

## Comments to the manuscript

# The CU Mobile Solar Occultation Flux instrument: structure functions and emission rates for NH<sub>3</sub>, NO<sub>2</sub> and C<sub>2</sub>H<sub>6</sub>

By Natalie Kille et al.

## General Comments

The authors give a detailed description about an instrument and its characteristics for Solar Occultation Flux (SOF) measurements in the UV-Vis and IR spectral regions built at the University of Colorado. They also show and discuss results from experiments where this instrument was used to measure the column densities and fluxes of ammonia (NH<sub>3</sub>), nitrogen dioxide (NO<sub>2</sub>), and ethane (C<sub>2</sub>H<sub>6</sub>) in various types of areas and loads of air pollution. The data was compared to literature and inventory data. The authors also used their findings to determine structure functions as a way to define trace gas variability over distance which is a valuable contribution with respect to remote measurements from satellites.

The methods are described in a clear way and the results are sound and relevant. The structure of the text is well chosen and allows a good and fluent reading of the manuscript.

## Specific Comments

General: The abbreviations RD10 and RD11 are mentioned throughout the text supposedly for "research day" but specified first much later in the manuscript in form of a caption to Table 5. But this kind of naming makes the reader curious: How do the results of RD01 to RD09 look like? How many more RDs are there? Can the authors please motivate why only the results of these two days are presented.

Lines 87 – 88: There are more sources that can be used to refer to earlier descriptions of the method. The SOF-method is described in an article by Mellqvist et al. (2005) and actually was patented by Galle and Mellqvist. I suggest to add a citation to this article.

Lines 105 – 111: While the respective footprints for TES, IASI, SCIAMACHY, and OMI are given this information is not presented for ACE-FTS and MIPAS. Please add this information.

Line 144: The authors mention that there EM27 FTS is customized. In which aspect is this EM27 FTS customized?

Line 165 and Table 3: Based on which information were these a-priori profile parameters chosen?

Line 253: How did the authors determine an uncertainty of 30 %. Has this number been arbitrarily chosen?

Section 3.1.1: The authors present their analysis of the precision and accuracy with respect to the measurements of NH<sub>3</sub> and C<sub>2</sub>H<sub>6</sub>. Please add an equivalent analysis for the measurement of NO<sub>2</sub>.

Lines 287 and Table 4: The total error was calculated by arithmetic addition. Since the error sources can be regarded as statistically independent parameters, the root sum of the squares should be used. Why is the relative precision, expressed in percent, not calculated and taken into account for the calculation of the total error?

Section 3.1.2 and Figure 4 and lines 553 – 560: Why is a dependency of the ILS modulation efficiency with the azimuth and elevation angles expected? Don't the results presented in Figure 4 rather reflect the quality of the alignment within the SOF instrument? Further, only the effect of the ILS on the retrievals of NH<sub>3</sub> and C<sub>2</sub>H<sub>6</sub> is discussed here. Why is a according discussion missing for the retrieval of NO<sub>2</sub>?

Figure 4: Is the scale on the x and y axes true for both unit circles?

Line 358: Why did the authors assume here an error in the wind of 30 %/sqrt(2)? To my understanding, this is not an uncertainty which decreases with an increasing number of days of measurements, here 2 days, if it is that what was assumed.

Line 377: Are the used O<sub>3</sub> mixing ratios presented by Pierce (2016) applicable for the sites and times of the measurements of this study?

Line 403 – 405: The connection of the higher C<sub>2</sub>H<sub>6</sub> emissions in Weld County as compared to the ones in Boulder County with fracking is very interesting. I think it would also be very interesting to present some numbers here, at least a number for the order of magnitude of the difference.

Line 441: Because of the presented climatic dependency of the NH<sub>3</sub> emissions, some indication would be helpful if the NH<sub>3</sub> emission flux of 0.65 kg/km<sup>2</sup>/hr suggested by the inventory is an average flux over the whole year or seasonally matches with the climate conditions during the conducted measurements. Maybe that could explain some additional contribution to the difference to the NH<sub>3</sub> flux found in this study.

Line 492: I assume that the average C<sub>2</sub>H<sub>6</sub> emission for site 1 should be presented here. In this case the uncertainty would be 19 kg/hr instead of 29 kg/hr.

Line 496: Could the authors give some more details about what kind of leaks they refer to?

Line 535: The variability length scale for C<sub>2</sub>H<sub>6</sub> is presented here as smaller than ~6 km. But in contrast to the cases of NH<sub>3</sub> and NO<sub>2</sub>, no horizontal resolutions of the respective satellites have been presented above. I would suggest to do that for the sake of consistency and completeness.

