Author responses to reviewers

Gramme et al. (2025): "Urban pollution monitoring with the AOTF-based camera: NO2 validation with other DOAS instruments"

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We thank the reviewers for their thorough reading and very valuable comments. Our detailed answers are provided below, with the reviewer's comments as a reminder in grey. Text that has been changed in the manuscript is shown in red.

Response to Referee #1

RC1: 'Comment on egusphere-2025-2255', Anonymous Referee #1, 25 Jun 2025

Review of Gramme et al. (2025): "Urban pollution monitoring with the AOTF-based camera: NO2 validation with other DOAS instruments"

The manuscript presents a novel ground-based NO2 imaging instrument based on acousto-optic tunable filter (AOTF). The new instrument builds on a previous AOTF-based instrument and aims at capturing high spatial and temporal variability of the reactive NO2, a key trace gas for air pollution studies. The capabilities of the new instrument are described and tested during a field campaign in an urban environment in Italy. The imager was mounted next to two DOAS-type well-established instruments (MAX-DOAS and Pandora). NO2 differential slant column densities (dSCD) obtained after performing the DOAS analysis of the three instruments' spectra are compared and their differences assessed. Overall, the imaging results show good agreement with the reference instruments (strong correlation for SCD observations), demonstrating the potential of the new instrument in the context of urban air quality monitoring. The authors assess the limitations of the new instrument and suggest future work to keep on improving the technique and its applications.

The manuscript is well presented and the methodology is well described. Figures are clear and support conclusions. Overall, publication is recommended after addressing the following comments in the manuscript to further strengthen its impact.

General Comments:

The manuscript could benefit from a more detailed comparison with other NO2 remote sensing instrument, particularly alternative imaging approaches such as grating-based imaging DOAS, gas correlation cameras (e.g. volcanoes studies) or Fabry-Perot systems. This would help to frame the novelty of the instrument presented.

Thank you for your comment. An additional paragraph was added in the introduction.

"In recent years, several new remote sensing instruments have been developed that attempt to capture this variability of the NO2 field with a high spatial and temporal resolution. These instruments work in the UV-visible wavelength range, where NO2 is a strong absorber. Many consisted in grating instruments, whose field of view is steered mechanically (Manago et al., 2018; Peters et al., 2019; Mettepenningen et al., 2024). Retaining all the strengths of the differential optical absorption spectroscopy (DOAS) technique (Platt and Stutz, 2008), the images are constructed slice by slice, which is subject to artifacts in case of a dynamic scene.

One prototype of a native NO2 imaging instrument relied on the gas correlation technique (Kuhn et al., 2022) but was only tested on large point source plumes. Another concept studied the potential of a Fabry-Perot interferometer based polychromatic imaging system for atmospheric trace gases remote sensing, including NO2, with an elaborated use of the periodic structures of the species cross sections (Kuhn et al., 2019). To our knowledge, no real-world application has been realized yet.

An acousto-optical tunable filter (AOTF)-based instrument produced high spatio-temporal maps of NO2 in the plume released by a thermal power plant (Dekemper et al., 2016). While the concept requires sweeping over wavelengths, it is a native imaging system with relatively high spatial resolution compared to other techniques. This paper discusses the improvements made to this instrument, and demonstrates its capability to make quantitative measurements of the NO2 field."

The manuscript uses NO2 dSCD for instrument comparison and, towards the end of the draft, the authors state a future use of the O4 bands for light path assessment. However, it could help the reader if the authors could clearly state at the beginning of the manuscript that the relationship between NO2 dSCD and actual concentrations of NO2 depends on several factors (e.g., aerosol, clouds, surface albedo), which may not have the same effect on all the three instruments. Indeed, including O4 band and inversion of NO2 concentration would be crucial for a thorough assessment of the capabilities of the (three) instruments, their detection limits and their comparability.
This is indeed a useful clarification, which we added in Section 4.1 (campaign objectives)

"In Rome, the Atmospheric Physics Laboratory (APL) of Sapienza University hosts the BAQUNIN super site (Boundary-layer Air Quality-analysis Using Network of INstruments), where several ground-based instruments are available that monitor the boundary layer air quality (Iannarelli et al., 2022). This urban observatory is equipped to host ground-based instruments such as the NO2 camera for inter-comparison/inter-calibration campaigns. It was selected as location for a first urban test campaign in a challenging environment showing strong spatial and temporal variations.

