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Atmospheric Measurement Techniques Discussions

Interactive comment on "The Cabauw Intercomparison campaign for Nitrogen Dioxide measuring Instruments (CINDI): design, execution, and early results" *by* A. J. M. Piters et al.

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We would like to thank both referees for their positive and constructive comments. Below, we address their comments, one by one. The original text from the referees comments is included in *italic font*. Proposed changes in the revised manuscript are included in **bold font**.

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Interactive Discussion

Discussion Paper

Answers to Anonymous Referee #1

1. The discussion of the lidar on page 5952 mentions that it has altitude-dependent vertical resolution, but this is confusing until it is made clear in the appendix that the lidar scans several elevation angles. While details of the scanning are appropriate for the appendix, it should be briefly noted at this point in the manuscript that this lidar is pointable and that it provides vertical resolution by scanning a range of elevation angles.

The following sentence has been added in the revised manuscript: **A vertical NO_2 profile is obtained by scanning a range of elevation angles, each elevation angle being sensitive to a different altitude.**

2. In section 4.1, the authors note that to assess accuracy of slant columns, certain algorithmic details were prescribed (wavelength range, cross sections, DOAS settings). This approach makes sense, but was there any attempt to understand what these instruments would have determined left to their own choices? In the absence of any recommended retrieval settings, the instruments will diverge when operating independently, but it is hard to know how large this divergence will be.

Standardised DOAS settings for the simultaneous retrieval of NO_2 and O_4 slant columns in the visible and UV spectral regions were recommended in Roscoe et al. (2010, Table 2). **Although no systematic investigation was performed to evaluate the impact of not following these recommendations, it is known from past experience (see e.g. Vandaele et al., 2005; Roscoe et al., 1999) that the use of different NO_2 cross-sections can be a significant source of divergence. E.g. retrievals performed without consideration of the NO_2 temperature dependence may introduce a bias as high as 20% on the slant columns. Comparatively the sensitivity to the wavelength range used for NO_2 fitting is smaller, although bias can still be produced due to possible enhanced interference with water vapour absorption, the Ring effect or the wavelength dependency of the air mass factor.**

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We have added the text in bold to the revised manuscript.

3. In section 4.1, it is noted that "all instruments meet the criteria for endorsement by NDACC." What is the criteria? It should either be defined here or a reference provided.

The criteria for endorsement of UV-Visible instrument by NDACC are described in details in the NDACC protocol for UV-Visible instruments. This document can be freely downloaded from the NDACC website (http://www.ndsc.ncep.noaa.gov/organize/protocols/). We have added this reference in the revised manuscript.

On page 5960, line 7: "Tropospheric" is misspelled.

This has been corrected in the revised manuscript.

Figure 9 provides a nice qualitative view of how the in situ measurements on the tower behaved at the three altitudes. It would be interesting if you were willing to provide a second panel plotting the time series of the difference in NO_2 between altitudes (3m-100m and 3m-200m).

We have adapted Figure 9 (also changing the colours, as requested by referee #2) to show a second panel with the differences in NO_2, and add a sentence to the caption: **The upper graph shows the absolute values of the measurements at each level, the lower graph the differences.**

For figure 12 it would also be interesting to plot the % enhancement seen in the molybdenum instrument compared to the average for the photolytic sensors.

We have adapted Figure 12 by adding a plot of the absolute and relative differences between the values derived from the NO_x analyser with molybdenum converter on one hand and with photolytic converters on the other. The following sentence has been added to the caption: **The middle and lower panels show the absolute and relative difference (enhancement) between the mixing ratio derived from the instrument with molybdenum converter and the average mixing ratio derived from the three**

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other instruments.

