Atmos. Chem. Phys. Discuss., 15, C8343–C8349, 2015
www.atmos-chem-phys-discuss.net/15/C8343/2015/

Atmospheric Chemistry and Physics Discussions

Interactive comment on "An online aerosol retrieval algorithm using OMI near-UV observations based on the optimal estimation method" *by* U. Jeong et al.

U. Jeong et al.

jkim2@yonsei.ac.kr

Received and published: 22 October 2015

Referee: 1

We reflected all the comments by the reviewer. The criticism and suggestions by the reviewer were appropriate and improved the quality of our manuscript. We appreciate such efforts.

The authors developed an online version of OMI near-UV aerosol retrieval algorithm using the optimal estimation method. The results provide useful information on retrieval algorithm of aerosol and uncertainty evaluation of inversion products. Overall this is an

interesting piece of work and appropriate for the journal. However, some minor revisions along the lines suggested below are requested. I would suggest this paper be published with revisions. 1. In order to emphasize the merit of OE-based algorithm, the AOT and SSA from the operational OMI and OE-based products are compared and validated against AERONET data during the DRAGON-NE Asia 2012 campaign. As shown in Fig. 6, the Q values for two algorithms are comparable while the OE-based inversion method indicates higher correlation coefficient. The authors should explain the improvement of OE-based AOT retrievals specifically. Also, it is needed to show the correlation coefficient with statistical significance because the sampling numbers are different. Furthermore, the SSA values from OMI operational products and OE-based inversion products show the similar correlation and the Q values from the operational algorithm are rather higher than those from the OE-based algorithm. Authors should explain the merit of OE-based algorithm to make the readers clearly understand this point. Ans) As the referee suggested, Fisher's z-values and Student's t-values were provided to evaluate the significances of the improvements. Following sentences were revised in the manuscript at pages 17, lines 340-344: "The Fisher's z-value between the correlation coefficients (Fisher, 1921) was 3.04 corresponding to two-tailed p-value of 0.0024. The Student's t-value for the difference between the two slopes is 2.10 with 512 degrees of freedom with the two-tailed p-value of 0.04. The statistical values show that the difference between two correlation coefficients and slopes are significant (p-value < 0.05)." And at pages 18, lines 358-366: "The retrieved 388 nm SSA from both the operational and OE-based algorithms showed similar correlation with the AERONET (r = 0.27 and 0.26 for operational and OE-based algorithms, respectively. Fisher's z-value is 0.1 with two-tailed p-value of 0.92). The retrieved SSA at 388 nm from the operational and OE-based algorithms showed slightly higher correlation with the converted 388 nm SSA from AERONET (r = 0.34 and 0.33 for the operational and OE-based algorithm, respectively) than with the 440 nm SSA from AERONET. However, the significances of the differences of r between converted and unconverted SSA comparisons were low (Fisher's z-values were 0.71 and 0.67 with two-tailed p-values

of 0.48 and 0.50 for operational algorithm and OE-based algorithm, respectively)."

The near UV aerosol retrieval algorithm has been developed during the past two decades through multidirectional efforts. However, improvements of aerosol inversion products using hyperspectral sensors such as OMI and global ozone monitoring instrument (GOME) are quite challenging due to the relatively large ground pixel size compared to typical imagers. However, the decadal aerosol information derived using the near UV channel since TOMS is unique, thus valuable, so that it has potential to be used at various field including climatology and air quality. The main purpose of this study is to suggest an alternative inversion method which provides additional information (error estimates, degrees of freedom, cost function, etc.) on the retrievals to optimize the applicability. However, the authors agree that the manuscript did not state the purpose of the study clearly as the referee indicated. The manuscript was revised as follows: Following sentences were added in the introduction of the revised manuscript at pages 3, lines 9-11: "The inversion products from such measurements provide various parameters of aerosols at diverse channels. Thus, appropriate sources of aerosol information need to be employed for relevant studies." At pages 3 lines 23 – pages 4 lines 29: "However, improvements of the aerosol inversion products using hyperspectral sensors such as OMI and global ozone monitoring instrument (GOME) are quite challenging due to the relatively low spatial resolution compared to typical imagers. Thus, the error estimates of retrievals using such sensors are particularly important to understand the reliability of the information, so that it can be used appropriately. The main objective of this study is to improve the applicability of the aerosol inversion products of OMI by providing the reliable error estimates of the retrievals."