The goal of the measurement campaign in Rome is to validate the correctness of the NO2 camera retrievals with two state-of-the-art remote sensing instruments: a Pandora and a MAX-DOAS, described hereafter. Both of these reference instruments measure dSCDs. By performing a light path assessment (e.g. using O4 absorption), and the inversion of NO2 concentration vertical profiles, their results can typically be converted to NO2 concentrations. As this paper focuses on the measurement and operational principle of the NO2 camera rather than on the processing of the results, only NO2 dSCDs are compared between the different reference instruments and the NO2 camera. The light path assessment, the inversion of the vertical profile, and the resulting NO2 concentration have a high priority on the NO2 camera roadmap through a pending integration into the FRM4DOAS framework (Van Roozendael et al., 2024) but are outside of the scope for this paper."

Also, the authors compare the new instrument with the two reference instruments and later on, they compare the reference instruments between themselves (last paragraph of Sect. 5.2). However, the authors are comparing three instruments, with three different field of view and two different DOAS (reference type) analysis. Also, as shown in Table 3, three different DOAS settings are used for the analysis. All these differences will affect the comparability of the data. The manuscript and conclusions could benefit if the two reference instruments were firstly compared with each other so a baseline for the quality of the comparison could be set. This could e.g. state (and quantify) the limitation of comparing NO2 dSCD analyzed with a fixed zenith reference spectrum (new instrument and MAXDOAS) with those analyzed with a sequential reference spectrum (Pandora).

Thank you for the good suggestion. To implement it in the manuscript, we inserted a new section (4.2.3), focusing on the differences in retrieval parameters and motivating them. We also reorganized the section 5.2 on the comparison results, as suggested.

"4.2.3 Differences in retrievals parameters

The retrieval parameters of the different instruments are listed in Table 3. Even though differences in retrieval settings can cause inter-instrumental differences, we have opted to keep the settings of the reference instruments the same as in earlier published results.

The summary in Table 3 underlines some inter-instrument differences in DOAS parameters. This results from a will to reuse prescribed settings from published results from each instrument separately. This is a potential cause for inter-instrumental differences in retrieved dSCDs.

In particular, the agreement on a reference spectrum is crucial to compare dSCDs from several DOAS instruments. The NO2 camera and the MAX-DOAS used a fixed zenith reference acquired on the 21st of March at 16:00 UTC for all their dSCDs. The Pandora, on the other hand, relies on centralized processing within PGN to obtain an NO2 dSCD. It is thus based on a sequential reference, defined as the spectrum taken at the lowest viewing elevation angle during each azimuthal scan (Cede et al., 2025, Product nvh3). Most of its dSCDs are then expected to be negative, requiring a post-processing step for comparability.

The difference in reference between the instruments could be compensated by computing a correction term for each Pandora azimuthal scan and adding it to all dSCDs in the scan. To compute this term, we compared the Pandora zenith dSCD during each scan with the corresponding (time-interpolated) retrieval of the MAX-DOAS. Their difference was added to all dSCDs at all viewing elevation angles in the same azimuthal scan from Pandora. When the scan contains several zenith observations, the averaged difference was used. This correction was also accounted for in the uncertainty estimates.

The difference in O4 cross-section is not expected to have a strong influence on the comparison results since we focus on the NO2 dSCD without performing the inversion to concentration profiles.

Finally, another significant difference between the instruments is the longer wavelength range used by the Pandora. We do believe it has an impact on the comparison results: this longer range is expected to include photons with a longer optical path, hence increasing the Pandora's dSCDs. However, we preferred to adhere to the well-validated operational settings of the international PGN network to retain its value as a reference instrument."

"5.2 Comparison results

Before comparing the NO2 camera with each reference instrument, we first present a baseline comparison between the MAXDOAS and the Pandora results. The purpose of this analysis is to set a baseline for the quality of the main comparisons, involving the NO2 camera. Even though both reference instruments have already been extensively validated, we do expect some differences in the results because of the imperfect time synchronization and the different DOAS settings, as explained in Section 4.2.3. A simple difference and a linear regression were used to characterize the relation between the Pandora and MAX-DOAS dSCDs, after applying the data filters discussed in the previous section. These statistics were calculated globally on all azimuth directions and outliers outside the interval [-2e16,2e17] molec/cm2 were excluded for the regression.

