**Interactive comment on "Formaldehyde total column densities over Mexico City: comparison between MAX-DOAS and solar absorption FTIR measurements"**

Answers to Anonymous Referee #2

We thank Referee #2 for providing detailed comments and suggestions.

All changes made in the manuscript, following Referee 2 comments and suggestions, can be easily identified in color **red**. NOTE: changes in color **green** represent changes made following comments and suggestions made by both Referees.

**General comments**

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.
**ANSWER:** Following the Referee suggestion the use of FTIR datasets used in other publications was emphasized and discussion was added to results presented from the Altzomoni site.

The following text was added: "HCHO VCDs measured at Altzomoni are in the same order of magnitude as HCHO VCDs reported by Vigouroux et al. (2018) for several "clean" sites stations belonging to the NDACC network, such as Zugspitze, other mountain site (however at a latitude of 47° and an altitude of 3 km) as well as for Mauna Loa, at a latitude of 20° and an altitude of 3.4 km." … "Vigouroux et al. (2018) report the same behavior (a maximum in the late afternoon between 16 and 18 local time) for other stations of the NDACC network: Bremen, Paris, Toronto and Lauder. Further analysis should be conducted regarding the diurnal HCHO cycle at Altzomoni, however the detected maximum at late afternoon could be attributed to upslope transport or to secondary HCHO production that has reached a maximum at a certain hour of the day."

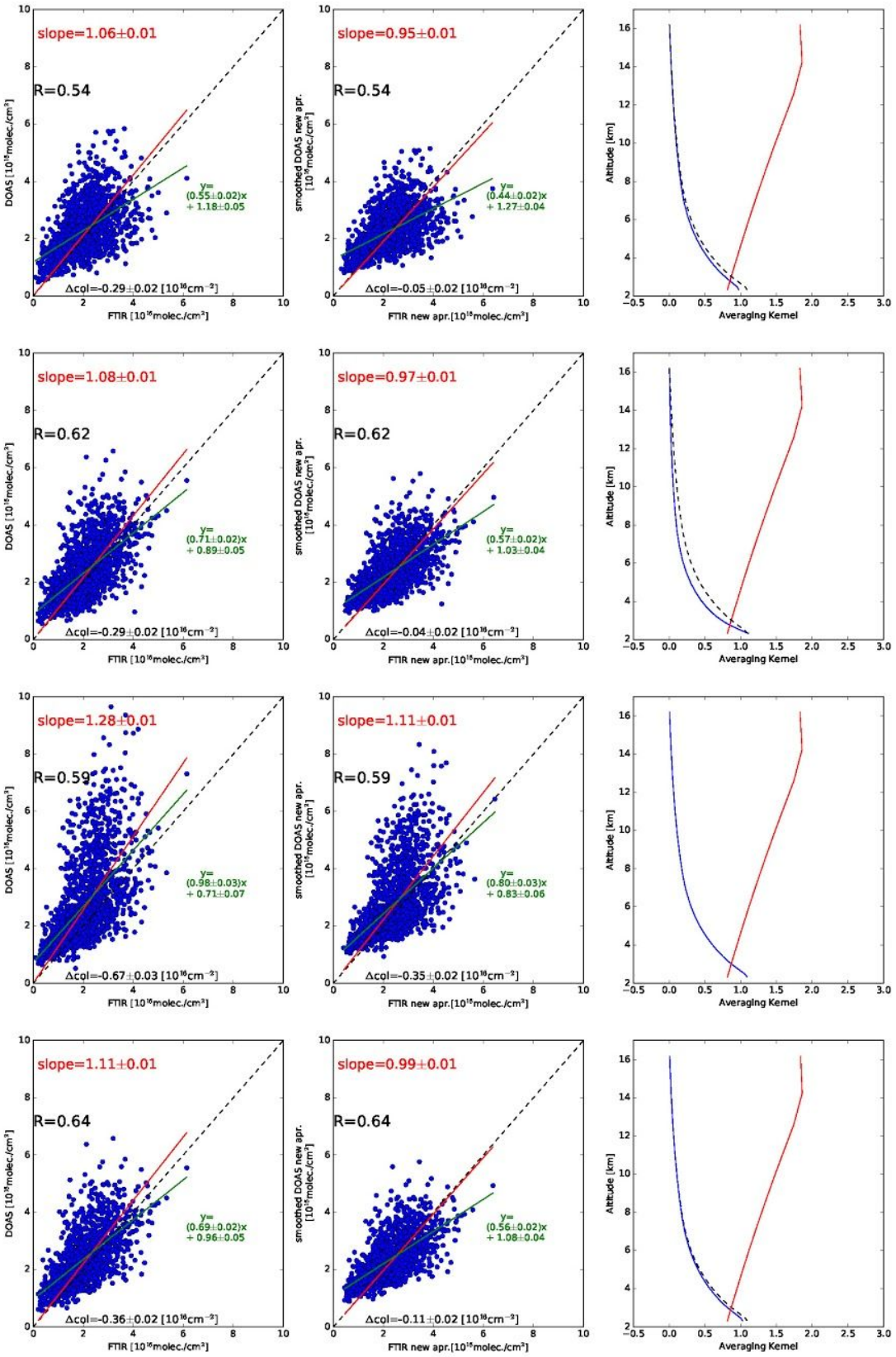
MAXDOAS HCHO data from Mexico is presented here for the first time (to my knowledge), and these datasets (v1, v2 and especially v3) need a bit more explanations. In Sect. 2.2, the MAXDOAS error estimation are not even mentioned! Information on the polynomial and offset choice in Table 1 are missing, 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 apriori, 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).
**ANSWER:** To address these issues, we now provide the MAX-DOAS error estimation as well as details regarding the polynomial and offset used for the DOAS HCHO retrieval. More explanation of the V1, V2 and V3 analysis is now given. The degrees of freedom for MAX-DOAS and for FTIR are now provided and the font size of Figure 8 was enlarged.