Technical Comments (specific changes are displayed in green color)

The use of capital letters in names and designations should be more consistent. One example can be found in the title "The CU Mobile Solar...", where the word "Mobile" in the title is written with a capital letter "M". Below, in the text body, it is used with a small letter "m". Another example can be found in line 138, but for this case also in Table 2, "...Center-to-Limb dDarkening (CLD)...".

The authors still use parentheses a lot which sometimes disturbs the flow of reading. I suggest to only use them for introducing abbreviations, for uncertainties or alike in combination with averages values, and of course for citations. Otherwise I suggest to think in the following way: is it important information, then it should be part of the sentence; if not, then omit it. For example cross-references to figures, tables and sections can often be separated by comma signs, e.g. "..., see Figure 5.". In this context I also noticed the use of parentheses as an indicator for different cases. An example of this can be found in line 111 "...and Ozone Monitoring Instrument (OMI, 13 x 24 km<sup>2</sup>) (NO<sub>2</sub>) (Boersma et al., 2009)". Rephrasing and using "...for NO<sub>2</sub>..." instead of "...(NO<sub>2</sub>)..." and would make reading more fluent. Examples like this can be found throughout the manuscript.

Often values and units are not separated by a blank space especially in the case of percentages, like in line 358 "... taken as 30%...". This is inconsistent throughout the manuscript. I suggest to consistently use a blank space, e.g. "... taken as 30 %...".

Many citations of personal communications are given. The authors are encouraged to complement these citations with a date.

Line 94: Please consider "... around ~~an area source~~ a source area ..."

Lines 247 and 320-321: The authors repeatedly use RD10 and RD11 to specify the days of the measurements. Unfortunately these are first introduced in the caption of Table 5 but not in the text. The authors are invited to introduce RD10 and RD11 accordingly for giving some consideration to the reader.

Line 104: Please consider "...to characterize the VCD variability of NH<sub>3</sub>, NO<sub>2</sub> and C<sub>2</sub>H<sub>6</sub> VCD variability on the spatial ...".

Line 123: Please consider "...Figure 1 shows ~~the that~~ photons along...".

Line 167 – 168: Please provide a date alongside with the URL, e.g. ".../waccm, seen at 10 July 2016)...".

Line 171: Did the authors mean "by a factor of 100 ~~over around~~" or "above"?

Line 175: What is meant by "contrasting" here?

Line 209: Please consider to replace "Each morning before..." by "In the mornings before...".

Line 231, Eq(2): Please consider a blank space or multiplication sign between VCD and vec(F).

Lines 249 – 250: "...the wind direction varies a maximal 180°" it cannot be more than ±180°, so I suggest "...the wind direction varies up to 180°".

Line 261: For the sake of clarity I suggest "...tool to quantify trace gas variability over horizontal distance...".

Lines 314 – 315: I suggest "There was a 0.5 % change in the retrieved NH<sub>3</sub> VCD and ~~0-0~~ no change seen in the C<sub>2</sub>H<sub>6</sub> VCD."

Line 384: Please consider "...indicating that ~80 % of NO<sub>x</sub> is visible as abundant in the form of NO<sub>2</sub>."

Line 492: Please consider "We determined that the average C<sub>2</sub>H<sub>6</sub> ... is 63 ± 29 19 kg/hr."

Figure 3: Please consider a legend. It is not clear which percentiles you expressed with the black boxes and whiskers in case of the individual mobile SOF measurements. Similar for the red and blue graphs where I assume that you present the mean value with some standard deviation, possibly with some factor.

Figure 5: The modulation efficiency for an elevation angle of 65° seems to be cropped away due to its offset.

Figure 8 panels a, b, d: The names of the places of the underlying map are very small and difficult to read. Maybe some orientation can be provided written manually on top of the maps. Alternatively, some longitude and latitude coordinates on some representative axes would do. Further, an increase of brightness of the underlying maps would help to highlight the VCD data.

Figure 8 panel e: I don't know how I should interpret the vertical, grey line at about 17:33. Further, in panel 3e, the letters for the cardinal directions seem to be shifted a bit too far to the right.

#### References

Mellqvist, J., Kihlman, M., Samuelsson, J., Galle, B., The solar occultation flux (SOF) method, a new technique for the quantification of fugitive emissions of VOCs, Proceedings of the Air and Waste Management Association's Annual Conference and Exhibition, AWMA, 2005