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Atmospheric Measurement Techniques Discussions

Interactive comment on "The CU Airborne MAX-DOAS instrument: ground based validation, and vertical profiling of aerosol extinction and trace gases" *by* S. Baidar et al.

Anonymous Referee #1

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GENERAL COMMENTS

Like in previous studies related to airborne scattered sunlight DOAS measurements, the work of Baidar et al. addresses the relevance of an accurate knowledge of the viewing geometry and further exploits the implementation of a motion compensation system on an AMAX-DOAS instrument to gain the maximum sensitivity at the layer where the aircraft flies. After describing the instrument, the authors present DOAS measurements performed over California in 2010. The authors do calculate VCD below the aircraft from the nadir viewing geometry (with geometrical approximation) and

compare it to ground based measurements, and invert trace gas vertical profiles from the limb viewing geometry with RTM calculations based on O4 dSCDs measurements.

Note that the motion compensation system embedded in the instrument represents a useful implementation to the experimental setup of the air-borne DOAS family (e.g. Petroli et al., Appl Optics, 2002; Bruns et al., Appl Optics, 2004; Weidner et al., ACP, 2005; Dix et al., AMT, 2009). Thus in fact the instrument presented in this work is not a novelty in itself. The adjective "unique" should be removed or modified in the manuscript.

The paper is generally well written although, for clarity, the results should be divided into "nadir measurements" (with geometrical approximation and its validation) and "no-nadir measurements" (vertical profile inversions based on O4 and RTM and WITHOUT validation). Hence the title of the manuscript should be clarified since the "ground based validation" it is only for the case of the nadir viewing measurements (which in fact is not a novelty). The work of Baidar et al. should be published in AMT only after addressing the following comments.

SPECIFIC COMMENTS

Page 7243 (Title): The DOAS community already suffers a very broad amount of abbreviations (LP-DOAS, MAX-DOAS, CE-DOAS, mini-DOAS, AMAX-DOAS, etc) mostly related to the measurement technique. Thus, since the relevant matter in this work is the measurement technique (MAX-DOAS), CU MAX-DOAS should be simplified into MAX-DOAS throughout the manuscript. Otherwise the community would end up with so many different MAX-DOAS as institutes or departments, when indeed we are talking of the very same measurement technique. The procedence of the instrument is to be considered in the main text, not on the title. The AMAX-DOAS instrument is validated through ground based NO2 comparison only for the nadir viewing geometry. No validation of any trace gas vertical profile is in fact presented ("ground base validation" should be "VCD validation").

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Page 7244, line 6: Aren't the trace gases retrieved in a spectral window rather than at a single wavelength? What is the meaning of "360 nm, 477 nm, 577 nm and 632 nm"?

Page 7244, line 7: what do you mean with "sensitively"?

Page 7244, line 8: the instrument is an AMAX-DOAS, therefore it is not "unique" but maybe "an improved" AMAX-DOAS.

Page 7244, line 14: How are the "2 km above and below the aircraft" estimated? Explain.

Page 7244, line 27: How can the profiles be "independent of the signal-to-noise at which the trace gas is detected"?

Page 7245, line 16: Missing reference to the so called mini-DOAS stratospheric balloon instruments (e.g., Weidner et al., ACP, 2005 and references therein). Note that they performed thorough sensitivity studies on the forward parameters in profile inversion as well as their propagation into the radiative transfer models.

Page 7246, line 9: the phrase "The DOAS technique. . ." should be moved to Sect. 3.1.

Page 7246, line 14: "larger" than? Explain.

Page 7246, line 18: All AMAX-DOAS are implemented in aircrafts by definition. The sentence "presents the first true AMAX-DOAS implementation..." should be removed or rephrased. All AMAX-DOAS used in previous works are also "true" AMAX-DOAS.

Page 7248, lines 9-10: Is the Hg lamp also used for calibration? If so, how often were the spectra calibrated?

Page 7249, line 6: A sketch of the telescope system as well as the optical fiber switch box would ease the understanding of the instrumental setup.

