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Atmospheric Measurement Techniques Discussions

Interactive comment on "Evaluation of MAX-DOAS aerosol retrievals by coincident observations using CRDS, lidar, and sky radiometer in Tsukuba, Japan" *by* H. Irie et al.

Anonymous Referee #2

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"Evaluation of MAX-DOAS aerosol retrievals by coincident observations using CRDS, lidar, and sky radiometer in Tsukuba, Japan" by Irie et al 2015 attempts to answer the need for correction factors to scale O2O2 dSCD in their aerosol inversion algorithm. The authors use multiple in-situ and remote sensing instruments to compare the surface aerosol extinction coefficients and total AOD at 476 nm. They determined that correction factors used in MAX-DOAS aerosol inversion algorithms to account for dSCD(O2O2) model-measurement discrepancy are viewing elevation angle dependent with the largest effect being at larger viewing angles (20, 30deg). While the paper is very important to the MAX-DOAS community I think the authors can contribute to the

topic significantly more if they address the following two questions: 1. Are the MAX-DOAS measurements of O2O2 accurate? 2. Is the aerosol inversion algorithm capable of correctly retrieving near surface AEC and total AOD and what adjustments are needed to make it work?

To answer the first question the authors have a unique dataset of in-situ and remote sensing aerosol property and profile measurements. They can do forward model RT calculations using all the information about the atmospheric state (aerosol optical properties, aerosol profiles, time dependent temperature, pressure and relative humidity profiles) with as few assumptions as possible. By selecting times with no clouds the authors can calculate theoretical dSCD(O2O2) and compare them with the time coincident measured MAX-DOAS dSCD(O2O2). In the forward model RT calculations polarization, refraction etc. should be accounted for with a fine vertical grid. If correction factors are needed the authors can make conclusions about the viewing angle dependence etc. Here the authors can also discuss instrumental errors in dSCD(O2O2) measurements as a function of viewing elevation angle and effect of aerosol heterogeneity along the photon path. I also would recommend to use Thalmen and Volkamer peak O2O2 cross sections at 477 nm as a function of temperature in RT calculations. In addition to temperature dependence of O2O2 cross section, the same correction factor viewing angle dependence can be the result of incorrect zenith sky reference "treatment". If a small (and incorrect) dSCD(O2O2) in the reference spectrum is subtracted from progressively increasing dSCD(O2O2) as a function of VEA, dSCD(O2O2) measured at lower VEA will have a smaller error than at larger VEA .

Since there are a number of assumptions used in inversion algorithms and the MAX-DOAS independent information is limited the inversion algorithms might not be able to retrieve the correct AEC and AOD independent of accuracy of O2O2 cross section (and its temperature dependence). The authors have mostly answered the second question by their analysis of VEA varying correction factor. Below are more specific comments.

- How valid is your assumption about constant aerosol profile during the 30 min scan time? Please elaborate based on LIDAR and CRDS measurements.

- What is the source of your time dependent temperature, pressure and relative humidity profiles? Have authors included RH in O2O2 calculations.

- Only scattering from aerosols impacts O2O2 absorption. Can authors elaborate on the contribution of the aerosol absorption to the total AOD at their site, based on the other measurements

- The inversion algorithm (retrieval of 4 parameters) used in this study might not be the best method to evaluate near surface AEC since extrapolating from these parameters to the full profile is somewhat arbitrarily. Starting from the top layers (100-3 km) and assuming exponential profiles within each layer may lead to biases in each layer. The MAX-DOAS sensitivity to aerosols above 1-2 km is very low so if the authors start from the 3-100 km they propagate the largest uncertainty in AEC to the lowest layers. If the AEC is wrong at 3 km, it will lead to biases at 2 km, 1 km and near surface AEC. In addition, using LUT versus on-line RT calculations limits retrieval to the scenarios/assumptions used to create LUT. Please discuss all these limitations

- I find the statistical analysis based on four AEC and AOD bins not sufficient. I also do not see any discussion of the bin selection justification in the text. The bins are arbitrary and can lead to somewhat different conclusions if selected using a different criterion. I will argue that this statistical analysis (R2 and slopes) cannot be used as a reliable tool to determine the "proper" correction factor or make any conclusions about the quality of linear fit (e.g. page 1025, line 20)

- The applied inversion algorithm does not include cloud RT. What percent of the retrieved profiles are taken under cloudy skies (passed screening)? What effect do these clouds have on the near surface AEC and AOD?

- Since MAX-DOAS sensitivity above 1-2 km is reduced the total AOD retrieved is probably expected to be somewhat lower than AOD from the sky radiometer. Could

the authors compare the AOD from LIDAR/CRDS up to 1-2 km in addition to total AOD from the sky radiometer?

Figure 2: Could the authors plot this graph to show only data at SZA relevant to MAX-DOAS?

Figure 3: LIDAR is "blind" below 120 m. I do not see any reason to make the equal mixing assumption bellow 120 m in this figure and especially show error bars. I would recommend comparing surface AEC from CRDS and LIDAR AEC at 120 m.

Figure 4: Please plot only time coincident measurements.

Figure 5: It might be better to use surface CRDS linearly interpolated to LIDAR AEC at 120 m for calculation of mean AEC values for 0–1 km from LIDAR. What criterion have you used to select LIDAR and CRDS bins? Linear regression on 4 points is not very convincing. . . especially since the larger AEC bins have fewer points with larger errors bars. What type of regression analysis was used?

I would recommend combining figures 4, 5, 11, 15 into a single figure, where:

- Left panel contains data as in Fig 4 but excluding MAX-DOAS retrievals: (Top) Near surface AEC values from CRDS, (middle) AEC values for 0–1 km from LIDAR (bottom) AOD values from sky radiometer;

- Right panel contains difference between time coincident MAX-DOAS retrievals and near surface AEC values from CRDS (top), AEC values for 0–1 km from LIDAR (middle) and AOD values from sky radiometer (bottom) accounting for MAX-DOAS and CRDS, LIDAR and sky radiometer errors. Color-coded for each correction factor scenario.

I would recommend combining Fig 5, 7, 12, 14, 16 where each figure is a separate panel.

Interactive comment on Atmos. Meas. Tech. Discuss., 8, 1013, 2015.