Regarding the specific explanation the following text was added in the manuscript, at the end of section 2.2 and just before section 3:
“Three different versions of HCHO VCDs were retrieved using the MMF code: **V1** retrieved VCDs from MAX-DOAS measurements conducted towards the east (telescope’s azimuth angle of 85° with respect to the north), **V2** retrieved VCDs from MAX-DOAS measurements conducted towards the west (telescope’s azimuth angle of 265° with respect to the north) and **V3** retrieved VCDs from MAX-DOAS measurements conducted towards both sides of the scanning plane. To simplify terminology, for the remainder of the manuscript version **V1** will be referred as "east", version **V2** will be referred as "west" and version **V3** will be referred as "both".

For **V1**, **V2** and **V3** the same *a priori* is used both for the trace gas and for the aerosol. For **V3**, the "scan" is simply treated as consisting of two different azimuth directions. The **V1**, **V2** and **V3** retrievals are performed independent of each other and differ in the definition of a "scan", where **V3** contains all pointing directions from **V1** and **V2** together. A single vertical profile is retrieved in both directions for **V3**, so assuming horizontal homogeneity. This assumption clearly is not fulfilled, however, it is also not fulfilled in a single viewing direction since the effective light path is around 5-20 km. As pointed out in the manuscript, the advantage of using both directions is a higher information content, the disadvantage is a more rigorous break down of the homogeneity assumption.“

As suggested by the Referee, V1 and V2 were added to the diurnal and seasonal cycles figures (now Figure 2 and Figure 3 due to a reorganization of figures suggested by Referee 1).

