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Discussions

Interactive comment on "Effect of Polyoxymethylene (POM-H Delrin) offgassing within Pandora head sensor on direct sun and multi-axis formaldehyde column measurements in 2016–2019" *by* Elena Spinei et al.

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We thank Anonymous Referee 1 for the comments and recommendations. Our responses to the referee comments are in italics font.

C1

0.0.1 General comments:

I would recommend adding one or two tables summarizing 1) which instruments have been used when/for which part of this work, to help the reader following which instruments have been participating to several steps;

> *We added table 1 (please see supplement) describing Pandoras used in this study with their appropriate modifications and part of this study where they have been used.*

2) the different steps of the Pandora HCHO "history" with some links to published HCHO Pandora papers: - pre2016: no HCHO possible; - spring 2016: window replacement and KORUS-AQ and CINDI-2 but issue of coherence between MAX-DOAS and direct-sun results; - april 2019: added temperature sensors for a few instruments and highlight of the potential link of HCHO creation with temperature; - lab measurements to confirm the findings; - summer 2019: new head sensor without POM-H Delrin to solve the problem; - measurements campaigns illustrating the findings.

> *We added table 2 (please see supplement) describing Pandora design modifications including references*

In the light of the "pre-2016" first point, there should also be some comments of Pandora HCHO measurements performed before 2016 (e.g., in Pinardi et al. 2013, for measurements in 2009 – is there any other ?).

> *Table 2 contains periods of operation and the publications used data from that period to the best of our knowledge*

C2

I would also include some more references in the introduction on satellite HCHO (only one is mentioned, while at least 8 are known - and given below) and on satellite validation.

We added the recommended references

In the abstract and/or conclusions, it would also be nice to also convert the findings from DU to molec/cm2, as this unit is usually used for HCHO retrievals.

We added "2.69 molecules/cm^2" to the abstract. There is a definition of DU in text p.2, line 42

0.0.2 Specific comments and technical corrections:

- P2, line 29-33: give some references for the other satellites, as done for SCIAMACHY. Several are suggested below.

We added the recommended references

- P2, line 37: give more references for other validation studies. Several are suggested below.

We added the recommended references

P2, last line: Lamsal et al. 2014 and Kollonige et al. 2017 are not given in the reference list. Consider adding other recent works with several Pandora NO2 measurements used for validation (Herman et al., 2019; Pinardi et al., 2020; Verhoelst et al., 2020).

• *We added the recommended references*

Please check completeness of the reference list in the whole manuscript (e.g., Reed et al., 2015, Gronoff et al., 2019 are also missing in the references).

We have checked the references

- P3, line 65 to 71: it would be nice to link the different steps, with the manuscript sections. Or at least add the link with the sections in the proposed additional table n2.

We added reference to the corresponding sections

- P3, line 74: Retrieval of weak absorbers such as HCHO was not possible from 'the pre-2016 Pandora direct sun measurements due to the telescope assembly front window etaloning": comment Pinardi et al., 2013 measurements of 2009.

Pinardi et al. 2013 reference MAX-DOAS HCHO only, no HCHO direct sun data from Pandora are presented. Only coherent light (e.g direct solar beam) causes etalloning by the window.

- P4, figure 1: please revisit the legend. What are the light blue points?

Both blue and light blue points represent HCHO emissions from the same instrument P46 but at different temperature ramp rates. We believe this is appropriate.

- P4, line 95: . . .the reference spectrum is *often* taken within. . . (not for the CINDI-2, as mentioned later in the paper)

MAX-DOAS data analysis for profiles is done with the scan reference. CINDI-2 MAX-DOAS data for profiles was also analysed with the scan reference (Tirpitz et al., 2020). Local noon reference was used for ΔS intercomparison not the final inversion. Zenith ΔS were subtracted from the ΔS at all other elevation angles

- P5, line 108: "A baffle holding tube, two filter wheels, and a dark filter" –> The baffle holding tube, the two filter wheels, and the dark filter. . .

corrected

- P7, line 149: remove parenthesis in "Figure (4). . ."

corrected

- P7, line 153: consider changing "follow-up work" to the relevant section of the manuscript.

