Comments on NO2 and HCHO measurements in Moore's from 2012 to 2016 from Pandora spectrometer instruments compared with OMI retrieval and with aircraft measurements during the Korus-AQ campaign by Jay Herman et al.

General comments.

This paper is about observations of tropospheric columns of HCHO and NO_2 in 8 sites located in Korea, by using a Ground Based-direct Sun spectrometric instrument prior and during a study about Air Quality called KORUS-AQ. Observations have a different temporal extension depending on the site and varies from 1 to 5 years.

Comparisons to NO_2 OMI-Aura OMNO2 V03 and to measurements made by using the CAMS instrument on board of an aircraft are also presented in this work.

Ground based (GB) data are very valuable and interesting and this paper states the importance of GB measurements in comparison to satellite measurements available at the moment of the campaign that cannot capture the diurnal variation of pollution, necessary to state the Air Quality. It is also very valuable the effort devoted to keep operative 9 different instruments during one to five years.

In my opinion the work is very descriptive with a lack of interpretation of the measurements, instead, this article is in the scope of AMT journal and it should be published after taking into account some specific comments and technical corrections.

Specific comments.

Introduction.

It would be clarifying if a brief introduction of the campaign, why in Korea, objectives, and kind of instrumentation or citation of other works done during this campaign (if it is the case) would be included in the introduction. Also why the target gases to be measured are HCHO and NO_2.

Previous works in AQ in Asian megacities (i.e., using MAXDOAS technique) should be also mentioned in the introduction to put these measurements in context.

Some information about the different instruments, technique and retrieval of data should be included in this work:

> I suppose that Pandora retrieval is based in a DOAS algorithm, but if not, the kind of algorithm used should be, at least, mentioned and cited. If it is the case, a small mention to DOAS retrieval or DOAS technique should be included in the text and cited.
>
> Regarding to OMI, characteristic of the data used would be welcome in order to sustain some statements about the differences between GB and satellite measurements mentioned along the text. I will revisit this point later on in the proper section.
>
> For the interpretation of CNO_2, it would be interesting to mention what is the contribution to CNO2 of stratospheric column, if stratospheric and tropospheric contribution can separated and what is the sensitivity to troposphere of Pandora instrument.

NO_2 during KORUS-AQ campaign.

For the interpretation of CNO_2, it would be interesting to mention what is the contribution to CNO2 of stratospheric column and for AQ purposes to what extent tropospheric column resides below boundary layer. Also would be important to state what the sensitivity to troposphere of Pandora instrument is.

Later on, in this same section you consider that measured CNO_2 at Anmyeondo is mainly stratospheric. How can you differentiate this stratospheric contribution?

In order to have a reference, which level of CNO_2 is typical of polluted places?

A previous intercomparison of two of the GB instruments used in this work has been done with a very good agreement. But, to what extent is this good agreement extensive to the remaining GB instruments?

From figure 2a, lower panel, it seem that there is a level of cloud or aerosol coverage that limits the agreement between the two GB compared instruments. It can be seen that between 17 and 18h where the difference between instruments is greater than 0.05 DU. Has been carried out any study in which this level has been delimited in order to exclude these data for this work? Or this situation only is observed when high coverage (due to cloud or aerosol) and low CNO_2 are coincident? Is this situation contemplated by applying the filter of CNO_2 error >0.1 DU?

In page 8, L185, it is said that figure 3 and 4 are consistent with a large NO_2 pollution source in the Seoul metropolitan area that tends to transport eastward to the eastern stations near Seoul. This is not totally clear for me since there must be sources in all the cities, as traffic. It is also difficult to see from the different axis for different stations in figure 3. Please, explain this point with more detail. In figure 4 it is difficult to see.

In line 189, are you referring figure 4 instead figure 5?

Busan is located in the eastern coast, maybe NO_2 is transported from Busan to the Ocean but attending to the eastward transport proposed for Seoul and eastern stations surrounding Seoul, the amounts of NO_2 in Busan shouldn't be given by transport from western locations? But considering that the mechanism of transport to the Ocean is the cause for CNO_2 dissipation in Busan, why are there some days that this mechanism doesn't work and concentrations over 3 DU are observed? Just in case, this situation is observed only 3 days. Is there any common pattern for them?

Occasional plumes observed at Anmyeondo, are supposed to come from Northwards or China, is there any evidence of this? Maybe a retro trajectory for these days? Literature?

