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Atmospheric Measurement Techniques Discussions

Interactive comment on "Two-dimensional monitoring of air pollution in Madrid using a MAXDOAS-2D instrument" *by* David Garcia-Nieto et al.

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Here we include our reply to the Anonymous Referee 1, but for the sake of clarity we have also attached the .pdf file.

We would like to sincerely thank the Reviewers for their support and constructive comments on the manuscript. Their comments have helped to improve the quality of our work. We provide here a detailed point-by-point answer (shown in blue), to their comments and suggestions. Reviewer 1:

The present manuscript presents a complete analysis of O4 and NO2 vertical profiles

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during three months in Madrid, Spain with the aid of ground-based MAX-DOAS 2-D observations. The aerosol and NO2 vertical profiles in multiple viewing azimuth directions are presented here as well as the horizontal NO2 distribution around the measurement site. Finally, the 2-D MAX-DOAS NO2 near-surface concentrations are compared with the in-situ NO2 measurements in Madrid. I recommend the publication of the manuscript after consideration of a major number of specific comments:

We thank the reviewer for her/his thorough and constructive comments, which we address below. Specific comments:

1. Page 1, Line 19: Please write the spatial resolution of the mesoscale events. We have included the spatial resolution (in the order of a few kilometers) in lines 25-26.

2. Page 1, Line 27: In my understanding, you used one inversion algorithm (not inversion algorithms) for the aerosol and the NO2. Please correct that and write the name of the inversion algorithm that is used (bePRO). We have changed it by “an inversion algorithm” in line 19 in the abstract.

3. Page 1, Abstract: I would recommend that you write in a more clear way, the main findings of this study and the main contributions/innovations that you have made. Thank you for this useful comment. We rewrote this part and we included in more detail the main findings of our study, from line 20 to line 24.

4. Page 2, Line 49: I would recommend to write that you have developed two MAX-DOAS instruments and not just MAX-DOAS instruments. We developed one MAX-DOAS instrument, for this reason we specify now “we have deployed a Multi AXis Differential Optical Absorption Spectroscopy (MAXDOAS) instrument” in lines 63-64.

5. Introduction: It would be valuable to add a paragraph in which you cite previous MAX-DOAS studies of two-dimensional measurements (like Ortega, Schreier, Wang, Dimitropoulou etc.) as well as studies where MAX-DOAS observations are compared with in-situ measurements. We have added a paragraph (lines 88-93) in which we cite

previous studies that report measurement using MAXDOAS-2D instruments.

6. Section 3.2: Where do you expect to measure higher NO2 concentrations (North, South etc.)? Based on previous studies, there is no clear, steady distribution of NO2 in Madrid. Instead there are strong spatial gradients and temporal changes (including considerable traffic hot-spots), thus making it difficult to predict with great accuracy how the NO2 will be distributed at a given time. However, mesoscale simulations in Madrid show that in general, higher NO2 mixing ratios are expected in the southern part of the city taking into account the population distribution and commuting patterns (see Picornell et al., 2019 for more details). We have included this issue in lines 214-222.

7. Page 7, Line 193: In your study, one complete MAX-DOAS scan takes one hour. The advantage is that you have a very nice horizontal sampling but at the other hand, you risk to measure the same NO2 air mass in multiple azimuthal directions (for example, during one hour, the NO2 that you observe in the North can be moved by the wind in the North East direction). Please add a sentence in which, you make clear the advantages and disadvantages of your choice. Understood. We have added it in lines 264-271. Indeed, it will be useful for the reader to include the advantages and disadvantages of such measurements setup.

8. Page 11, Line 252: After the filtering of the MAX-DOAS measurements, which is the percentage of accepted scans? We have included the percentage of cycles (slightly above 90 %) that were considered valid (concerning the quality checks) as input for the RTM. You can see this part in lines 349-352.

9. Page 11, Line 264: The RTM is the forward model and the bePRO is the inversion algorithm. Please correct this. We have modified this part, (line 356 in our revised manuscript).