Due to small differences in the scanning schedule of the Pandora and MAX-DOAS, this direct comparison includes only 69 measurement points, much less than the comparisons involving the NO2 camera. The results, presented in Fig. 9, show a root-mean-square error (RMSE) of 7e15 molec/cm2 and a mean bias of 2e15 molec/cm2. The line of best fit has a slope of 0.99±0.04 and an R2 value of 0.97. In this direct comparison, we would actually expect a regression slope above 1, due to the longer wavelength range used in the Pandora. However, the very limited number of points might have prevented us from observing it, as shown by the confidence interval.

The main analysis compared the NO2 camera to each reference instrument, computing a simple difference and a linear regression with the same methodology as the baseline analysis. The summary statistics are detailed in Table 4. In particular, the root-mean-square error (RMSE) obtained is 1.4e16 molec/cm2 compared to both references, and the mean bias is very small, at 1.3e14 molec/cm2 (MAX-DOAS) and 1.4e14 molec/cm2(Pandora). The regressions and the corresponding scatter plots are shown in Fig. 9. The regression slope obtained is 0.99 for the comparison with MAX-DOAS. For Pandora, the slope is 0.94, which is significantly smaller than unity. A possible explanation is the Pandora's longer wavelength range."

About the impact of different fields of view on the dSCDs: from preliminary results of CINDI-3 (private communication with Martina M. Friedrich), no systematic difference was observed between Pandora vs SkySpec instruments, which rules out any significant effect of the FoV. However, we didn't discuss this aspect in the article given the lack of a published reference.

Specific Comments:

Unless otherwise stated, all suggested changes hereunder were implemented in the manuscript as recommended.

P3, L52: *"…, many more wavelengths are now acquired in routine operations in order to achieve higher accuracy"*. Please be more specific.
The text has been adapted to include more details.

"During the AROMAT campain operations, only four wavelengths
were acquired. In Rome, routine operations included wavelengths between 427 and 454.9 nm, sampled every 0.15 nm. Further details of the wavelength sampling are described later in Section 4. This allows to apply a DOAS algorithm and achieve higher accuracy."

P3, L56: Instrument description. Is the instrument calibrated radiometrically? How does temperature changes affect the AOTF spectral tunning?

The instrument is not calibrated radiometrically, but this is not required for DOAS. The temperature dependence of the AOTF tuning curve is discussed in Section 3.2 (Level-1 Processor). The method for wavelength correction is presented there, based on a Fraunhofer reference.

"... The optical wavelength filtered by the AOTF at a given acoustic frequency is known to depend on the crystal temperature, varying by about 0.1 nm per K. Although this variation can be computed and corrected for, a more precise wavelength registration is obtained by detecting the Fraunhofer lines, which are clearly visible in the measured spectra."

P3, L70: *"more compact"*. Please provide size.

The reader is now referred to Table 1, which contains the length of the optical channel and the weight of the camera.

P6, L118: *"In that case, a 1-D NO2 field can be observed"*. Do the authors mean "can be observed per azimuth?". In that, case, would it be a 2-D field?

Clarified: we mean "1-D array of NO2 slant columns can be retrieved in one single acquisition". We also merged this with the next paragraph, which relates to sweeping along the second dimension.

P6, L124: *"...capture complete images of the scene, but one wavelength at a time"*. How long does it take to gather one image at a given λ before moving to the next λ?

The per-frame exposure time is usually around 1 s, as mentioned in Section 2.3, L104.

P7, L128: *"lower signal-to-noise ratio"*. Does the instrument have a SZA limit where the SNR is far too low to assure the quality of the observation? Given the case, please provide such SZA limit.

During CINDI-3, we were able to perform retrievals until sunset. One sentence was added in the manuscript in Section 2.4.

"This lower SNR allows observations with SZA up to 90° while maintaining the per-frame exposure at 1 second, but twilight observations would require adaptations."

P7, L131: *"... focusing on a limited number of wavelengths"*. How do authors decide how many λ are a minimum? Please specify the rationale behind.

We added two references from the literature, using 8-10 wavelengths. Please note that our initial remark concerns an alternative possible use of the instrument and is not directly related to the article scope. In order to keep the text focused on the mode of operation for urban applications, we prefer to not further discuss other operation modes that have not been used during the data collection of this paper.