Diurnal variation of CNO_2

Is there any explanation for the increasing of CNO_2 at the late afternoon? The high amounts of CNO_2 observed at Seoul even in the morning are associated with an anticyclonic situation when high pressures confine pollutants in the boundary layer? Or it is always the same, no matter the meteorological situation is? The evolution from days 130 to 150 could indicate an anticyclonic situation followed by a low pressure system (rain or wind) because the following days seems to be less polluted. This meteorological situation could also explain the increase along the day of CNO_2. Regarding the eastern stations around Seoul, they have not only the transported air masses from Seoul but also their own sources. This is not easy to interpret without a chemical model but do you think it could explained the two maxima observed at midday and at late

afternoon at Olimpic Park and Taehwa Mt? It is a pity that the series for these last stations stops at day 150, maybe the same behaviour than at Seoul could be observed.

Could you cite instead the source for automobile emission from which the brochure of Thermo Sci is taken?

To compare to Boersma et al. and extract any conclusion it would be necessary to know if the meteorological situation considered in Boersma et al., is the same than in this work. Is it the same? This is not clear enough in the text. The situation observed by Boersma et al. is in the same kind of environment?

Longer-term changes in CNO_2

Figure 6 and text would be gain in clarity if L(t), M(t) and ZM(t) would be identified in the figure 6.

It is difficult to see any monthly variation in the black line of panels B and E in that scale. Please, change the scale from 0 to 1.5.

Less polluted stations, Gwangju and Anmyeondo show a positive trend in CNO_2 whereas the remaining stations that are more polluted show a negative CNO_2 trend. This is difficult to understand. Could you explain it a little?

Comparison with OMI satellite Overpass Data.

Differences observed between OMI and GB instruments are surely due to the different observed air masses by OMI and GB, part of it would be due to the OMI FOV as it is stated in the text. In fact a better coincidence observed in Gwangju support this fact. This could be stated in the text since if differences are only due to OMI FOV, comparison would be more coincident in western stations.

To discuss this point a brief description of how have OMI data been calculated is important to include. OMI overpass is only one point per day. But how has this point been calculated? By using the closest orbit to the station, as a averaging of some measurements? In this case a plot where the different points used by a OMI overpass could support the FOV as a cause of the observed differences. Small discussion about sensitivity of OMI to lower tropospheric NO2 and a discussion comparing it to Pandora sensitivity in troposphere or boundary layer is missed out in the text as well.

But the differences are also due to the hour of the overpassing. It is not possible for OMI to capture the elevated CNO2 observed at late afternoon, but you can check if the comparison improves when you don't consider late afternoon GB data.

Figure 9b is difficult to see. As you are using 3 month average data, it would be useful to see line+symbol instead only line. In that case it would be possible to see if there is not a displacement of minima, it is not clear for me if they are coincident.

Please make minor grid lines darker for this figure and enlarge the plot in order that details can be seen.

It is very interesting that seasonal evolution is captured by OMI and GB the first two years in both stations and in the last two years for Seoul. But there is a double maxima in spring captured by GB in 2013 and 2014. Although it is not exactly in the scope of this paper, is there any explanation for this apparently unusual seasonal behaviour, especially for year 2014?

The minimum in CNO2 observed by GB in Busan at the end of 2014 is really surprising, is there any explanation for such behaviour?

I don't think that the objective of OMI were to stated AQ in big cities, it is clear that continuous monitoring is a better technique to know the evolution of pollutants along the day in order to control the impact of pollutants on public health.

Formaldehyde from five Korus-AQ sites

I don't know if this is even possible, but in order to investigate differences observed in CHCHO from PSI and aircraft instrument, it would be interesting to have both instrument measuring together a couple of days from GB in the same location. In this way it would be possible to estimate whether the differences are due to different retrieval or observation technique more than to the approximations made to correct the observed column from aircraft to compare to GB instrument.

In figure 18, most of plotted days don't show the expected diurnal evolution, but an increase of HCHO along the day with greater amount observed at late afternoon, is there any explanation about this? The same behaviour is observed in figure 19a for the same station, it seems to be the habitual diurnal variation of HCHO for this site.

Technical corrections.

Page 5, L 136. 2.0 should be 2

Figure 2a. Please include a grid in the lower panel that permits to see the level of ±0.05 DU.

Figure 2a. Please remove last sentence of the caption.

Figure 2b. Please do not include an explanation in the caption but in the text.

Page 10 line 237 4.0 should be 4

Figure 6. Dots are extremely difficult to see, please make them darker. Missing labels in x axis of panel A, B and E.

Figure 6. Please explain in the caption what is the dark line in panel B and E. Re-organize the text in the caption, it is very confusing.

Figure 6. Greater plots and vertical grid would be also very useful.

Figures 17 and 18. Please include vertical grids. Put greater tick labels.

Figures 19a and 19b, please darken the dot, they are difficult to see. Add vertical grids to the left panels.

Figure 19b panel B, correct typo for Anmyeondo.