Answers to Anonymous Referee #2

1) Although the photos are helpful, a diagram that summarizes the viewing geometry for most of the spectrometers would be helpful. In Section 2.3, having a simple figure or two to allow a novice to understand the terminology will make this section and the other descriptions of instruments (in Appendix) less jargony. Photos don't tell the reader a lot without a basic frame of reference. The paper is written as if specialists only will read it. This is not a good assumption because this will be a long-lasting and highly cited paper and should provide the basic information to ensure that this is so. The paper can serve as a reference for people who are starting to work in this area of technology. For an AMT article, having the technology clearly spelled out is important.

We agree that an explanatory picture would be very helpful here. We have added a figure to the revised manuscript, with a diagram showing the MAX-DOAS instrument layout, and a diagram showing the typical MAX-DOAS viewing geometry. We expect that these figures will help the non-specialists and the newcomers in this area to understand the basics of the MAX-DOAS technology.

2) Some of the graphics are very poor. Figures unreadable because legends are too small. Some colors almost overlap in value/tone and cannot be distinguished from one another. These are: Figure 7 (color scale labels reproduce poorly); Figure 9 (blue and black hard to distinguish); Figure 16 (unreadable labels on axes).

These three figures have been improved in the revised manuscript.

3) This Reviewer found the information about aerosols discouraging - poor agreement, but the data were not well-digested or described (Section 4.6). Maybe some other papers will do this important topic more justice but the current one is inadequate. Con-

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sider removing this discussion altogether.

The comparisons performed on the surface aerosol extinction derived from different instrument types is an important part of the CINDI campaign. Therefore we think it is necessary to leave the section in. However, in the revised manuscript, we have given somewhat more detail on the derivation of the in-situ surface measurement, and refer more clearly to the Zieger et al. paper. We have changed Sect. 4.6 in the revised manuscript as follows:

Zieger et al. (2011) compared **the lowest levels of the** surface aerosol extinction **profiles** retrieved by four MAX-DOAS instruments, using different algorithms, with in-situ **surface values of the aerosol extinction. These in-situ values were determined from the combination of measurements of the scattering coefficients at different relative humidities and the dry absorption coefficient. Zieger et al. (2011) found good correlation** between the MAX-DOAS instruments and the C**aeli** lidar with in-situ extinction values, **but** the MAX-DOAS data are generally significantly larger than the corresponding in-situ values by a factor ∼1.5 to 3.4. **The Caeli lidar values (extrapolated to the ground using the measured backscatter signal) were a factor of 1.12 to 1.76 larger than the in-situ values. Several hypotheses were brought forward, for example the limited vertical resolution of the MAX-DOAS retrieval (especially during lofted layers) and possible particle losses in the in-situ inlet system. Zieger et al. (2011)** found that the agreement is better for low AOD and low PBL cases (see Fig. 18). The retrieval for some of the instruments also improve**d** when ambient in-situ measurements of the asymmetry factor and the single scattering albedo **we**re used as input.

4) The references are full of 'in preparation' and multiple page numbers that are very confusing. Examples: Roscoe et al (page 5979; Spinei et al.

The references have been checked and updated in the revised manuscript. Multiple page numbers after a reference are included by the AMT system; they refer to the

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page numbers of the current manuscript, where the reference is mentioned.

5) The paper has some grammatical fine points that can be improved as follows.:
Page 5938. Line 24... agree within 25% of one another. (Add words)
Page 5941 Line 4. Better wording... Simultaneous (spelling check) observations at 3 m altitude drovided the opportunity to demonstrate that there is a bias between the ....
*Page 5982. Line 26 Cabauw is *a* rural site...*
Page 5945 line 2. First time, (add comma) Line 13. Relative humidity; thus, drying frustrates...
Page 5946, line 13. All seasons. It also supports aviation at...
Page 5952. ...all day. Only the presence of...
Page 5953. Line 17. Duration in time (what times? Periods).
Page 5958, Line 26-27. Factor of 6; this variability....

These have all been corrected in the revised manuscript.

Interactive comment on Atmos. Meas. Tech. Discuss., 4, 5935, 2011.