

## ***Interactive comment on “Formaldehyde total column densities over Mexico City: comparison between MAX-DOAS and solar absorption FTIR measurements” by Claudia Rivera Cárdenas et al.***

### **Anonymous Referee #2**

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The paper presents MAXDOAS and FTIR HCHO measurements around Mexico City, for a period of about 6 years. MAXDOAS data at several viewing directions are included, showing horizontal inhomogeneities. Comparisons between the MAXDOAS data and FTIR are presented, resulting in MAXDOAS larger values, from about 5% to 28% depending on the direction. An FTIR background site is also briefly presented, with its daily and seasonal variations. The scientific content of the paper fits well the scope of AMT and the manuscript is well written and of interest for the community. I recommend publication after the suggested revisions below.

General comments

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The datasets are important (in length and for their high HCHO VCD columns) and the comparison of MAXDOAS and FTIR is of great interest, and they would deserve some more explanations. FTIR datasets have already been used in other publications (e.g., Vigouroux et al., 2018; 2020) and this should be emphasized a bit more, putting the 2 sites in the context of other existing HCHO FTIR. Also the Altozomoni site is showed in Sect. 3.4, but only very shortly.

MAXDOAS HCHO data from Mexico is presented here for the first time (to my knowledge), and these datasets (v1, v2 and especially v3) need a bit more explanations. In Sect. 2.2, the MAXDOAS error estimation are not even mentioned! Information on the polynomial and offset choice in Table 1 are missing, and more explanations of the v3 analysis should be given. It is said that “VCDs retrieved using measurements from both sides of the scanning plane are in general larger than VCDs retrieved using data from measurements of only one of the sides. This result can be explained by the larger amount of information available for the retrievals when dSCDs in different elevation angles and both scanning directions are used” (end of P.9 and P. 11), but it is never mentioned how this v3 is done. How are the opposite directions treated in term of a-priori, aerosols content, . . . ? Is the retrieval considering an homogeneous atmosphere for the retrieval, or are the differences for v1 and v2 somehow taken into account for the v3 retrieval? An illustration of the behaviors of v1, v2 and v3 on a typical day would be a nice addition (and also adding v1 and v2 on the diurnal and seasonal figures 3 and 4). Also the degrees of freedom should be quantified (numbers in figure 8 are small and difficult to read).

Add reference and discussion of Vigouroux et al., 2009 (Reunion Island), and Franco et al., 2015 (Jungfrauoch) to better highlight the difference in sensitivities between MAXDOAS and FTIR. The AVK are shown in the last column of figure 5, but they maybe deserve a specific figure instead, comparing the AVK of FTIR, MAXDOAS v1, v2 and v3 on the same panel. When seeing the AVK, the 2 measurements are not sensitive at all at the same altitudes, so if the HCHO is not homogeneously distributed,

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we don't expect the same measurements.

The comparisons between MAXDOAS and FTIR are a bit perturbing, as Figures 2 to 4 seems to suggest a bias of 50%, when all the data are considered (are the MAX-DOAS data cloud filtered?), while figure 5, when the coincident measurements are selected, seems to indicate smaller bias (28% if considering v3 with the slope passing by the origin – although the non-forced regression show an important systematic intercept). The different regressions of Fig. 5, should be discussed in more details. Also figure 2 shows better MAX-DOAS to FTIR comparison during 2013-2014, while since 2015 the MAX-DOAS are up to twice the FTIR values. Is there a reason for that? Has the instrument or the measurement strategy changed?

Instead of (or in addition to) comparing hourly MAXDOAS v3 to FTIR in Figure 10, why not compare the morning FTIR data with the MAXDOAS measuring to the East, and afternoon FTIR to MAXDOAS measuring to the West? Adding the measurement directions to the map of Figure 1 could help the reader understanding the measurements at each site. Giving some explanations on the inhomogeneities in HCHO seen by OMI could also help the reader (is there any specific vegetation? Industry? How is the orography around Mexico city? Can some HCHO be “trapped” by winds and terrain?). Are the conclusion of Section 3.3.2, with the larger abundances on the eastern side of the scanning plane during the morning hours, and a change after 12h LT, supported e.g. by wind direction changes? How is this gradient explained? Are the other MAX-DOAS Mexican sites HCHO measurements confirming this horizontal inhomogeneities?

Also, a more fundamental question. There has been recent studies (e.g. with Pandora, <https://amt.copernicus.org/preprints/amt-2020-158/>) showing contamination of “plastic” material from the instrument, emitting HCHO in case of hot temperatures – is this eventuality been excluded here? Is there any relation of the measured HCHO with the temperature?

