Review of

A wide field-of-view imaging DOAS instrument for continuous trace gas mapping from aircraft

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General Remarks

This manuscript describes an instrument for mapping trace gas distributions from an aircraft platform. Configured in a downward-looking port, the instrument collects solar UV/visible radiation scattered either on the Earth's surface or in the atmosphere between the aircraft and the ground, and analyzes it for the characteristic spectral absorption of certain chemical species – in this case NO_2. Though not entirely new, the ability to map spatial distributions of atmospheric pollutants is a topic of growing importance in the atmospheric sciences community, and thus the description of this specific instrument does represent a significant and useful contribution to the literature. Furthermore, the paper is well-written and quite rigorous in its treating of potential difficulties (e.g. stemming from a variable air mass factor), and I recommend publishing it in Atmospheric Measurement Techniques after only a few rather minor corrections and additions have been made. These are described in the comments below.

Specific Comments

Title: The word "continuous" in the title appears to imply that the mapping measurements are performed continuously. Usually, continuous measurements are ones that are performed without interruption for a long period of time, e.g. days or weeks. This is clearly not the case here. I assume the authors are referring to the lack of gaps in the mapping data, but perhaps this can be expressed in some other way, e.g. "two dimensional trace gas mapping" or "high resolution trace gas mapping"?

P3592, L13 – The spatial resolution depends on flight altitude. This should probably be mentioned here. Also see line 17, where a spatial resolution of 30m is given. This also depends on altitude, correct?.

P3593, L7 – Here, perhaps you should more clearly explain that the reaction of NO with ozone is in steady state with the photolysis of NO2 unless this system is perturbed e.g. by the input of NO from an industrial stack into the atmosphere.

L13 – It's probably better to state that tropospheric O3 "impacts" air quality, since it does have a few positive impacts as well as the negative ones.

P3594, L27 – You mention two previous applications of imaging systems on aircraft but fail to mention the application by General et al who flew a similar instrument (HAIDI) to characterize the plume of Mt. Etna. I believe that this instrument is more similar to the AirMAP than the other two that you do

mention here. Please include a brief description of the HAIDI and a short comparison of the AirMAP and the HAIDI, as you do for the other two. Please be certain to include the relevant references for this too:

General, S., Bobrowski, N., Pöhler, D., Weber, K., Fischer, C., and Platt, U., 2014. Airborne I-DOAS measurements at Mt. Etna BrO and OClO evolution in the plume, J. Volcanol. Geotherm. Res., doi:10.1016/j.jvolgeores.2014.05.012.

General, S., Pöhler, D., Sihler, H., Bobrowski, N., Frieß, U., Zielcke, J., Horbanski, M., Shepson, P. B., Stirm, B. H., Simpson, W. R., Weber, K., Fischer, C., and Platt, U., 2014. The Heidelberg Airborne Imaging DOAS Instrument (HAIDI) – a novel Imaging DOAS device for 2-D and 3-D imaging of trace gases and aerosols, Atmos. Meas. Tech. Discuss., 7(3), pp. 2187–2257, doi:10.5194/amtd-7-2187-2014.

P3595, L9 – Does this sentence still hold true when compared to HAIDI?

P3596, L26 – Please be more specific with regard to the fiber diameter. Is the core-to-core separation the distance from the center of one fiber to the center of the next, or is this the distance that the cladding in between two adjacent fibers takes up? Both dimensions are important. The distance from the center of one fiber to the center of the next combined with the focal length of the imaging optics effectively gives the spatial resolution, independent of flight altitude, correct?

P3597,L7 – Please give a reference for pushbroom and whiskbroom imaging. I believe that your reference to Lohberger et al e.g. describes this.

3598, L21 – This sentence explains several different concepts, so I'm not really sure what the "latter" refers to here. Also not sure what the "basis for mapping purposes" means. Please be more specific.

L23 – Change to " a ground pixel size of 30m along track is achieved". Again, this must depend on flight altitude, correct?

