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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Dual-wavelength aerosol vertical profile measurements by MAX-DOAS at Tsukuba, Japan" *by* H. Irie et al.

Anonymous Referee #1

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The manuscript entitled 'Dual-wavelength aerosol vertical profile measurements by MAX-DOAS at Tsukuba, Japan' by Irie et al. is a follow- up of a previous publication on the retrieval of atmospheric aerosol extinction profiles by Multi-Axis DOAS measurements of the O4 collision complex.

The retrieval has been performed using the same algorithm as described by Irie et al [2008], but the time series now extends over 5 months (previously 2 months) and also includes aerosol retrievals from measurements of the O4 absorption around 360 nm. This allows to deduce information on the Angström exponent. The aerosol retrievals are compared to coincident Lidar and sky radiometer measurements. Since the retrieval algorithm has already been described in detail in the first paper, the manuscript is very short and concise. On the other hand, the amount of improvement of the re-

trieval algorithm compared to the first paper is relatively small. Apart from the extension to another wavelength, the algorithm remained unchanged and no attempts have been made, for example, to improve the vertical resolution or to infer aerosol microphysical properties (apart from the Angström coefficient).

I recommend the publication in ACP after some modifications as described below.

General comments:

The retrieval algorithm is based on the well established optimal estimation technique. However, the authors do not make use of the main advantages of this retrieval technique - namely the possibility to quantify the various error sources (e.g., measurement noise, smoothing error), the information content of the measurement, and the sensitivity of the retrieved to the true profile (i.e., the averaging kernels). In addition to the comparison of the retrievals with Lidar data, a thorough discussion of error sources and sensitivity to the true state vector as described by Rodgers [2000] is missing.

I suggest to add the following information, which is important for a thorough quantification of the differences between the retrievals at 360 and 477 nm:

(1) Averaging kernels

(2) Error components (noise and smoothing error, model parameter errors)

(3) Information content, i.e. degrees of freedom for signal

Some important questions, which could be addressed using the existing dataset, still remain open:

- How well can MAX-DOAS capture interesting dynamical features of the boundary layer, such as boundary layer break-ups? To address this, graphs of time series of retrieved aerosol extinction would be very illustrative.

- Is the quality of the retrieval dependent on the SZA, i.e. are there any systematic errors at high SZA?

ACPD

8, S10216–S10220, 2009

Interactive Comment

- How do clouds affect the quality of the retrieval?

- Are parts of the discrepancies between DOAS, lidar and sky photometer caused by the sampling of different air masses?

A main conclusion drawn from the data presented here is that the observed systematic underestimation of the extinction at higher altitudes is caused by a small sensitivity at these altitudes. This is not correct since (1) the sensitivity with respect to aerosols is not described by the box airmass factor and (2) small sensitivity does not necessarily cause an underestimation of the retrieved quantities. O4 box airmass factors need to be replaced by weighting functions with respect to aerosol extinction (K = dSCD/dk), and the influence of the a priori on the retrieved profiles needs to be investigated.

Specific comments:

A comparison has not only been performed with Lidar, but also with sky radiometer measurements. This should be stated in the abstract.

Introduction:

The statement '...MAX-DOAS measurements could contribute not only to monitoring of the atmospheric composition changes but also to the understanding of the Earth system' is very general. Atmospheric composition is already part of the Earth system. Can you be more specific?

Measurements:

Please specify which a priori has been used for the retrieval.

Results and discussion:

P19362, L14: Please specify how the Lidar and MAX-DOAS data have been binned to generate the data shown if Fig. 2.

The fact that MAX-DOAS extinction coefficients are systematically smaller than lidar

ACPD

8, S10216–S10220, 2009

Interactive Comment

is explained by the use of an inappropriate lidar ratio (P19362, L22). However, the same tendency is found when comparing aerosol optical depth from MAX-DOAS with sky radiometer measurements, which suggests that in fact MAX-DOAS retrievals are systematically too small, and not that the lidar extinction profiles are wrong. How do the aerosol optical depths from lidar compare to sky radiometer measurements?

An underestimation of the extinction above 1km is found. Since the sensitivity of the measurements to aerosols decrease with altitude, I wonder to what extend this is influenced by the choice of the a priori profile. This needs to be investigated in order to consolidate the conclusions drawn in section 5 (see below)

Fig. 5 shows O4 box airmass factors, i.e. the sensitivity of the SCD to the partial VCD at a given altitude. However, the important quantity for aerosol retrievals is not the box-AMF but the sensitivity of the measurement to aerosol extinction, i.e. the weighting function K = dSCD/dk. It is not specified for which elevation angle the box airmass factors are shown.

In Fig. 6, MAX-DOAS aerosol extinction between 0 and 1 km is compared to the aerosol optical depth from sky radiometer. It would be more useful to compare the integrated aerosol optical depth from MAX-DOAS with sky radiometer, instead. I cannot see how it can be concluded that '..MAX-DOAS is capable of deriving alpha vertical profile information' (P19364, L27) from this comparison.

Conclusions:

It is stated that O4 box airmass factors are a measure for the sensitivity of MAX-DOAS measurements for aerosols. This is not correct (as already stated above). Instead, the weighting function dSCD/dk describes this sensitivity. Also, it is not correct that a small sensitivity at certain altitudes necessarily leads to an underestimation of the retrieval. Instead, the retrieved extinction should be closer to the a priori at altitudes where the sensitivity is low. Thus it cannot be concluded that 'the cause leading to systematic errors was identified' (P10366, L4) without providing information on the a priori profile.

ACPD

8, S10216–S10220, 2009

Interactive Comment

Technical comments:

As far as I can judge as a non-native English speaker, there are only very few technical issues:

P19358, L19: Insert a comma after ’change’

P19359, L12: Insert ’of’ after ’wavelength’

Interactive comment on Atmos. Chem. Phys. Discuss., 8, 19357, 2008.