Add reference and discussion of Vigouroux et al., 2009 (Reunion Island), and Franco et al., 2015 (Jungfraujoch) 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, we don’t expect the same measurements.
**ANSWER:** The Vigouroux et al. (2009) reference is already in the text. The Franco et al. (2015) reference was added to the manuscript, as suggested by both Referees.
For the sake of clarity, we suggest that showing the AVKs in Figure 5 provide complementary information while analyzing the different comparisons between FTIR and MAX-DOAS and for this reason we have decided to leave the AVKs panels in Figure 5, but we added a dashed line of the AVK of the version 3 to all AKV panels. An error was found in the program plotting the total column AVKs of MAX-DOAS, this was corrected and is now presented in the updated figure. More explanation was given to the differences of AVKs for FTIR and MAX-DOAS V1, V2, V3 and the new comparison: V1 vs FTIR during the morning and V2 vs FTIR during the afternoon. The modified Figure 5 is shown below:




Modified Figure 5

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?

**ANSWER:** Figure 2 (now Figure, 1 due to a change order suggested by Referee 1) includes all measurements. In this first figure, data is not filtered as everything that is available for both measurement techniques is presented. The different regressions on Figure 5 were discussed in more detail.

The MAX-DOAS measurement strategy was changed in 2015, adding more measurements at lower elevation angles. We would like to point out that adding more measurements at low elevation angles enhances the sensitivity at lower altitudes, where the FTIR has lower sensitivity and hence, capturing better concentrations of HCHO at low altitudes with MAX-DOAS will result in an increase in the bias.

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?

**ANSWER:** Following both Referees suggestions, the comparison between FTIR and DOAS V1 during the morning and FTIR and DOAS V2 during the afternoon was conducted. The results, presented in Figure 5 (fourth line) reveal a better agreement between the two measurement techniques. The text of the caption of Figure 5 as well as the text of section 3.3.1 was modified accordingly.

The measurement directions were added on the map of Figure 1 (now Figure 2 due to the re-ordering suggestion from Referee 1). While discussing Figure 9, information was added regarding the orography around Mexico City and how it can impact wind patterns and transport in the basin.

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?

**ANSWER:** The interference by HCHO in the PANDORA instrument was, according to our knowledge, due to the use of the material Delrin, we are using Nylamid. In the case of using any thermoplastic (as both PANDORA and MAX-DOAS are using), the possibility to have interference of volatile organic compounds is all the time possible. In the case of the MAX-DOAS measurements, and due to the fact that the reference (“zenith measurement”) is taken only a few minutes before the elevation angles measurements, we consider that this effect, if exists, is not an issue, since it can be considered to be canceled out because all the measurements conducted during a same cycle (that lasts only a few minutes) would have the same influence.

**Specific comments and technical corrections**

- 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”
**ANSWER:** The change was made, as suggested by the Referee.

- P2, line 29: “..satellite product and that of a chemical transport model” -> “and from results of a chemical...”
**ANSWER:** The change was made, as suggested by the Referee.

- P2, line 29: “ Tirpitz et al. (2020) found very good agreement” -> please quantify
**ANSWER**: The following text was added “(an average root-mean-square difference of $1.4\times10^{15}$ molec/cm$^2$ )”.

- 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?
**ANSWER:** We commented on this fact while presenting Figure 3 (now Figure 2). In general terms the observed differences in both studies: a decrease of HCHO in the afternoon reported by the Lei et al. (2009) study and the MAX-DOAS datasets reporting an increase of HCHO after 16 h in this study could be attributed to the duration of the experiment reported by Lei et al. (2009) which is a three-day modeled episode constrained by ground-based measurements conducted in 2003 and the length of the datasets that are being reported in the current study (more than 8 years of data between 2013 and 2020). In addition the measurement strategies are different, in this study we are reporting the amount of HCHO in the entire tropospheric column, while in the Lei et al. (2009) study the HCHO surface concentration (measured and modeled) is being reported.