P3602, L20 – You show that the spectral resolution is slightly degraded for pixels close to the edge of the sensor. You write that the "varying image quality along the spatial axis" is responsible. I assume you mean that aberrations of the object lens become significant for rays ending close to the detector edge. Perhaps clarify this sentence. Also, doesn't this mean that the spatial resolution is also degraded (in cross-track direction) for those pixels? Is that an issue at all? Perhaps the pixels actually begin to overlap slightly? I don't think it's mentioned in the text.

P3603, L3 – You mention that the SRF shape and width do not vary with wavelength. This is indeed an important characteristic, but it is seldom perfectly fulfilled. It is quite common for spectrometers to show some degree of variation in shape at least. There are various ways of dealing with this – from simply ignoring minor variations to using a variable SRF for cross-section convolution. In any case, it might be useful to include a little more information on the tests that were conducted to ensure there was no significant variation in the SRF, and perhaps state that the SRF was 'reasonably constant' or that 'no variations were detected', rather than discounting this effect altogether.

P3604, L7 – Can you very briefly explain why a "constant intensity offset" is fitted? I assume this means that a constant intensity Ic is subtracted from (or added to) the measurement before the linear fit is used to derive column amounts? Ic is then varied in the non-linear fit? Is Ic meant to describe the contribution of stray light in the spectrometer? If so, is the assumption that this stray light is constant across the detector a valid one?

L19 – Significant spatial variations along flight direction are described here, but fig 7 shows a time series. Perhaps it is better to speak of temporal variations here, although I understand that they correspond to a spatial variation. Also, some of this variation is clearly noise. It might be a good idea to mention the magnitude of the noise, and then say that the temporal variations in the data are clearly larger than the noise alone.

P3606, L3 – Here and elsewhere the "central flight pattern" is mentioned. It did not become clear to me what part of the flight track this actually refers to. It seems to me that all the plots of the flight track over the power plant show the same area. In this case, maybe it is better to simply refer to the "flight track above the power plant area".

P3606, L9 – You mention that the NO2 slant column amounts do not exhibit stripy features and are generally consistent for different viewing angles. You state that these features would appear if there were viewing angle dependencies of the slant column results. In the next section, you then show that the AMF depends on the viewing angle, and use a geometrical approximation to correct for this effect. These two statements appear to be in conflict with one another. Shouldn't the slant columns exhibit enhanced values towards the sensor edges when compared to the nadir observations? Granted, this would only be visible in areas in which significant amounts of NO2 were actually located beneath the aircraft, particularly above the power plant plume. I'm a little bit confused by this finding.

P3607, equations – These equations and SCIATRAN model results are valid when observing trace gas distributions on spatial scales that are larger than the lateral distance that light travels on its way from the aircraft altitude to the ground and back up again to the instrument. In the worst case, this length scale $L = H * (\tan(\Theta) + \tan(\Theta i))$. For e.g. a solar zenith angle of 30 degrees and a viewing angle of 20 degrees, this length scale L approaches the flight altitude H. If flying at 1km altitude, this means that in this admittedly worst case, the radiation passed through the atmosphere about 1km away on its way down to the Earth. If measuring a plume of smaller dimensions at considerable altitude, the radiation might miss the plume on its way down, only passing through it on its way up after having been scattered on the ground. These 3 dimensional effects obviously can affect the AMF in some cases, particularly when observing localized plumes. It will likely be quite difficult to quantitatively deal with these 3 dimensional effects in this study. Also, the stack plume is likely quite close to the ground and so the issue might be negligible. However, I feel that the issue is at least worth mentioning and it could be worth conducting a back-of-the-envelope calculation to determine if it is relevant here or not, thus also alerting others that in the case of high altitude plumes measured under high solar zenith angles, this can be problematic.

P3613, L15 and Figure 17 – This shows some variability in the NO2 emission rate as a function of distance from the stack .The variability in the plot is largely within the measurement error. However, the flight track shows that there were several additional transects of the power plant plume that were conducted closer in. Adding emission rates derived these to the figure could potentially show the expected increase with time beyond the measurement error, and this plot might then even be used to attempt to improve the constraints on the NOx emission rate (e.g.by assuming a constant O3 concentration and photolysis rate and fitting for an exponential approach to the steady state NO/NO2 ratio). Then one might not have to guess a value for r. Personally, I think that would be quite interesting and I wonder if you might consider it.

