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Atmospheric Measurement Techniques Discussions

Interactive comment on "Evaluating different methods for elevation calibration of MAX-DOAS instruments during the CINDI-2 campaign" *by* Sebastian Donner et al.

Anonymous Referee #1

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This paper by Donner et al. describes and evaluates four different methods for elevation angle calibration of MAX-DOAS instruments in the field. It evaluates the four methods using multiple MAX-DOAS instruments during the CINDI field campaign and concludes that all four methods are suitable for field calibration. Since there is a lack of papers documenting calibration of MAX-DOAS elevation angle, and this paper would be a first step towards standardizing elevation angle calibration for MAX-DOAS instruments, I suggest the paper be accepted with minor changes.

Major comments:

The paper lacks description of laboratory calibration methods used before the field

campaigns. It is mentioned that the instruments are calibrated in the lab before deployment on the field but no descriptions are provided. I think it would be very helpful to have some description of laboratory calibration methods and compare the pros and cons of the laboratory vs field calibration methods. What are the challenges of reproducing laboratory calibration methods? Is laboratory calibration better than field calibration? What is the accuracy and precision of laboratory calibrations?

The paper concludes that all four methods are suitable for field calibration of MAX-DOAS instrument even though the horizon scans could result in an offset of 0.3-0.6 degrees. In the introduction, it is mentioned that a 1 degree error in elevation angle at 0 degree elevation angle could result in $\sim$20% error in NO2 dSCD. Thus, recommending a method which could result in similar bias that the authors are trying to minimize does not seem right. I suggest the authors modify their conclusions to reflect this information provided in the introduction. I also suggest recommending one or two methods based on uncertainty of the method and ease of implementation.

The far lamp, near lamp and white stripe test all relies on knowing the optical axis of the instrument for accurate calibration. If the optical axis of the instrument is well known, could you calibrate the elevation angle using a bubble or digital level? Did any group level their instruments using such a level before the field campaign? I think this is a very important information as bubble or digital level is the simplest way to calibrate elevation angle. So, how does this method compare with the methods presented in the paper?

The paper simply glossed over the backlash issue. This is especially important for the 2D-MAX-DOAS instruments which are capable of doing elevation angle scans at any azimuth angles. The authors found a 0.4 degree difference between scanning from the bottom vs top and decided to just scan from the bottom. I think 0.4 degree is quite significant. How many of the instruments suffer from such a backlash issue? I suggest the authors include some comments/best practices to avoid such issues especially for a 2-D MAX-DOAS?

Minor Comments:

P1, Line 5: This method was applied to more than 12 instruments as can be seen from Figure 19-21. Why did you not include all the instruments in the paper? I suggest make the number of instruments in the paper consistent.

P4, Line 27: How accurate are these inclinometers? I would think the motor steps are more accurate than the inclinometers.

P5, Line 20: What was the resolution used for the initial calibration?

P7, Line 10: How is the light source aligned with the optical axis of the instrument using the laser level?

P7: Near lamp measurements: What are the pros and cons of near lamp measurements? What is the expected accuracy of near lamp measurements? I think the near lamp measurements need to be described in detail as it is likely easier to set up.

P9, Line 5: How does the calculated FOV compare to the reported FOV in Table 2 for different instruments?

Section 4.1: I think the main message of this is lost amongst different type of instruments and different scanning modes. Please consider making this section concise. The main message of this section is (1) independent laboratory calibration between different groups agree within 0.9 degrees, and (2) far lamp calibration method is stable. I don't think all the figures are needed to convey these points.

P14, Line 4-6: It seems that 0.9 degree spread is related to the initial laboratory calibration and not FOV? Why do you think this is related to the FOV?

P14, Line 28 – P15, Line 17: A lot of text to say we don't know what is going on. And it does feel like the author is rambling at times. Please be concise. May be it is better left for a separate paper.

P14, Line 18: Change section title to "comparison between far lamp and horizon ele-

vations" as there is already a comparison between methods section.

P17, Line 13: How do you come up with 0.1 degree uncertainty? Based on the far lamp and near lamp measurements results for IUP-Hd, there is a bias of -0.3 degrees for the near lamp measurements?

P18, Line 2: How do you come up with 0.1 degree uncertainty? Is this an estimate of reproducibility error? What is the uncertainty of the Gaussian fit in figure 11?

Table 1: Please remove instrument ID. While it saves the authors from remaking Figure 21 and 22, it is very confusing to the reader. There are already too many acronyms and having a suffix that is not needed is not helpful.

Table 3: Was the instrument calibrated using the far lamp before 08/09? Are these just test of reproducibility?

Figure 3: Based on the lower part, the elevation angle of the lamp should be negative?

Figure 5: Why are the measured intensity not symmetric? How does this asymmetry affect instrument elevation angle calibration?

Figure 7: How do you make sure the laser level is aligned with the optical axis of the instrument to calibrate the elevation angle?

Figure 9: Please mention what is the red dashed line in the figure?

Figure 11: This shows that it is the best method? Why is this not recommended exclusively?

Figure 12: Panel c: I think it might be better to show average than sum? Same with Figure 13-15.

Figure 12-15: I think it would be better to combine these into one figure. Also, all these figures are likely not needed.

Figure 18: What is mean of fit errors? Instrument label is confusing?

Figure 19: There are instruments that are not listed in Table 1. Make the markers little larger. How is the expected horizon calculated?

Figure 20 and 21: Add the expected horizon on the plot. There are instruments in the plot that are not listed in Table 1. Either add them to Table 1 or remove from the figure.

Figure 24 and 25: Why are the error bars for different instruments so different? It seems like there were different number of measurements for different instruments. I think it would be more appropriate to include standard error of mean as the error bar.

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