Specific comments and technical corrections

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- P2, line 21: consider changing “The advantage of the MAXDOAS technique in comparison to the traditional DOAS approach is that vertical column densities of several gases can be retrieved with some information on the vertical distribution” to “The advantage of the MAXDOAS technique in comparison to the zenith-sky DOAS approach is that vertical column densities can be retrieved with some information on the vertical distribution in the lower troposphere” - P2, line 29: “..satellite product and that of a chemical transport model” -> “and from results of a chemical. . .” - P2, line 29: “Tirpitz et al. (2020) found very good agreement” -> please quantify - P3, line 3: “The authors indicate that HCHO emitted by primary sources dominates . . . HCHO decreases by approximately 1/3 in the afternoon”: this is not what is seen in this study (Figure 3 shows larger HCHO in the afternoon). Could you comment this while presenting Figure 3? - P3, line 26 and P4, line 3: “records spectra at 0.075 cm<sup>-1</sup> resolution” and “typically at 0.005 cm<sup>-1</sup> resolution“. What is the difference in resolution between the 2 FTIR instruments implying for HCHO measurements? Should we expect a difference in noise? Sensitivity? - P4, line 23: “azimuth angle of 85 with respect to the north”: this means 85° E? but in line 27, the sequence starts first in the West and then to the East – please clarify (and add the azimuth measurements directions in Fig.1) - P4, line 27: how long is this measurement sequence taking in term of time? - P5, tabl1: give details of polynomial and offset - P5, line 9: why aerosols uses a Tikhonov regularization while trace gases retrievals uses optimal estimation? - P5, line 15: 338nm is not the middle of the 324.5-359nm interval (but it is close to it: 341nm!). What is the interval for the O4 SCD retrieval? - P5, end of Sect 2.2: give the HCHO MAXDOAS error estimations, as done at the end of Sect 3.1 for FTIR. - P6, figure 1: the numbers of the colorbar are difficult to read. - P6, line 17: “report values in the same order of magnitude, however, higher values in MAX-DOAS measurements than the FTIR instrument are apparent” -> from Figure 2 and 3, MAXDOAS data seems often about twice as large than the FTIR. . . . How would v1 and or v2 compare here? - P7, fig2: there seems to be much more variability in the MAXDOAS after 2015 compared to 2013 and 2014. Is there a reason for it? - P7, line 14: “nevertheless, the values do not differ significantly and

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present similar seasonal cycles” – I would rephrase the “do not differ significantly” to something like “the 2 datasets are within each other error bars/temporal variability” - P8: are figures 3 and 4 only made with coincident hourly averages/months or with all the available datasets ? can this explain part of the variability? - P9, line 9: “measurements conducted towards both sides of the scanning plane.” -> explain more how v3 data are retrieved. This is not so usual. - P9, line 30: “linear regression not constrained to zero is shown in red” in Figure 7, while it is green for the not constrained to zero for Figure 6. It is a bit perturbing. Keep same color conventions. - P11, line 2: give some numbers for the different DOF for v1, v2, v3. The differences (37% for v1 vs v3 and 28 % for v2 vs v3) seems a lot for a not so large difference in DOF seen in Figure 8, but numbers would help. Why DOF for v1 are so “not symmetrical” around 1? - P12, line 6: “how the retrieved profile” -> “how the retrieved profile” - P12, eq 2): explain bold vs non-bold “Xapr” - P13, line 1: “that AKtot is without units and shown” → as shown?! - P13, line 6: systematic -> systematic - P14, line 5: “After 12 h LT, conditions change so that larger HCHO VCDs are measured towards the western side of the scanning plane, peaking at 13-14 h.” – can you put this in relation to distribution shown by OMI in Figure 1 (overpass around 13h30LT)? - P14, figure 9: do you have information on wind conditions, to try to also separate/estimate possible contribution of different wind direction to the east-west difference during the day? - P.14, sect 3.3.3: try to compare FTIR to v1 in the morning and to v2 in the afternoon, when the sun is in the same direction that the MAXDOAS pointing direction. - P15, line 17: “Neither the retrieved FTIR profile nor the MAX-DOAS profile retrieval have sufficient degrees of freedom, therefore the strategy of using the profile information from one instrument together with the averaging kernel of the other instrument is not too promising.” – reformulate. “sufficient degrees of freedom” to do what? Give values for the DOF! - P15, line 28: “So the average of  $\Delta\text{colDOAS}$  and  $\Delta\text{colFTIR}$  are zero.” → the errors are not mentioned in the above paragraph, and these do not simplify one another, no? - P15, eq 8: end of the equation is missing: “. . .” - P16, figure 10: there seems to be a specific behavior for scatter plots at 12h and 13hLT, with a second “blob” of points not at all on the 1:1 line.

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Can you comment this? - P17, line 6: “limited to just this hour” -> “limited to just one hour”? - P17, line 11 and 12: to my feeling, this sentence would be better suited after “The slope is given by the averaging kernels of the two instruments and the shape of the variable profile v. In Mexico City, we could assume that at 9 h LT the mixing layer is well mixed with HCHO up to a certain height with a constant concentration but with 0 or at least a constant HCHO value above this height. For this simple assumption (the only Eigenvector is constant in the mixing layer but 0 above it), the slope is the . . .” - P17, line 23: “therefore given due to the fact that” -> “therefore given by the fact that” - P17, sect 3.4: comment a bit more this background FTIR dataset (at least mentioning how it compares in Vigouroux et al., 2018 and 2020).

Suggested References:

Franco, B., Hendrick, F., Van Roozendaal, M., Müller, J.-F., Stavrou, T., Marais, E. A., Bovy, B., Bader, W., Fayt, C., Hermans, C., Lejeune, B., Pinardi, G., Servais, C., and Mahieu, E.: Retrievals of formaldehyde from ground-based FTIR and MAX-DOAS observations at the Jungfraujoch station and comparisons with GEOS-Chem and IMAGES model simulations, *Atmos. Meas. Tech.*, 8, 1733–1756, <https://doi.org/10.5194/amt-8-1733-2015>, 2015.

Interactive comment on *Atmos. Meas. Tech. Discuss.*, doi:10.5194/amt-2020-208, 2020.

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