

Interactive comment on “MAX-DOAS tropospheric nitrogen dioxide column measurements compared with the Lotos-Euros air quality model” by T. Vlemmix et al.

Anonymous Referee #1

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General comments

The manuscript entitled 'MAX-DOAS tropospheric nitrogen dioxide column measurements compared with the Lotos-Euros air quality model' by Vlemmix et al. describes the comparison of MAX-DOAS measurements of the NO₂ vertical column density with results from an air quality model. NO₂ is one of the key compounds in urban pollution and its continuous monitoring is of great importance. In contrast to in-situ observations, the remote sensing of NO₂ has the advantage of being less sensitive to local variations in the trace gas concentrations, since the average over a larger volume is observed. Therefore MAX-DOAS observations are very suitable for the comparison with model

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calculations. In this paper, a relatively simple method (compared to full vertical profile retrievals) for deriving the NO₂ VCD, including a correction for situations where clouds have an impact on the measurements, is presented and validated against model simulations. Diurnal, weekly and seasonal variation in NO₂ are discussed in detail. The scientific questions addressed in this paper fit well within the scope of ACP and I recommend publication after some minor modifications described below.

The paper is well written and the methods are described in a clear and concise way. It is well structured, except that the discussion of the radiative transfer and the definition of the airmass factors (Section 2.2.2) should be presented prior to the discussion of the impact of clouds (Section 2.2.1). Also, a short description of the instrument and the measurement uncertainties is missing.

The abstract is far too long and requires substantial shortening. It contains many unnecessary technical details which can be omitted and should rather be discussed in the main body of the paper.

Sections 2.2.1 and 2.2.2 should be swapped: The discussion on the impact of clouds in Section 2.2.1 is not understandable without knowledge on the definition of the box-AMF provided in Section 2.2.2. The definitions and nomenclatures defined in 2.2.2 should be used in the course of the discussion of the sensitivity on clouds in 2.2.1.

It is stated several times in the manuscript that aerosols have a relatively small effect on measurements performed at 30° elevation angle. However, no evidence is provided for this statement, and it is also not clear to what extent variations in the aerosol load could lead to systematic errors in the retrieved NO₂ VCD. Therefore, some sensitivity studies on the impact of aerosols on the retrieved tropospheric VCD should be performed or appropriate references should be provided.

Specific comments

P28899, L9: It is not clear if 'one kilometer' refers to the distance along the LOS, the

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vertical, or the horizontal dimension. Please clarify.

Section 2.1: A technical description of the instrument (instrument type, entrance optics, wavelength range, spectral resolution, spectrometer, detector, field of view, etc.), as well as according references, are missing here. Also, the elevation angle sequence should be specified (although only 30° is used), as well as the time required for one sequence. It is not clear what a 'mini MAX-DOAS' instrument is.

Section 2.2: Although the retrieval has already been described elsewhere, a summary of the quality of the retrieval (typical RMS residual, random and systematic errors, detection limit) obtained during this campaign should be provided.

P28901, L17: It is not true that 'the differential cross sections corresponding to the various trace gases are mutually orthogonal'. They are not orthogonal, but linearly independent (which is sufficient for the separation in a fitting procedure).

P28902, L6: Describe what a 'Ring' cross section is, and add according reference (e.g., Chance and Spurr, 1997).

P28902, L20: Have the spectra been averaged prior to the analysis or has the average dSCD been calculated after the analysis?

Section 2.2.1: As already mentioned in the general comments, this section should appear after 2.2.2, since it is difficult to understand the impact of clouds without knowledge on the airmass factor concept and the way simulations of the radiative transfer were performed. The nomenclature specified in Section 2.2.2. should be used in 2.2.1.

P28904, L3: ' I_α^0 is the simulated sky radiance without NO_2 and $I_\alpha^{\text{NO}_2}$ is the simulated sky radiance with NO_2 at a certain altitude z .

P28904, L22: Are you referring to Lidar observations of NO_2 ?

P28910, L10: I would say that the agreement between model and measurement presented in Figure 4 is better than 'reasonable'.

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P28912, L13: Here it is argued that cloud-free cases show better agreement because the systematic difference between model and measurement is better for cloud-free than for cloudy cases. On the other hand, the numbers in Table 2 show that the correlation coefficient is better for cloudy covered than for cloud-free cases, from which one could draw the opposite conclusion.

P28912, L23: It is not clear whether you have performed these simulations yourself or you have adapted these findings from somewhere else.

P28913, L28: It is stated that summer months were excluded from the comparison because the model would not perform well in this period. I would appreciate if this data would be shown, since this would allow to quantify the differences between model and measurement and to investigate the reasons for the model uncertainties.

Figure 11 should be removed, since it shows almost the same map as the right panel of Figure 3, except for the additional arrows which are not really necessary for the discussion in Section 4.4.

P28918, L15ff: A dependence of NO₂ VCDs on wind speed has been observed. What are possible reasons for this dependence?

P28919, L22: It is not clear what is meant with '...despite a strong variability in both data sets...'. Actually, a high variability in the observed parameter should be of advantage when performing a statistical comparison between two independent data sets.

P28921, L19: It is not clear what is meant with stronger oscillations in the monthly cycle.

Technical corrections

P28896, L11: Replace 'done' with 'performed'.

P28896, L13: Replace 'a viewing elevation angle is used of 30° above the horizon' with 'a viewing elevation angle of 30° above the horizon is used'.

P28896, L28: 'A correlation of 0.72 was found'.

P28897, L10: Replace 'active nitrogen' with 'reactive nitrogen'.

P28897, L15: 'In addition, NO_x ...'.

P28897, L24: 'a comparison of tropospheric NO₂ column forecasts over Europe for 2008/2009'.

P28898, L5: Replace 'Whereas' with 'While'.

P28899, L4: Replace 'For concentrations' with 'In terms of concentrations'.

P28900, L7: Delete 'MAX-DOAS'.

P28900, L23: Insert a comma after 'In total'.

P28901, L1: Replace 'at' with 'on'.

P28909, L20: Replace 'equivalent' with 'equal'.

P28911, L2: 'As in this situation the modeled wind comes...'.

P28911, L21: Remove second occurrence of 'this day' in this sentence.

P28912, L4: Replace 'Gaussian' with 'Gaussian distribution'. Mention that $\sigma = 5.5 \cdot 10^{15}$ molec cm⁻² refers to all data.

P28914, L15: 'The *average* diurnal cycle'.

P28914, L16: '... only data from the months September, October (2008), and March and April (2008 and 2009) were used ...'.

P28915, L5: 'The dependence of tropospheric NO₂ columns from MAX-DOAS and Lotos-Euros on various meteorological parameters was investigated:'.

P28916, L18: replace 'three hundred thousand' with '300 000'.

P28921, L5: 'For daily averaged tropospheric NO₂ columns a correlation of 0.72 is

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found, and a linear regression shows that ...'.

P28921, L13: '...low weekly cycle in the *modeled* emissions'.

P28921, L19: Replace 'monthly cycle' with 'seasonal variation'.

Caption of Fig. 3: Replace 'High emissions in the North Sea catch the attention, but note that these have a large uncertainty' with, e.g., 'The high emissions present in the North Sea are subject to a large uncertainty'. Replace 'De' with 'The'. The map on the right side is not topographical.

Caption of Fig. 5: Replace 'pabel' with 'panel'.

Caption of Fig. 6: Replace 'which is argued' with 'as discussed'. Remove 'the' before 'Sect.'.

Caption of Fig. 7: 'In black the number of hourly averages for that month *is shown ...*'

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