"In the context of satellite retrievals, Ruiz Villena et al. (2020) proved the feasibility of discrete-wavelength DOAS using only 10 carefully chosen wavelengths and reaching correlations above 99 % with the operational products from OMI and TROPOMI. The power plant campaign described by Dekemper et al. (2016) follows a slightly different approach based on 8 wavelengths. This way, the number of images required can be decreased, bringing the time for a single scene measurement below 10 seconds."

P8, L161: "PRNU" How is the PRNU characterized?

We have adapted the text to clarify how we obtained the PRNU.

"The final step in Level-1 processing is to correct for pixel response non-uniformity (PRNU), a type of instrumental bias where some pixels would show a different sensitivity from others when exposed to the same input signal. Because this PTC analysis showed no significant non-linearity in the instrument's response, we could use the PTC data to model the PRNU with a simple per-pixel scaling factor independent of the wavelength and of light intensity, even though these hypotheses may not be fully correct."

P9, L166: *"cosmetic step"*. What do the authors mean with that? Do you mean the PRNU correction could be omitted? Is PRNU 100% independent of light intensity?

Yes, PRNU was observed to be independent of light intensity in our in-lab PTC analysis. We made this more explicit at the beginning of the paragraph. The chosen type of PRNU correction has no impact on Level-2 data, which we also stressed again in the text.

"The final step in Level-1 processing is to correct for pixel response non-uniformity (PRNU), a type of instrumental bias where some pixels would show a different sensitivity from others when exposed to the same input signal. Because this PTC analysis showed no significant non-linearity in the instrument's response, we could use the PTC data to model the PRNU with a simple per-pixel scaling factor independent of the wavelength and of light intensity, even though these hypotheses may not be fully correct. This scaling factor is computed on one reference zenith cube, typically the same as used in Level-2 data processing, taking the per-pixel average intensity across all wavelengths. Note that the first step of Level-2 data processing (see below) is to compute the ratio between the zenith and scene intensities. Therefore, regardless of the choice of linear scaling used in the PRNU correction, it will not have any impact on the Level-2 product. That correction can thus be considered as a cosmetic step, only useful when displaying Level-1 images."

P14, L266: *"lowest elevation angle"*. Which angle? Elevation angle of the Sun or of the telescope? Clarify

We have added a clarification in the text.

"The Pandora, on the other hand, relies on centralized processing within PGN to obtain an NO2 dSCD. It is thus based on a sequential reference, defined as the spectrum taken at the lowest viewing elevation angle during each azimuthal scan (Cede et al., 2025, Product nvh3). Most of its dSCDs are then expected to be negative, requiring a post-processing step for comparability."

P14, L267-269: The way it is written how the MAX-DOAS is compared to the Pandora observations seems a bit confusing. Please, detail the procedure in more detail.

We rephrased it and moved it to the new Section 4.2.3 (see earlier comment for text)

P16, L295-296: *"not shown"*. Including the comparison with Pandora could assist the reader and the conclusions (supplementary?).

As we have significantly more available data points for the MAX-DOAS, we believe that our message is stronger if we only show the MAX-DOAS points. Adding the Pandora data would, in our opinion, extend the manuscript without adding value. However, if the reviewers insist, we can add or provide these figures as well.

In addition, the conclusions from this graph align with choices made during the CINDI-3 campaign, where elevation angles below the horizon are being dropped from the comparison.

P16, L296-297: *"…short slant column of NO2 between them and the instruments."* What do the authors mean? A shorter light path?

Indeed, now clarified

"This is due to the presence of buildings (visible in Fig. 7), inducing much shorter light path for some instruments."

P17, L325: The authors refer to the effect of "moving clouds". How would aerosols affect?

We expect that the effect from quickly moving aerosols plumes will be similar to moving clouds, even though the induced variability on measured spectral intensities will be weaker than clouds. We added this in the text.

"These artifacts are created by the moving clouds or aerosols, whereas the lower region of the image is left unaffected."

P21, L346: *"Given the unconventional concept of the NO2 camera…"*. What do the authors mean by "unconventional"?

We meant the sequential acquisition of wavelengths (compared to gratings, see Sec 2.4); now clarified.

"Given the unconventional concept of the NO2 camera where wavelengths are acquired sequentially rather than simultaneously, the first and main purpose of the campaign was to validate its measured NO2 SCDs with the coincident observations of the reference instruments."