- P3, line 26 and P4, line 3: “records spectra at 0.075 cm-1 resolution” and “typically at 0.005 cm-1 resolution“. What is the difference in resolution between the 2 FTIR instruments implying for HCHO measurements? Should we expect a difference in noise? Sensitivity?
**ANSWER:** The difference is that for the higher resolution instrument the DOF improves by 0.1, as the instrument located at Altzomoni has a higher resolution (longer path length), but because the instrument is also more stable and better, errors might be smaller in Altzomoni as well. For more details please see Vigoroux et al., (2018). Blumenstock et al. 2020 have shown that the error due to channeling is a very important error source for a weak absorber as HCHO in NDACC-FTIR instruments as the one collocated in Altzomoni, such a detailed study is not available for the Vertex 80 instrument. The use of calculated hourly mean for the comparison reduces the random error in the measurements for the instrument located in Mexico City, where we measure almost ten times more spectra in this hour.

- 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)
**ANSWER:** As suggested by the Referee the measurement directions were added to Figure 1 (now Figure 4 due to changes suggested by Referee 1) and a clarification regarding the measurement

directions was made. The text where this is clarified is presented at the end of section 2.2 (in color green).

- P4, line 27: how long is this measurement sequence taking in term of time?
**ANSWER:** With this setup, a complete scan takes about 7 min. This text was added to the manuscript.

- P5, tabl1: give details of polynomial and offset
**ANSWER:** A polynomial order 5 was used along with an offset order 1 (linear offset) (Hendrick et al., 2016; Pinardi, 2017). This information was added to the text before Table 1 -in green since both Referees suggested this information should be added-.

- P5, line 9: why aerosols uses a Tikhonov regularization while trace gases retrievals uses optimal estimation?
**ANSWER:** This is a very good question. We have a quite inhomogeneous mix of constraints and retrieval strategies, FTIR-retrievals (Vertex/UNAM and NDACC/Altzomoni) are done with Tikhonov constraint and the MAX-DOAS uses Tikhonov for the aerosol retrieval but OET optimal estimation for the gas retrieval.

First we would like to point out, that in this work we try to use the Averaging Kernel and *a prioris* to correct *a posteriori* for the different retrieval strategies, as the real information of the measurement should not depend too much on the used retrieval strategy, at least if the result is used carefully with the AVK and it's *a priori*.
Tikhonov constrains the form, while OET constrains typically the values.

As described in Friedrich et al. 2019, the *Sa* for $NO_2$ was constructed from a model simulation of gas concentration profiles in Mexico City. The concentration of the model could be compared to in situ measurements (at least near the ground) and it might be plausible to use it as *a priori*.
For gases there is *a priori* information available which is more related to the value than to their distribution.

We did not have simulation for aerosol concentrations, and the absolute value of the aerosol concentration in a certain altitude is not measured anywhere.

We have a good estimation of the diurnal behavior of the profile shape of the vertical aerosol distribution but not the values. Since using a Tikhonov regularization restricts the shape, as mentioned above, it seems more fitted to use this regularization for the aerosol retrieval instead of optimal estimation.

The *a priori* of the aerosol is *a priori* for each hour of the day. The hourly *a prioris* are constructed from long term ceilometer data and a measured climatology. The ceilometer measurement and the obtained climatology of the aerosol distribution is described by Garcia-Franco et al. 2018

For trace gases on the other hand, we do not have such a diurnal climatology based on measurements. Hence the optimal estimation method is better suited. Although we have model estimations for each hour, we choose to not use a time dependent a priori and instead include this variability via a better estimation of the SA matrix.

García-Franco, J.L., Stremme, W., Bezanilla, A. Ruiz-Angulo, A., Grutter, M. (2018) Variability of the Mixed-Layer Height Over Mexico City. Boundary-Layer Meteorology 167, 493–507. https://doi.org/10.1007/s10546-018-0334-x

- 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?
**ANSWER:** The phrase was modified to "in between the range of the wavelength interval used for the QDOAS retrieval". The interval for the $O_4$ dSCDs retrieval is 336 to 390 nm, this information was added to the text as well.