Page 7249, line 24: I understand that the retrieval of O4 does not require such a high resolution system as does the retrieval of the other trace gases presented in

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the manuscript. However, the "TG" spectrometer-detector system presented in the manuscript would also be valid for retrieving O4 (at least the 360 nm absorption band). Considering the space/weight/power limitations usually linked to most aircraft deployments, what would be the reason for adding a spectrometer (i.e., needing thus 2 racks) dedicated only to measure O4 in an aircraft deployment? Possible deployment issues on different aircrafts and/or campaigns could be spared if only one spectrometer (1 rack) is used. Additionally the fiber setting would also be simplified. The only requirement in case the O4 absorption band at 477 nm would be needed is a wider spectral coverage of the TG spectrometer.

Page 7250, line 9-10: Why the filters are only considered for the TG spectrometer?

Page 7253, line 4: Introduce the reason of interest for measuring NO2, HCHO, CHOCHO and aerosols.

Page 7254, line 8: What is the principle of the DOASIS software for calculating the Ring cross-section? How does that software calculate the Ring spectrum? It doesn't appear in the associated reference.

Page 7254, line 14: Not only "excess". It is a difference no matter the direction of the variance.

Page 7254, line 27: Shouldn't be Eq (1) dVCD instead of VCD? Explain the difference.

Page 7255, line 8: Assuring that an error is "very high" is quite ambiguous. Define "very high" in this case.

Page 7256, line 26: How is the value of the aerosol asymmetry parameter determined?

Page 7257, line 21: "higher" than?

Page 7257, line 27: It depends on the extinction of the atmosphere due mostly to aerosols and clouds. Are clouds considered at all? If so, please explain how.

Page 7258, lines 14-16: The phrase "For 0° EA. . . . . ." is only true in the case of

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Rayleigh atmosphere and single scattering approximation. What happens when the aircraft crossed a cloud or an aerosol layer?

Page 7258, line 26: That approach also assumes the atmospheric layers to be horizontally homogeneous. How can you assure that in the case of a polluted environment with several emission sources?

Page 7259, line 3: Actually above 10 km, what is the amount of O4 in the atmosphere? Would that 20-80 % error be due to the measurement error or to the pointing accuracy error?

Page 7259, line 19-22: E.g., Kritten et al., 2010

Page 7260, line 1: Don't you measure dSCD and not SCD?

Page 7261, line 2: For clarity, the results should be divided into nadir measurements (with geometrical approx and its validation) and no-nadir measurements (profile retrieval based on O4 and RTM and without validation). Thus the title of the manuscript should be clarified since the "ground based validation" it is only for the case of the nadir viewing measurements (which in fact is not a novelty). Note that, for instance, the Sect 4.3 "determination of O4 SCD in the reference spectrum" is only relevant for the no-nadir measurements.

Page 7261, line 21: Again, why keep on adding abbreviations to the original name? The origin of MAX-DOAS is a ground based instrument. Why GMAX-DOAS? Please try not creating new acronyms when they are indeed not new instruments and/or techniques.

Page 7262, line 4: Given the measurement error of MAX-DOAS instruments at 20°, how is that VCD 10% error estimated? Please explain the error propagation throughout all the calculations in the manuscript.

Page 7262, line 18: Detail the cloud filter used.

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Page 7262, line 29: How is then the validity of the geometrical approach affected under horizontally non-homogenous atmospheric layers?

Page 7263, line 17: the temperature dependence of O4 cross-section was actually reported much earlier. Correct reference.

Page 7264, line 7: where does that regression appear?

Page 7264, line 23 (Fig. 10): How is the error propagation in the case of the aerosol retrieval?

Page 7264, line 23: Is the retrieval performed for one single type of aerosol? If so, how realistic is that simplification?

Page 7265, line 10: How are those "10 km" estimated? That value depends on the wavelength, altitude and aerosol conditions. Clarify.

Page 7266, line 13: "aerosols as a source of glyoxal". Is there any experimental work in literature confirming that suggestion or the opposite? Please, provide some references supporting that statement.

Page 7266, lines 16-17: Is that elevated O3 layer considered in the RTM calculations for the aerosol and for the trace gas inversion?