In order to emphasize the advantage of the iterative inversion method, following sentence was inserted in the revised manuscript at pages 4, lines 39-41: "In addition, iterative inversion methods such as OE provide additional retrieval masking parameters (e.g., cost function and convergence criteria)." At pages 8, lines 145- pages 9, lines 165: "Such interpolation error typically depends on the interpolation method,

number of the nodal points, and analytic characteristics of the parameters in LUT. In order to reduce the interpolation error, higher resolution of LUT nodal points is necessary which requires larger amount of numerical computation. Furthermore, in order to modify the retrieval algorithm, whole LUT should be re-calculated even for a few number of target retrievals. The errors from the interpolation are also hard to evaluate as the LUT becomes more complicated. On the contrary, online retrieval methods can reduce such errors from the interpolation and are numerically efficient particularly for the smaller number of target retrievals. Thus, online retrieval method is appropriate for the research purposes since retrieval sensitivity study typically use smaller number of sample compared to the operational purposes and prefer rapid and accurate results. In our experience, the online retrieval method was numerically more efficient compared to the LUT-based retrieval method by order of 1 or 2 for less than few thousands of retrievals. Furthermore, the online retrieval methods are optimized to avoid local minima by employing additional constraints to find more reliable and stable solutions (Kalman, 1960; Phillips, 1962; Tikhonov, 1963; Twomey, 1963; Chahine, 1968). However, employing online calculation as operational retrieval method requires large numerical computation. Thus, using the online calculation as a benchmark results for the LUT-based algorithm is recommended to develop the optimized LUT for the operational purposes. Recent efforts to minimize the numerical cost of radiative transfer model and to increased calculation speed are expected to make the online calculation more practical even for the operational purposes."

In order to emphasize the merit of error estimates using the OE-method, Figure 8 was revised to show the advantage of using OE method for error estimation compared to the operational method as follows:

Figure 8. Comparison between estimated uncertainties of the 388 nm AOT (x-axis) and biases of retrieved AOT from AERONET measurements (y-axis). The panels (a) and (b) are based on the operational and OE-based retrieval/error-estimation algorithm, respectively. At pages 18, lines 370 – pages 19, lines 383: "The estimated retrieval un-

certainties of the AOT at 388 nm from the operational algorithm (ε_omi, $\pm$30% or 0.1) and estimated ε_sol were plotted against the biases relative to AERONET measurements as shown in Figure 8. The percentages of AOT retrieval biases from AERONET falling within the estimated retrieval errors of operational (Qomi) and OE-based method (Qsol) were 64.8% and 65.9%, respectively. The Qsol was higher than Qomi despite the mean value of ε_sol (0.20) was lower than that of ε_omi (0.21). The error bars and black squares in Figure 8 represent the moving σ and average value of the retrieval biases from AERONET as a function of estimated error, respectively. As shown in Figure 8 (b), ε_sol better explained the moving σ of the actual biases (r=0.93) than ε_omi in Figure 8 (a) (r=0.52). Fisher's z-value between the correlation coefficients was 2.33 with two-tailed p-value of 0.02. The systematic biases of ε_sol and ε_omi (represented by the moving average of each error estimate) are typically related to other error sources, including forward model parameters and sub-pixel cloud contaminations. Since the ε_sol of retrieved AOT considers the theoretical sensitivity of the retrieval biases to associated parameters, it explained the retrieval uncertainties better than the ε_omi, which only considers the retrieved AOT values."