- P5, end of Sect 2.2: give the HCHO MAXDOAS error estimations, as done at the end of Sect 3.1 for FTIR. -
**ANSWER:** The following text was added in section 2.2: "For the retrieved HCHO MAX-DOAS VCDs, the calculated noise error of the mean column is 5.8% while the systematic error due to uncertainty in the spectroscopy is 2.2%."

- P6, figure 1: the numbers of the colorbar are difficult to read.
**ANSWER:** The font size of the numbers of the colorbar was increased.

- 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?
**ANSWER:** The differences between values were quantified and were added to the text, they are reported for V1, V2 and V3 using FTIR as the reference.

- 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?
**ANSWER:** In 2015 more elevation angles were added to the measurement sequence so that more measurements would be taken at lower elevation angles. We would like to point out that adding more measurements at low elevation angles enhances the sensitivity at lower altitudes, where the FTIR has lower sensitivity and hence, capturing better concentrations of HCHO at low altitudes with MAX-DOAS will result in an increase in the bias.

- P7, line 14: "nevertheless, the values do not differ significantly and 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" -
**ANSWER:** The change was made following the Referee recommendation.

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?
**ANSWER:** Figures 3 and 4 were made with all the available datasets and as the Referee suggests, part of the variability could be explained by this.

- P9, line 9: "measurements conducted towards both sides of the scanning plane." -> explain more how v3 data are retrieved. This is not so usual.

**ANSWER**: The explanation of the retrieval of V3 was added earlier in the manuscript, at the end of section 2.2.

- 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.
**ANSWER:** As suggested by the Referee, the color of the linear regression line was changed to green in order to keep the 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?
**ANSWER:** The average degrees of freedom for V1, V2 and V3 were added, the text was modified as follows “… are used (average values being 0.692 for V1, 0.782 for V2 and 0.970 for V3) (Figure 8)...” In addition Figure 8 was modified so that the font size of both the x and y axis was larger so that numbers could be more clearly observed.

Regarding the skewness of degree of freedom values for V1:
Asymmetry might be due to rejection of spectra is not symmetrically distributed, rejection occurs typically if there are obstacles or saturation, as the viewing angle is close to the sun angle.

- P12, line 6: “how the retrievd profile” -> “how the retrieved profile”
**ANSWER:** The correction was made, as suggested by the Referee.

- P12, eq 2): explain bold vs non-bold “Xapr”
**ANSWER:** All “Xapr” should be bold. The change was made.

- P13, line 1: “that AKtot is without units and shown” ! as shown?! -
**ANSWER:** We use the suggestion “as shown”

P13, line 6: systematic -> systematic
**ANSWER:** The correction was made, as suggested by the Referee.

- 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)”?
**ANSWER**: As suggested by the Referee this statement was put in relation to the distribution shown by OMI, the following text was added: “The average HCHO distribution over the MCMA, reconstructed from OMI data (Figure 4), provides evidence of a larger enhancement of HCHO columns towards the western side of the MCMA at OMI overpass time, coinciding with our findings in terms of the identified horizontal inhomogeneity as well as timing.”

- 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?
**ANSWER:** We have meteorological information at ground level, however since we are reporting the amount of HCHO in the entire atmospheric column, the representativeness of ground-based

meteorological information could be limited while trying to estimate or separate the possible contribution of different wind directions. The following text was added to the comments of Figure 9:

"The observed changes could also be related to orographic and meteorological conditions. Fast et al. (2007) report that surface wind measurements over the city indicate the production of strong convergence in the basin during the late afternoon, created by opposing propagating density currents and a gap flow originating in the southeastern corner of the basin. The authors conclude that in the MCMA short-range transport can be produced by the complex terrain surrounding it, producing local and regional circulations."

