulation it would be fairer to mention that it is both an estimate and that it is dependent upon more than just the spectral range of the measurement, particularly when the measurement noise for the proposed instrument has only been estimated. As such it is a little strong to state that should the diagonal value of the AK be 1 the measurements have 'perfect' information for ozone at that layer. Even to have something like perfect information this might not necessarily imply you have perfect retrieval knowledge, or that you can know the ozone in that layer with perfect accuracy or precision. The terms 'appropriate' or 'sufficient' would be better.

Response #3 We agree with the reviewer's comment. We have added that "It should be noted that in addition to the spectral range, the AK matrix also depends strongly on the assumed a priori covariance and the measurement error, both of which are assumed to be the same here for both OMI and GEMS measurements." in page 6740 line 20 before "When ". We have changed "stratospheric ozone information" to "stratospheric ozone information in terms of DFS" in the abstract and "perfect information "to "sufficient information" in page 6740 line 21.

Comment #4: Title of Section 5.2 (page 6744) should be 'Comparison of stratospheric proïňĄles' to avoid ambiguity.

Response #4: We have changed it to "comparison of stratospheric profiles"

Comment #5: Section 4 (page 6740 line 30) it is worth considering that if the sub-column prior constraint for both the OMI and GEMS proïňĄles in the stratosphere is relatively small, then the sub-column retrieval errors will also remain very small irrespective of spectral range has been used and other than the reduction in DFS it would reveal little about how the retrieval has been affected on its own.

Response #5: It is not clear about where the reviewer point out as there is no line 30 on page 6740. However, we have corrected the associated text.

Added Text (p. 6742, line 17). It should be noted that despite GEMS's very weak vertical sensitivity above $\sim$25 km based on averaging kernels, the increases in retrieval errors appear to be small. This is because the a priori error for this altitude range is already very small (5-7%), the retrieval errors also remain very small irrespective of spectral range and the comparison of retrieval error might not reflect all the impact of reduced spectral range.

We have deleted the last sentence of section 4: "The reduction of the spectral range thus has some impact on the quality of the stratospheric ozone profile retrievals from GEMS" as it becomes inconsistent with some of the added text.

Comment #6: Page 6747 line 2. While it is clear that there is 'little difference for tropospheric ozone retrievals' using the proposed GEMS wavelength range compared to OMI, elsewhere it is stated that the bias in the UTLS is affected. Unless your tropospheric ozone column is retrieved via a different scheme it follows that any impact on the UTLS potentially impacts the tropospheric column and the stratospheric column, so there is a minor inconsistency here.

Response #6: Note that for middle and high latitude, 68-215 hPa are in the lower stratosphere. For low latitude, 68-215 hPa contains both lower stratosphere and upper troposphere (mostly in the troposphere). According to Figure 5, the 68-215 hPa column ozone is about 15 DU, 75 DU, and 145 DU, respectively. The ozone column is much larger in the middle and high latitudes.

Revised Text (p. 6745, line 26 $\sim$ p. 6746 line7): The GEMS performance for the middle column O3 slightly increases the positive biases by $\sim$ 0.8 DU (0.4%) at low latitude and $\sim$ 4 DU (1.5%) at mid/high latitude in relation to OMI. For the lower column O3, the largest difference between OMI and GEMS with MLS is at mid latitude: mean biases increase from -9.1 DU ($-13.$ %) for OMI to -15.5 DU (-20.8 %) for GEMS. The high latitude also shows the significant increase in the absolute mean biases from -7.9 DU to -12.2 DU. In contrast, the low latitude mean biases increase by 0.5 DU (3 %) due to the exclusion below 300 nm. In this pressure range, the ozone is mostly retrieved in the upper troposphere in the tropics and is in the lower stratosphere at mid/high latitudes. In addition, the lower column O3 is much smaller in the tropics than those at middle and high latitudes. Therefore the mid/high latitude lower O3 column is more strongly impacted by the exclusion below 300 nm than the low latitude. Overall, the impact of the 270 to 300 nm spectral information on retrieval is found to be larger in the lower column O3 than middle column O3 despite the negligible difference in the retrieval sensitivity around the tropopause between OMI and GEMS as shown in Fig. 2. This is because the relative a priori error (thus the retrieval error) for the lower O3 column is significantly larger than that for the middle column O3.

Revised Text (p. 6746, line 13): the SCO negative biases might be largely contributed by the retrievals in the tropopause region. Revised Text (p. 6748, line 1-3): Even for below 3 hPa, some improvements are found. However, the ML climatology tends to increase the differences between retrievals and ozonesonde measurements generally in the upper troposphere and lower stratosphere (UTLS) compared to the LLM climatology (not shown here). Revised Text (p. 6748, line 7): but GEMS has larger biases, especially at mid latitudes.

Comment #7: Page 6747 line 22. Another way to interpret the statement that GEMS proïňAles above 3hPa would be improved if a better prior were used, is that it would just be returning a better prior (particularly when compared to MLS which also comprises the prior). In that case the retrieval itself is not necessarily improved. It might be more appropriate to retrieve fewer, deeper layers above this, but it is a good result to establish the useful vertical limit of the retrieved proïňAle .

Response #7: We agree with what the reviewer suggests. In order to make it clear we have revised the text as follows.

Revised Text (p. 6747, line 19-22). Because GEMS contains little vertical information above 3 hPa as shown in Figure 2, comparisons at layers above 3 hPa show large de-

pendence of GEMS retrievals on a priori (LLM climatology), with the large differences corresponding to large differences between a priori and MLS. This suggests that the large GEMS ozone biases above 3 hPa can be reduced by using better a priori information.

Comment #8: Figure 2. It is hoped that this would appear bigger in the final PDF. At present it is far too small to read all of the information on the panels without some difficulty. Typographical Corrections: Page 6741, line 10, ‘erros’ should be ‘errors’.

Response #8: We will try to make this figure bigger in the revised version. We have changed English in the revised version according to your suggestion.

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