2. In my opinion, the other merit of OE-based algorithm is to provide the information on forward model parameter errors in determining the accuracy of AOT and SSA retrievals. As shown in Fig. 9, the average and standard deviation of forward model parameter errors are suggested and their importance on the retrieval accuracy of AOT and SSA are evaluated. I wonder whether these points are the originality of this study or the factors well-known from previous studies are quantitatively confirmed. If the latter, authors should suggest the references. If the former, it is needed to emphasize this point as the other merit of OE-based algorithm in the Abstract and Results. Ans) Similar error budget estimation of OMAERUV was performed by Torres et al. (1998;2002b) using the sensitivity study. Most parameters are the same and some of them are not (e.g., specific aerosol PSD, half width of aerosol vertical distribution) as listed in Table 5. Thus major difference between this study and previous studies is that this study provides error estimates for individual retrieval while prior error estimates represents the

whole retrieval. As the referee suggested, in order to emphasize such advantage, following sentences were inserted in revised manuscript at pages 21 lines 444-449: "Note that the relative significances of the ε_fs of retrievals depend on their condition. It is additional merit of the error analysis using OE method that it provides specific error estimates of individual target event retrieval (e.g., dust or biomass burning event). While analysis studies using satellite inversion products have often suffered from the statistic reliabilities, more reliable error estimates in this study are expected to contribute to the assessment of significances of the analysis."

Specific comments 1. P14: In this study, the dust event on 28 April 2012 was selected. During the DRAGON-NE Asia 2012 campaign, do authors apply for other dust events? In OMI AI shown in Fig. 3, what do the negative values of AI mean? Ans) During the DRAGON campaign, there were only 3-4 days of dust event over DRAGON spatial domain. Furthermore, most of them were screened out due to clouds. For those reasons, the day was only day that sufficient number of dust products were retrieved. In our knowledge, there have been arguments about the negative AI. After screening the surface and cloud effect, it shows possibilities to be used as a scattering index of aerosols. However, before screening them, most of the negative AI is known to be caused by cloud/surface. Please compare two figures in Figure 3 and refer to the following reference, Penning et al. (2009), for detailed study. "Penning de Vries, M.J., S. Beirle, and T. Wagner, 2009, UV Aerosol Indices from SCIAMACHY: introducing the Scattering Index (SCI), Atmos. Chem. Phys., 9, 9555-9567."

2. P14 L19-20: Authors mentioned "affected by snow and cloud contaminated pixels". On 28 April, is it possible to be contaminated by snow? Ans) The effect of snow surface on satellite measurements depends on the light-path geometry, wavelength, atmospheric profiles, and etc. At near UV wavelength used in this study (354 and 388 nm), the signal is strongly affected by the snow cover due to the high reflectance for OMI light-path geometry condition. Please refer to the following reference for the detail: "Torres, O., A. Tanskanen, B. Veihelmann, C. Ahn, R. Braak, P.K. Bhartia, P. Veefkind,

and P. Levelt, 2007, Aerosols and surface UV products from Ozone Monitoring Instrument observations: An overview, J. Geophys. Res., 112, D24S47."

3. P14 L25-26: Authors should check the latitude and longitude, "East Mongolia (36,138) Ans) Sorry for this mistake. The sentence was corrected at the revised manuscript at pages 17, lines 327-328 as follows: "The operational algorithm performed single-channel retrieval around East Mongolia (47°N, 115°E), while the OE-based algorithm performed two-channel retrieval for all cases."

4. P15 L18: Add "i.e.," within parenthesis. Ans) The sentence was revised at the revised manuscript at pages 17, lines 348-349 as follows: "In this study, retrievals with χ larger than a certain value (i.e., 2.0 in this study) have been rejected."

5. P17 L5-6: "Thus the further error analysis in Torres et al. (2002b) was not performed in this study" is confusing. Ans) The sentence was revised at the revised manuscript at pages 19, lines 393-395 as follows: "Thus the further error analysis of cloud contamination from Torres et al. (2002b) was not performed in this study"

6. P17 L13: Check the "AERONET climatology during the campaign period". Ans) The sentence was revised to avoid the confusion at the revised manuscript at pages 20, lines 400-401 as follows: "To analyze the assumed ni at 354 nm, the S_b was also obtained from AERONET statistics during the campaign period."

7. P18 L1: Replace "surface albedo" to "surface reflectance" shown in caption of Fig. 9. Ans) As the referee suggested, all the terminology "surface albedo" were replaced to "surface reflectance" throughout the manuscript.

Please also note the supplement to this comment:
http://www.atmos-chem-phys-discuss.net/15/C8343/2015/acpd-15-C8343-2015-supplement.pdf

---

Interactive comment on Atmos. Chem. Phys. Discuss., 15, 16615, 2015.