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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Longpath DOAS tomography on a motorway exhaust gas plume: numerical studies and application to data from the BAB II campaign" *by* T. Laepple et al.

T. Laepple et al.

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General comments

The PhD-Thesis from Dominique Bäumer was published in 2003 and not in 2002.

Response to Referee 2

Statement "DOAS as multi-component measurement method", Page 2437

We agree that our statement was not fully correct because the absorption cross section of most aromatics are not in the same wavelength range as the ones of the other noted species. Except of the aromatics all the noted species can be measured simultaneously. In the revised version this statement was changed to: "One advantage of DOAS is the simultaneous measurement of several trace gases (e.g. NO2, SO2,

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HCHO, HONO, and ozone in the UV region between 280 and 380 nm)"

"temporal stability of the NO2 plume"

In our results we didn't discuss the temporal stability of the NO2 plume because the non-simultaneous measurements allow us only to reconstruct concentration fields averaged over a long period of time (5-7h). In future campaigns the use of multibeam instruments will enhance our time resolution. We agree that temporal fluctuations of the NO2 plume during the non simultaneous measurements lead to errors in the reconstruction. This important type of error was explained and quantified in our work. (Page 2451, Line 5 "the so called stepping error, which occurs if the different light paths are not measured simultaneously", in chapter 7.1 we quantified this type of error) In Fig. 11a) the propagated measurement error which is mainly due to the sequential measurements of a non stable plume is shown. Due to the long averaging periods, the contribution to the total reconstruction error is relatively small.

"influence of chemical reactions"

For the shape of the NO2 plume, chemical reactions are important because the main sources of NO2 at the motorway are chemical reactions and not direct emission. Therefore the concentration maximum is on the downwind side of the motorway. This was added in the final version.

"meteorological situation"

please see our response to Referee 1.

"Bäumer NO2-plume"

In his PhD-Thesis Bäumer (2003) used the mesoscale chemistry transport model system KAMM/DRAIS to model NO2 concentration distributions for the motorway situation. He used emission and wind data from a former campaign in 2001. In Bäumer (2003) vertical profiles at different times of day are shown. The results of his calculations for 13:00 CET (unstable stratification) show similar features (plume height, absolute

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concentration) as our reconstructions from period 1/2, the ones for 21:00 CET (stable stratification) as period 3. Because of the different auxiliary conditions both results cannot be compared quantitatively. Therefore we wrote “it is interesting to note” without going into details. Additionally to the results published in his PhD-Thesis Bäumer put a 2D NO2 field to our disposal which in our manuscript we referred to as CTM-BABII plume (Bäumer, pers. comm.). This concentration field was used to generate the a-priori concentration fields (explained in Sect. 5.1) and is shown in Fig. 4 a)

“maxima of concentrations in higher altitudes”

In Fig.7 c) at around 40m altitude, concentrations 5-10ppb higher than the background concentration were reconstructed. To quantify the significance of this feature we can use the estimated error maps from Figure 11 and 12:

Fig.11 a) Propagated measurement error: In this area a standard deviation around 0.5ppb due to the propagated meas. error was calculated.

Fig 12 a) Bias of the reconstruction due to the discretization and inversion: The bias in this area which was estimated from numerical experiments shows an overestimation of the reconstruction of 2-3.5 ppb

Fig 12 c) Discretization and inversion error: The standard deviation due to this error type in this area is around 2.5 ppb.

Regarding the bias and the standard deviation of the reconstruction in this area this feature is not very significant. This lack of significance is feasible because no lightpath is crossing this area and therefore no information is available (see Fig. 4a)

“IMK”

IMK is explained in line 5, Page 2441

Response to Referee 1

Sec. 1.3 “...absolute reconstruction error...” In page 2440, Line 14 we wrote: “To our

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knowledge the absolute reconstruction error has not yet been estimated in tomographic applications in atmospheric sciences"

We still agree with our statement. The study mentioned by the referee 1, (Wilson and Thomson, 1994) quantifies the propagated measurement error and the inversion error but neglects the discretization error. This error occurs when the real continuous field cannot be exactly approximated by the state model (in our notation from chapter 4). Wilson and Thomson (1994) assume that the propagation medium can be adequately described by a set of parameters. If only a few measurements are available (which is the case in trace gas tomography as well as in acoustic tomography) the number of parameters which can be determined by the measurements is limited and therefore the discretization error occurs.

- Sec. 6

"meteorological situation"

In the final version of the manuscript we added a short description of the meteorological situation to Section 6: "The meteorological situation of the day of the study was a weak anticyclonal circulation, clear sky conditions and light to moderate winds. After a nightly inversion due to radiative cooling, a shallow convective layer developed in the diurnal cycle which reached 1500m-2000m altitude. On synaptic scales the pressure differences were small; therefore the advective processes were not dominating."

"Do the different lengths of the three time periods influence the comparability of the results ?"

The length of the time periods is relatively similar: 7h, 6h and 5h.

Still the different lengths have two effects:

1.) The stepping error, which is the main part of the measurement error gets smaller when the time period gets longer due to the longer averaging period. For each period, this stepping error is calculated separately as described in Section 7.1. Due to the small

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significance of this error type (around one order less important than the discretization and inversion error, see Fig.11a / Fig 12 c) we only showed the error distribution for one time period (period 1). The relative stepping error for the column densities is between 1.2 and 2.3 percent. For this variability, the change in the variability of the NO2 field due to the traffic change is more important than the differences of the time period length.

2.) Further the reconstructions are average fields over the time periods. For the comparability of the three time periods it is more important to choose similar conditions (time periods where the wind situations are approximately perpendicular to the motorway were chosen) than to have exactly the same length of intervals.

- Sec. 7.1:

We agree that a 'constant' measuring object is important during the measurement time of one stepping cycle (the time interval until all lightpaths are measured). In our study this was not the case and therefore we quantified the error due to successive measurements of different lightpaths on an unstable measuring object in Section 7.1. as stepping error.

The time difference between single measurements along a single lightpath (the stability of the plume between different measurement cycles) is not important when we aim to reconstruct the average 2D-field over a time period. The measurement and the reconstruction process are linear (in the inversion process each projection of the row acting method is linear and the state model is linear) and therefore averaging the data equals averaging the reconstructed fields. We agree that averaged fields over several hours are not easy to interpret especially when the situation is changing during the averaging period. But the limited measurement setup (two classical DOAS-telescopes) didn't allow us to retrieve more information. The main aim of this study was to investigate and demonstrate a new measurement technique. In future campaigns when multibeam telescopes will be available this problem will be significantly reduced.

In the final manuscript we clarified that the shown reconstructed 2D-fields are temporal

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averages over the time periods and do not represent instant concentration fields.

References:

Bäumer, D., Transport und chemische Umwandlung von Luftschadstoffen im Nahbereich von Autobahnen -Numerische Simulationen, Ph.D. thesis, Fakultät für Physik, Universität Karlsruhe, 2003.

Wilson, D.K. und Thomson, D.W., Acoustic tomographic monitoring of the atmospheric surface layer. J. Atmosph. Ocean. Technol. 11, 751-769, 1994

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