P21, L361: What is the result of those changes in illumination conditions?

We meant changes in light path, which would affect the NO2 dSCDs; now clarified.

"The main problems encountered were related to the stability of the shape of the AOTF response function, and to changes of illumination conditions during the acquisitions, affecting the obtained NO2 dSCDs."

P22, L373: "pollution events" are often linked not only to NO2 but also to particles. The draft could benefit if the authors could assess the possible effect of aerosol on observations.

Assessing the aerosol effect would require to correctly evaluate air mass factors by retrieving O4 dSCDs. Unfortunately, we cannot do it for this campaign, due to the limited wavelength range acquired. This is however on our roadmap for the future campaigns (compatibility with FRM4DOAS and derivation of VCDs).

Technical Corrections:

P1, L2-5: *"Existing instruments..... hot spots and quick variations"*. This is a rather long sentence. Consider splitting it.

The sentence has been split.

P3, L53: *"In the following section,…"*. Please change to "In Sect. 2.4,…"

The sentence has been adapted accordingly.

"In Section 2.1, we describe the instrument, its operating scheme, and the raw data it produces. Sections 2.2 and 2.3 discuss the spectral response function of the instrument and the data acquisition respectively. Then, in Section 2.4, we discuss the main differences between this instrument and the conventional diffraction grating-based spectrometers which are currently used to monitor the field of NO2 as part of operational networks."

P3, L70: "RF". Define acronym.

The acronym has been written in full.

P5, L97: "Fig. 6". In the text of the manuscript, "Fig. 6" appears before Fig. 3, 4 and 5. It would ease things for the reader if the number of the figures were re-numbered.

The reference to Figure 6 has been removed as it is not necessary for the reader to understand the paragraph.

P8, Fig. 5: Please add the units of the vertical and horizontal axes

These were the pixel row and column (or, equivalently, elevation and azimuth). We had removed them since they are not relevant to illustrate the concept and only clutter the image.

P11, L214: "PTC". Define acronym.

The acronym is now defined in Section 3.1.

P14, L262: *"In order to dSCD comparable…"*. Consider rephrasing it "In order to compare dSCD from…"

The sentence has been rewritten and has been included in Section 4.2.3.

P14, L272: *"The each different…"*. Change to "Each different…"

"The" has been dropped from the sentence.

P17, L327: *"comparison made earlier"*. In Table 4?

Table 4 is indeed referenced now.

P20, L331: *"Sections 3.4, 4.2.2 and 4.2.1"*. Better change to "Previous sections"

The text now uses "Previous sections".

P20, Table 5: Please, specify for which elevation angle are those values

The caption now clarifies that these statistics are calculated globally across all included elevation angles.

Citation: https://doi.org/10.5194/egusphere-2025-2255-RC1

Response to Referee #2

RC2: 'Comment on egusphere-2025-2255', Anonymous Referee #2, 07 Jul 2025

Gramme et al. present a new ground based NO_2 instrument, which in contrast to conventional differential optical absorption spectroscopy (DOAS) applications does not measure the whole spectrum at once and instead measures a whole 2D image at a specific wavelength and shifts through the wavelengths using an acousto-optic tuneable filter. Each image represents the measured intensities at a specific wavelength, which in combination can be evaluated using the DOAS technique. This allows the instrument to capture a 2D NO_2 field every few minutes. The instrument is based on a proof-of-concept optical breadboard of the VIS channel for the ALTIUS mission and has been refined and improved to work as a ground based NO_2 instrument. The instrument was set up next to and compared to two state of the art ground based remote sensing instruments, a Pandora and a MAX-DOAS. NO_2 differential slant column densities are obtained and compared to each other for each instrument. The NO_2 camera shows a good agreement with the two reference instruments. The capabilities of the NO_2 camera are highlighted and possible issues are discussed. Generally, the manuscript is well written and the methodology is well explained and I will recommend it for publication, but beforehand I would suggest some minor improvements to the manuscript.

General comments:

If I understand correctly the camera needs a little longer than 188 seconds to measure all the data cubes necessary for a single dSCD. How are the dSCDs affected if there are highly inhomogeneous illumination conditions, e.g. when there are fast moving clouds all over the horizon?