Page 7266, line 22: How can the capability of inverting vertical profiles be independent of the signal-to-noise of the measurements when in fact the error of the measurement is part of the formula for the mathematical inversion? Please, clarify.

Page 7267, line 1: quantify "small".

Page 7277, Table 1: The cross-sections used in this work are not updated. Please quantify the effect of using the latest HCHO (K. Chance and J. Orphal, 2011) and H2O (HITRAN 2009) on the retrieved dSCDs. Please, explain how you correct for the temperature dependence of H2O in the retrieval. Why don't you use only one O4 cross-section?

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Page 7278, Table 2: How are the “2 Rings” calculated? Please detail the why the Ring cross section is modeled as well as the influence of including 1 or 2 Rings in the HCHO retrieval. Why the 2 Rings were only included in the HCHO retrieval and not in the retrieval of the other trace gases? Since two NO2 cross-sections were included in the retrieval of NO2, how do you interpret the resulting dSCDs when in fact you are orthogonalizing them? Which dSCDs were used for the retrieval of NO2 profiles?

Page 7279, Table 3: How is the detection limit calculated from the DOAS measurements (formula)? The detection limit for H2O is missing. ÉŻ360 is not shown anywhere in this work. Either include results or exclude from table.

Page 7280, Table 4: Please define “most probable conditions” and explain the error propagation.

Page 7281, Table 5: What would then be the total error in the aerosol extinction coefficient? How would that error propagate into the trace gas retrieval?

Page 7289, Figure 8: How do you calculate VCD from dSCDs from the ground-based MAX-DOAS. How does the VCD calculated with the nadir measurements compare with the VCD after the inverted mixing ratio NO2 vertical profile?

Page 7291, Figure 10: The authors do infer an aerosol vertical distribution based on the O4 dSCD retrieved at 477 nm (Fig. 10) and use it for the inversion of the vertical profiles of several trace gases. Is the inversion of HCHO vertical profile based on the aerosol extinction coefficient at 477 nm or at 360 nm? If the earlier, an estimation of the wavelength dependence (and error propagation) of the extinction coefficient would be needed. If the later, an additional figure of the aerosol extinction profile at 360 nm (similar to Fig. 10) would assist to understand the retrieved HCHO. Please explain how the error bars are calculated in the extinction profile. Please specify the asymmetry parameter and single scattering albedo used in the RTM as well as the effect of changing those parameters on the retrieved aerosol profiles (and hence on the traces gas profiles). Do you consider only one type of aerosol? Do you distinguish between aerosols

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and clouds?

Page 7292, Figure 11: Showing the dSCDs as well as the AMF plots would assist the reader. Please include at least the AMF calculations. The FWHM of the averaging kernels seem to be of 0.5 km. That would be therefore the vertical resolution of the measurements, isn't it?. Please, define the a priori covariance considered on the inversions. Include detection limits of the shown profiles. As commented before, what aerosol profile is used in the inversion of the HCHO vertical profile? ÉŻ360 or ÉŻ477? Why is the water mixing ratio given in %? How do the authors go from mixing ratio to relative humidity? Where IO and BrO detected during the flights?

TECHNICAL CORRECTIONS

Page 7244, line 3: please delete "remote sensing" from the phrase "uses solar stray light remote sensing to detect"

Page 7244, line 6: change "dimmers" to "dimer".

Page 7244, line 26: correct "are" to "is".

Page 7244, line 27: the extinction coeff. at 360 nm is not presented in this work. Introduce or remove.

Page 7246, line 3: change "only one" by "the"

Page 7246, line 10: Reword "These instruments also lack. . .." By e.g. "However these instruments lack. . ."

Page 7246, lines 21-24: The phrase "The motion component. . .." is grammatically wrong. Rephrase.

Page 7248, line 4 and line 16: Delete "on the".

Page 7254, line 2: Start a new paragraph for introducing VCD.

Page 7255, line 1: define dAMF.

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Page 7283, Figure 2: (E), (F) and (G) cannot be found in the picture.

Page 7285, Figure 4: Include the RMS plot of each fit, the units of the retrieved dSCDs as well as the SZA of the measurements.

Page 7286, Figure 5: Please include “nadir measurements” in the capitation.

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