P3617, L1 – I was a little bit confused about this section. First you derive VC and Int for both the motorway and the bright field. Then you seemingly subtract the VC derived for the field from the VC derived from the motorway. I thought this was done to correct for variability in the AMF caused by the enhanced albedo (which is at least similar for the two locations). You arrive at 3±2.2e15 molec/cm2. However, you then describe how much an additional correction for variations in the albedo would affect the values. Didn't you already correct for this effect by using a differential measurement, i.e. looking at the motorway relative to the bright field?

Minor Corrections

Particularly on the first few pages, there are a large number of sentences that do not follow the basic structure of subject, predicate, object (S-P-O) but instead start with the object or a subordinate clause instead. While grammatically correct, overuse of this inverted sentence structure tends to make the material more difficult to comprehend. I recommend rewording some of these sentences to a more simple S-P-O sentence structure. Examples of these inverted sentences include:

Abstract first sentence: "For the purpose of trace gas measurements and pollution mapping, the AirMAP has been developed, characterized and successfully operated from aircraft"

might be changed to:

"The AirMAP has been developed, characterized and successfully operated from aircraft for the purpose of trace gas measurements and pollution mapping."

Other examples:

Abstract second sentence

Abstract line 8 – "With a wide-angle…"

Abstract line 14 – "From a maximum.."

Abstract line 18 – "For accurate spatial…"

P3592,L14 – Replace “single” with “individual” in “… by 35 individual fibers…”

L22 – use simple past: “AirMAP was operated on the…”

L24 – “AirMAP clearly DETECTED the emission plume downwind OF the …”

P3593, L6 – “NO2, is an important trace gas in the…”

L18 – “…NO2 lifetime, THE spatial and…”

P3595, L6 “… by an industrial consortium, AND first data…”

P3596, L12 – Here in particular, I recommend switching to S-P-O sentence structure : “The NO2 column amount below the aircraft was observed during multiple overpasses over the power plant exhaust plume.”

L18 – remove “currently” here. If you’d like to talk about other wavelengths, perhaps do so in the outlook.

L27 “… guide allows both optical imaging and flexible…”

P3597, L24 – “of the detector WAS performed…”

L27 – What are “additional instrumentation parts”? Do you mean “the rest of the AirMAP setup”?

P3599, L 10 – Recommend removing “adequately”. This is implied by the rest of the sentence.

L12 – Is “AHRS” a standard acronym. I wasn’t familiar with it, and I don’t think it’s introduced.

P3600, L4 – Perhaps choose a different symbol for longitude? λ is already used elsewhere for wavelength.

P3601, L10 – Recommend replacing “right” with “correct”

P3602, L7 – Remove “far”.

P3604, L6 – Replace “takes care of” with “accounts for”

L19 – Replace “strong” with “significant”

P3605, L16 – This sentence is confusing, perhaps try: “The relative occurrence of a given NO2 column density is plotted in a histogram with a bin width of 0.5e15 molec/cm2.

P3606, L1 – “NO2 enhancements are CLEARLY above the detection limit”

P3607, L9 – “… 2.6 DIRECTLY below the aircraft…”

P3610, L7 – “… during a DESCENT INTO a regional airport…”

P3612, L26 – I believe the ratio of reaction rates for the NO – NO2 reactions is typically called the "Leighton Ratio". Perhaps introduce this term here? It might be useful for literature searches.

P3613, L16 – replace 'assured' with 'assumed'.

P3616, L9 – 30 m uncertainty for geolocation assuming what flight altitude?

L10 - replace "entering" with "that enter in"

L13 – replace "pieces" with "segments"

P3617, L28 – insert "with" after "meters, "

P3620, L5 – replace "have been" with "were"

L24 – Perhaps also mention OClO?

P3621, L1 – "focusing" is misspelled.

Fig 3 caption – "… shows the HIGH REFLECTIVITY OF the motorway…"

Fig 5 – I can't distinguish between the solid and dotted lines in my copy

Fig 6 caption – Replace "strong" with "significant" or "considerable"

Fig 12 – It does appear that one part of the track sticks out a bit – in particular, the flight segment that was conducted approximately in north-south direction seems to give slightly lower values for the background than the rest of the data. Can this be easily explained?