Moving clouds indeed have a major impact on the retrieved dSCDs because they introduce signal variations that are not well captured by the DOAS polynomials. This is clearly visible in the DOAS fit's RMSE. Illustrations of their effect are shown in Fig. 10a and 11. The text now discusses these artifacts in Section 5.3.

"In addition, some figures show artifacts in the upper part of the image. These artifacts are created by the moving clouds or aerosols, whereas the lower region of the image is left unaffected."

Table 3 shows the different fit settings for the different instruments, which are slightly different for each of them. I assume there is a good reason for the different fit windows, polynomials etc. for each instrument, but maybe you can elaborate a little bit on this. Is there a specific reason for using different O2 dimer cross-sections?

Most of the differences are for "historical reasons", since we kept the parameters of each instrument close to their values in previously published campaigns. An additional section (4.2.3) was added, explaining this and briefly discussing the expected impact of the main changes.

"4.2.3 Differences in retrievals parameters

The retrieval parameters of the different instruments are listed in Table 3. Even though differences in retrieval settings can cause inter-instrumental differences, we have opted to keep the settings of the reference instruments the same as in earlier published results.

The summary in Table 3 underlines some inter-instrument differences in DOAS parameters. This results from a will to reuse prescribed settings from published results from each instrument separately. This is a potential cause for inter-instrumental differences in retrieved dSCDs.

In particular, the agreement on a reference spectrum is crucial to compare dSCDs from several DOAS instruments. The NO2 camera and the MAX-DOAS used a fixed zenith reference acquired on the 21st of March at 16:00 UTC for all their dSCDs. The Pandora, on the other hand, relies on centralized processing within PGN to obtain an NO2 dSCD. It is thus based on a sequential reference, defined as the spectrum taken at the lowest viewing elevation angle during each azimuthal scan (Cede et al., 2025, Product nvh3). Most of its dSCDs are then expected to be negative, requiring a post-processing step for comparability.

The difference in reference between the instruments could be compensated by computing a correction term for each Pandora azimuthal scan and adding it to all dSCDs in the scan. To compute this term, we compared the Pandora zenith dSCD during each scan with the corresponding (time-interpolated) retrieval of the MAX-DOAS. Their difference was added to all dSCDs at all viewing elevation angles in the same azimuthal scan from Pandora. When the scan contains several zenith observations, the averaged difference was used. This correction was also accounted for in the uncertainty estimates.

The difference in O4 cross-section is not expected to have a strong influence on the comparison results since we focus on the NO2 dSCD without performing the inversion to concentration profiles.

Finally, another significant difference between the instruments is the longer wavelength range used by the Pandora. We do believe it has an impact on the comparison results: this longer range is expected to include photons with a longer optical path, hence increasing the Pandora's dSCDs. However, we preferred to adhere to the well-validated operational settings of the international PGN network to retain its value as a reference instrument."

The O2 dimer cross-sections of the Pandora is the one required by the Pandonia Global Network. The cross-section used by the NO2 camera is the same as the one used during the CINDI-3 campaign for the NO2CAM-SMALL window, whereas the cross-section selected by the MAX-DOAS team is the one from the O3VIS window from the CINDI-3 campaign. This difference in O4 cross-section is not expected to have a strong influence on the comparison results since we focus on the NO2 dSCD without performing the inversion to concentration profiles.

In the estimation of the uncertainty of each NO2 dSCD, the systematic contributions are ignored so far, but maybe you are able to provide a rough estimate for some systematic contributions already.

The estimation of uncertainty is described in Section 3.4, where systematic contributions are indeed ignored, definitely resulting in under-estimated uncertainties. To mitigate this, we propose an alternative empirical approach specific to the campaign results in Section 5.4, and argued that this, however, is likely an over-estimation of uncertainties. In Table 4, we observe a factor 7 between these two estimates.

Finding individual contributions of different systematic terms already requires sensitivity studies. This assessment represents a large effort which will come a bit later, as the instrument keeps on evolving. A full error budget for the instrument will be worth a separate publication when it is completed.

Specific comments:

L266: I am little bit confused by this, does the PGN use a low telescope elevation angle measurement as the reference? Please clarify this part.
Indeed. This paragraph has been extracted into a new section focusing on the differences, and the correction was clarified.

"The Pandora, on the other hand, relies on centralized processing within PGN to obtain an NO2 dSCD. It is thus based on a sequential reference, defined as the spectrum taken at the lowest viewing elevation angle during each azimuthal scan (Cede et al., 2025, Product nvh3). Most of its dSCDs are then expected to be negative, requiring a post-processing step for comparability."

