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Atmospheric Measurement Techniques Discussions

Interactive comment on "Mobile MAX-DOAS observations of tropospheric trace gases" *by* T. Wagner et al.

T. Wagner et al.

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Reply to the comments of Alexander Cede (Referee #1).

First of all we want to thank this referee for the positive assessment of our manuscript and the helpful comments. We almost completely followed them as outlined in detail below.

General comments: "Mobile MAX-DOAS observations of tropospheric trace gases" by T. Wagner et al. describes an algorithm that can be used to retrieve vertical column densities (VCD) of trace gases from mobile platforms. The algorithm is applied to MAX-DOAS measurements taken form a car during a trip from Brussels to Heidelberg.

The paper fits well into the scope of ACP and reads well. The authors describe a new method for the analysis of MAX-DOAS observations from mobile platforms. Instead of taking the zenith viewing measurements at each scanning sequence as a reference (which is often done for ground based MAX-DOAS measurements to obtain VCDs), a single zenith viewing measurement is used for all data during the measurement period. Then they use a statistical method to determine the difference between the slant column density (SCD) in the reference spectrum and the SCD in the stratosphere, DSCDoffset (section 3, figure 3). The latter is needed to obtain absolute VCDs from the data. While the concept of taking a single reference spectrum and determining its SCD by statistical means is not necessarily new (see e.g. Herman et al., J. Geophys. Res., 114, D13307, doi:10.1029/2009JD011848, 2009), the authors can claim to be the first ones having applied this concept to car MAX-DOAS measurements.

Author reply: We added the reference to the paper from Herman et al.

The error estimation for DSCDoffset uses the basic assumption from page 2862, line 9: "The deviations of DSCDoffset from the true value occur randomly, because the probabilities that the trace gas concentration was either higher or lower during the first measurement are the same." The data around the power plant show that this is not always true (figure 3). The authors explain that around the power plant the geometrical approximation for the air mass factor (AMF) is not valid and have therefore removed those points before fitting the polynomial. The region around the power plant produced many more negative outliers than positive ones (figure 3). So does this mean that whenever the geometrical AMF is not applicable, the data tend to be biased low? What about all other situations (i.e. not around the power plant)? Do (even small) inaccuracies in the geometrical AMF systematically produce more negative biases than positive ones and therefore shift the whole fitted polynomial to lower values and consequently lead to an underestimation of the VCDs? The authors should comment on the questions of the previous paragraph.

Author reply: This is an interesting aspect. In fact, in cases where plumes exist in

well defined small volumes (e.g. a sphere), the sensitivity of MAX-DOAS observations is almost independent of the elevation angle (as long as the plume is in the field of view). That means, for such conditions DSCDmeas is similar for low elevation angle and 90° elevation. Inserting similar values for DSCDmeas(alpha) and DSCmeas(90°) into equation 14 or 15 systematically leads to a negative DSCDoffset if the geometric approximation is used for the AMF. We added this information to the text (sections 3 and 4.3). In section 3 we added the text: 'It should, however, be noted that for observations of localised plumes this assumption could be violated. Such measurements can be identified and should be removed from the determination of DSCDoffset(SZA) (see section 4.3).'

In section 4.3 we added the text: 'Note that in cases of such localised plumes the measured DSCDs for different elevation angles typically become rather similar. Together with the use of AMF which are calculated for horizontally extended plumes (e.g. geometrical AMF), this leads to a systematic negative bias of DSCDoffset in equations 14 or 15. Fortunately, this negative bias (together with the strong variation of DSCDmeas) allows a clear identification and removal of measurements affected by localised plumes.'

Specific comments: - Page 2854, line 16: Clarify the sentence "The only requirement: : :easily fulfilled)." What exactly does it mean ": : :scanning sequences within continuous measurement period"?

Author reply: We added more information and changed the text to: 'The only requirement of the technique is that a sufficient number (typically > about 20) of successive MAX-DOAS elevation angle scanning sequences (see Fig. 1) are performed within a continuous measurement period. A continuous measurement period is defined here as a period, during which the instrumental properties do not substantially change (e.g. as a result of a temperature change of the detector). This is typically fulfilled for measurements carried out during one day or part of a day (for very stable instrument conditions also longer periods are possible).'

- Page 2855, line 24: What is the "simplest case"?

Author reply: We replaced the sentence by: '... in the simplest case (e.g. without aerosols and clouds, see also section 2.3) the atmospheric light paths can...'

- Page 2855, line 25 and page 2859, line 10: There is no need for the personal communication reference since peer-reviewed references are also given.

Author reply: To our knowledge, the suggestion to use a geometric AMF together with observations at high elevation angles was made by Andreas Richter. We would like to leave the reference to the personal communication in order to reflect the heritage of the idea.

- Page 2856, lines 2 to 5: The two sentences give the impression that the only reason vertical profiles can not be retrieved from car MAX-DOAS observations is that the view at low elevation angles is often blocked, and for airborne observations vertical profiles could be retrieved. This is in contradiction to section 2.4 (and figure 1, top). I suggest the authors add that vertical profiles from mobile platforms can in general only be retrieved if all viewing angles are measured at the same time, except the speed of the moving platform is small compared to the spatial variability of the trace gas field, which might be the case for measurements from ships.

Author reply: Many thanks for this hint! We replaced the sentences by: 'In principle, also vertical profiles of aerosols and trace gases could be retrieved from mobile MAX-DOAS observations, as long as the time for an elevation scanning sequence is small compared to the variation of the atmospheric concentration with time (depending on the spatial gradients and the driving speed). For car measurements, in addition the view at low elevation angles (i.e. at a few degrees) is often blocked by obstacles like buildings or trees. For airborne and ship MAX-DOAS observations [Leser et al., 2003; Heue et al., 2005; Wang et al., 2005, 2006; Bruns et al., 2006; Dix et al., 2009], also viewing angles close to the horizon might be used. For ship MAX-DOAS observations profile retrievals should in general be possible. For airborne MAX-DOAS observations,

profiles might be retrieved outside from polluted regions or at high altitudes.'

- Equation 3: Shouldn't "=DSCDtrop(alpha)" be removed from equation 3? It does not seem to be correct at this stage. It 'becomes' correct later when DSCDmeas(90) is used as reference (equation 5).

Author reply: We removed "=DSCDtrop(alpha)" as suggested.

- Page 2860, lines 17-24: what exactly do you mean with "(also the actual integration time to the : : : is reduced)".

Author reply: We decided to remove the statement in brackets. What we meant was that for fixed read-out times of a detector the fraction of the time for the readout process compared to the duration of the actual measurement incresases if the total integration time of an individual measurement is reduced. However, for most observations this effect will play no important role.

- Page 2865, line 2: the duration of an individual measurement is said to be 20-25sec; are these several cycles over a certain integration time? What are typical integration times?

Author reply: We added the typical number of individual scans (between a few tens and more than 200) at the end of this sentence.

- Page 2866, lines 16 t 20: Explain what errors are meant in the sentences "From the scatter we estimate: : :compared to other error sources."

Author reply: These errors mainly include uncertainties of the tropospheric AMF (e.g. caused by the geometric approximation or the influence of clouds). We added this information to the end of the sentence.

Interactive comment on Atmos. Meas. Tech. Discuss., 2, 2851, 2009.