Fast, J. D., de Foy, B., Acevedo Rosas, F., Caetano, E., Carmichael, G., Emmons, L., McKenna, D., Mena, M., Skamarock, W., Tie, X., Coulter, R. L., Barnard, J. C., Wiedinmyer, C., and Madronich, S.: A meteorological overview of the MILAGRO field campaigns, Atmos. Chem. Phys., 7, 2233–2257, https://doi.org/10.5194/acp-7-2233-2007, 2007.

- 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.
**ANSWER:** Following both Referees suggestions, the comparison between FTIR and DOAS V1 during the morning and FTIR and DOAS V2 during the afternoon was conducted. The results, presented in Figure 5 (fourth line) reveal a better agreement between the two measurement techniques. The text of the caption of Figure 5 as well as the text of section 3.3.1 was modified accordingly.

- P15, line 17: "Neither the retrieved FTIR profile nor the MAX-DOAS profile retrieval have sufficent 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!
**ANSWER:** Values for the DOF of the MAX-DOAS were given in section 3.3.1. In addition the text was clarified as follows: "Neither the retrieved FTIR profile (1.1) nor the MAX-DOAS profile retrieval (<2) have sufficient degrees of freedom to consider the retrieval as profile retrieval, therefore the strategy of using the profile information from one instrument together with the averaging kernel of the other instrument is not too promising."

- P15, line 28: "So the average of DcolDOAS and DcolFTIR are zero." ! the errors are not mentioned in the above paragraph, and these do not simplify one another, no?
**ANSWER:** In order to improve the explanation, the text before Equation 7 was modified as follows:
"The average of the product of the columns of both instruments is theoretically given by the following equation, for that purpose we introduce the errors epsilon_FTIR(i), and epsilon_DOAS(i), where *i* is the index which identifies a certain hour:"

And before Equation 8 we added the following text:
"… So the average of ΔcolDOAS and ΔcolFTIR are zero. In addition we assume that the errors epsilon_FTIR(i), epsilon_DOAS(i) are independent and in average zero, we assume also that they are independent with respect to AK_DOAS(i), AK_FTIR(i), Xtrue(i), so that we can simplify the calculation of equation (7) to equation (8)."

- P15, eq 8: end of the equation is missing: "..."
**ANSWER:** It was unlucky using the "...", we have removed them and write explicitly in the line before what we assume:

… So the average of ΔcolDOAS and ΔcolFTIR are zero. In addition we assume that the errors epsilon_FTIR(i), epsilon_DOAS(i) are independent and in average zero, we assume also that they are independent with respect to AK_DOAS(i), AK_FTIR(i), Xtrue(i), so that we can simplify the calculation of equation (7) to equation (8).

- 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. Can you comment this?
**ANSWER:** Good observation:
We produced the same plot for V1 and V2, but it seems not to be related to one special site.
around noon. So these values might be responsible for the larger variability in the V3 and are not easily to be explained by the sampling of different air masses.
The average sensitivity of version v3 near the ground is slightly larger than v2 and v1, which would explain a factor of up to 1.5 to pollution spikes near the ground, but not the observed factor of larger than 2.

- P17, line 6: "limited to just this hour" -> "limited to just one hour"?
**ANSWER:** The change was made, as suggested by the Referee.

- 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 ..." -
**ANSWER:** The change was made according to the Referee's suggestion.

P17, line 23: "therefore given due to the fact that" -> "therefore given by the fact that" -
**ANSWER:** The change was made, as suggested by the Referee.

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).
**ANSWER:** As suggested by both Referees, the dataset of Altzomoni was discussed in more detail in the manuscript and put in context with other high altitude sites worldwide and previous work.

**Suggested References:**
Franco, B., Hendrick, F., Van Roozendael, M., Müller, J.-F., Stavrakou, 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 GEOSChem and IMAGES model simulations, Atmos. Meas. Tech., 8, 1733–1756, https://doi.org/10.5194/amt-8-1733-2015, 2015.