Technical corrections:

L53 – L 55: These two sentences are similar and I guess one of those is leftover from a previous iteration of the manuscript.
The text has been adapted as follows:

"In Section 2.1, we describe the instrument, its operating scheme, and the raw data it produces. Sections 2.2 and 2.3 discuss the spectral response function of the instrument and the data acquisition respectively. Then, in Section 2.4, we discuss the main differences between this instrument and the conventional diffraction grating-based spectrometers which are currently used to monitor the field of NO2 as part of operational networks."

Table 1: Table caption should be above the table.
Table 2: Table caption should be above the table.
Both captions have been moved above their respective table.

L123: "Instead of scanning the scene, (Dekemper et al., 2016) proposed..." remove the () around the citation.
The parentheses have been removed.

Table 3: Table caption should be above the table.
The caption has been moved.

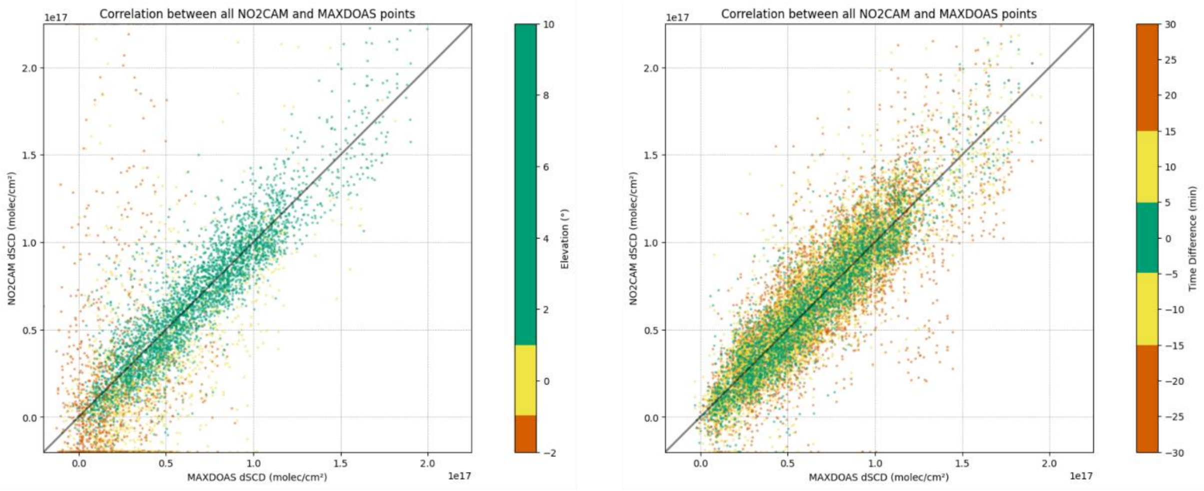
L219: I assume uz,L1 and Iz,L1 are the uncertainty and Intensity of the zenith measurements, however I think it's good practise explain all variables in an equation.
Both have been added, other equations have been checked and now have all variables explained.

L259: "... its outputs is provided in (Cede et al. 2025) and ..." remove the () around the citation.
The parentheses have been removed.

L262: The first part of the sentence is missing a verb.
The sentence has been removed, its content has been incorporated in the new Section 4.2.3.

Figure 8: Please check if this figure is suitable for red / green color blindness.

Thank you for bringing this to our attention. We have modified the color palette of the figure and checked the new figure using Coblis (https://www.color-blindness.com/coblis-color-blindness-simulator/) and a BYU tool (https://bioapps.byu.edu/colorblind_image_tester). Results from BYU show that this improved image is friendly for people with red-green color vision deficiency with 92% confidence.



(a) (b)

Table 4: Table caption should be above the table.

The caption has been moved to the top of the table.

Figure 9: the titles of the subfigures are clipped

The figure has been regenerated to prevent the clipping.

L331: “Sections 3.4, 4.2.2, and 4.2.1 above…” change the order of the sections so they appear in ascending order.

Following a comment from Reviewer 1, the references to specific sections have been removed. The paragraph now starts with “Previous sections …”.

Table 5: The table caption should be above the table.

The caption has been moved to the top of the table.

Citation: https://doi.org/10.5194/egusphere-2025-2255-RC2