10. Page 12, Line 290: It's not exactly an analogous process because for the O4 and aerosol, non-linear calculations are performed and for trace gases as NO2, we have linear calculations. Please verify if it's the case for bePRO and correct or not this

sentence. Thank you for this appreciation. We have clarified that a linear analysis is made to estimate the vertical concentration profile of NO2 using the light paths derived from the non-linear analysis of the O4 and aerosol (from line 364 to line 372).

11. Page 13, line 310-318: You have used Standard atmosphere profiles, which are widely used in studies like the present one. But, you should include an uncertainty estimate of using a standard profile instead of a real profile (by meteorological measured data). We have developed a more detailed uncertainty analysis. We have included the uncertainty sources in the whole analysis from line 482 to line 490. Concerning the use of a given atmospheric profile, we have concluded that the RMS of the relative variations (within the first 10 km height) was of about 8 %. We went a step further and estimated that, regarding the light paths, the RMS of the relative changes coming from the atmospheric profile choice was below 2 %.

12. Section 4.2: You should a paragraph in which you present an average error estimate of the retrievals and add a Table with all the error sources (smoothing error etc). As described above, we have completed the section with the average uncertainties of the retrieval. A table has been included and appears in the text from line 493 to line 501.

13. Section 4.3: In your results, you should discuss the range of the estimated horizontal distances for the UV and Vis during your measurement period The range of the estimated horizontal distances appear now in lines 517-519.

14. Figure 6: These results are from which measurement day and scan/hour? I assume that it is not the whole period, right? Yes, these results are for the entire period, in line 540 it is marked that this correlation is for the entire campaign. We usually do this with the purpose of checking the goodness of the analysis for the entire campaign, it is a useful and rapid way to assess the simulations.

15. Figure 7: How do you explain the aerosol peak at around 50 deg. VAA and in high altitude? This aerosol peak could come from traffic because there is a main road at

this VAA. However, we are not sensitive above the boundary layer to know if this peak could be due to uncertainties in the RTM. Anyway, that would be one of the main ideas of this work: that the O4 DSCDs are the ones which drive the light path analysis. As shown in Section 4.2, an aerosol loading may cause a quite similar (or even the same) effect as small variations in the atmospheric profiles or parameters. However, this does not affect the light path estimation and the subsequent trace gas analysis, hence only affecting the certainty of assigning an irradiance extinction as aerosol (specially in higher layers), lines 565-569.

16. Page 20, Line 465: Why do you use the UV distance and the Vis which is larger? We have mentioned in line X that we only take into account the air quality monitor stations which are at a distance from our MAXDOAS equal or lower than 10 km, and the UV light path ranges typically in the order of 8-10 km, hence that is why we chose the NO2 retrieved in the UV region for the comparison. It appears now in lines 658-662.

17. Figure 10: Please include a 1:1 line and put the same axis limits in both x, y axis in order to quantify rapidly the underestimation on the near-surface NO2 concentrations by the MAX-DOAS Figure 11 (previously figure 10) has been modified in order to show 1 to 1 axis, so that the underestimation is easier to observe, as you suggest (line 672).

18. Page 21, Line 480: You write that the slope is lower than 1 (it is 0.4) which is true but you should add a sentence in which you discuss this finding. Is it in agreement with previous studies that compared MAX-DOAS and in-situ? We have completed this part including some previous works in which similar conclusions were reached (we also discuss the slope value from line 686 to line 689).

19. Conclusions: You should make this section larger and discuss more your results We have now a more complete summary and conclusions part (section 6).

20. Through the whole manuscript, references should be added, as I mentioned in previous comments Several references have been added through the entire work.

Technical corrections

1. Page 2, line 34: gaseous pollutant concentrations instead of gaseous pollutants concentrations Changed. Now line 44.

2. Page 3, line 73: path lengths instead of paths lengths Changed. Now line 99.

3. Page 11, Line 256: inversion algorithm method instead of inversion algorithms. Changed. Now line 356.

Please also note the supplement to this comment:
https://amt.copernicus.org/preprints/amt-2020-239/amt-2020-239-AC1-supplement.pdf

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