We removed this sentence

- P7, line 160: add a comma before 118

corrected

- P7, lines 147 to 148 and lines 160 to 161: as proposed in the general comments, consider adding a table with the Pandora numbers, their construction year, and in what part of this work they appear.

Table 1 was added

- P8, line 161: "Three other Pandora" –> The other three Pandora

corrected

- P8, line 169: consider adding here the information on the 1000 W FED lamp given in line 186 and the LED lamp (cf line 2018 and 2016), or removing this information from line 169.

We removed this sentence

- P8, line 170: what is the meaning/purpose of the "The head sensor was not disturbed during the measurements" ?

We intended to emphasize that the instrument position was not changed. We removed it.

- P8, line 175 to 179: these DOAS settings seems the generic ones used in the laboratory study (332-360nm), but actually in P10 line 250, these are different (300-350nm) (and also different than the in-field settings, P13 line 396, 332-359nm), so this is a bit perturbing. Is there any reason why changing wavelength ranges, polynomial and offset order? For the inclusion of trace gases, this is clear/mentioned when relevant.

We performed identical tests for all pandora instruments. The new pandoras had no detectable HCHO absorption in multiple fitting windows. Since the results were not impacted by the window choice one single fitting window was chosen for both SO2 and HCHO retrieval. We also wanted to emphasise the low fitting residual for 50 nm fitting window.

- P9, line 193: "using the pre-installed Bosch BME280 digital humidity, pressure and temperature sensor on Spark-Fun Atmospheric Sensor Breakout Board" -> this is a detail of the new head sensor. It would be maybe better to introduce it in Sect 2.3 when introducing the Pandora internal head sensor temperature?

We added the information about the internal temperature sensor to Section 2.3

- P9, lines 208 to 210: the Pandora 118 was also tested with a LED lamp in addition to the FEL lamp. Is this shown somewhere? Why is this done? What was expected (differently) from this additional test?

Some literature suggested that UV and VIS radiation (200-800 nm) was responsible for Photo-oxidation at those wavelengths. We were curious whether more HCHO will be emitted while using FEL vs LED light source. We did not see any statistically meaningful difference between the retrievals.

- P10 and P11 (figure 6): POM-free and Delrin-free. These are used as synonyms? In P13, line 281, also POM-H is used. Use one name everywhere.

We corrected all to POM-H Delrin free

- P12, line 268 and elsewhere in the manuscript: replace Kreher et al., 2019 by Kreher et al., 2020.

corrected

- P12, line 269: there are two point at the end of the line.

C7

corrected

- P14, line 314: "contribution" seems to be in bold

corrected

- P17, line 348: add reference to Fig 5 for the "small generation rates inside Pandora 148 head sensor (a = 0.0041 DU)" ?

corrected

- P17, lines 53: give an estimation and a reference (Pinardi et al., 2013 ?) of the "fitting noise for most DOAS instruments" (usually in molec/cm2!).

We added: (0.3 DU = 8×10^{15} molecules/cm^2, Table 7 in Kreher et al., 2020.

- P17, line 357: add "Sept. 2016" after the coordinates and update Kreher reference.

added

- P18, line 378: if I followed well all the Pandora numbers, 32 was involved in the GSFC field campaign, and 31 and 46 in the lab measurements wrt temperature. A table would definitely help follow which instrument has been used when!

Table 1 was added

C8

- P20: suggestion to add in each bullet conclusions the Pandora numbers relevant to each bullet (or not if it is already clear in an additional table), and the relevant Figure supporting each conclusion (e.g., Fig 5 for the 1rst point). Also add molec/cm2 estimation in addition to DU values.

> *Since Table 1 was added we have not modified the Pandora listing in conclusions. We added Figure references to the conclusions.*

- P20, point 5: maybe cite publications that were made with Pandora direct sun HCHO data between 2016 and 2019, and that should not be considered "valid"?

> *We added references to those publications in Table 2. We replaced build with operational to emphasise that any other Pandora whether part of a field campaign or routine measurements cannot be used in the current form*