

Response to Report#1

Dear reviewer,

Thank you very much for you giving minor corrections on our manuscript. We have carefully considered every comment, and made corresponding revisions in the revised manuscript and marked every change in red.

Point to point response is following:

1. Some suggestions:

P1, L17 : using A Multi-AXis Differential

P2, L5: cut out the word “suitably”

P2, L6: This finding MAY indicate...

P2, L19: ...road cleaning [procedures] {optional word to add}

P2, L22: ...weather conditions [compared with] previous years

P2, L25: ...add a REFERENCE to the end of this line please.

P3, L4: ... Wang et al.

P3, L5: {would reduce significant figures here, 62%, 41%, etc.}

L14: VCDs

L15: {replace “surrounds” with “its surroundings based on THE Ozone...” or with”its suburbs based..”

P4, L17-20: {check with the journal as to how radicals are represented correctly and make sure you are using the correct notation}

P5, L5: ...called Multi-AXis Differential {see P1, L17}

L12: ..in THE Huairou District..

L19: {I think you have a typo here, replace HONO with HCHO, right?}

P6, L5: ...in the Yanqi Lake [region] near ...

L6: from October 1, 2014 TO January

L8: ...the mountains TO the southwest...

L10: ..and Tianjin ARE the primary pollution sources {or ...ARE primary pollution hotspots.}

L18-19: ...(Thermo Scientific, Model 42i), and ozone ...photometry (Thermo Scientific, Model 49i).

P7, L4: ...six elevation angles (EAs) 3, 5, 10 etc {add the degree symbol to each angle please}

FIGURE 3 – {not sure where your scattered light is, please fix the figure}

L5 : {this is a typo from me, change SCANS to scans}

L11: ... of -10.6C to 20.7C.. {keep degree signs though}

L14: cut out the words {with a wind speed of less than 3.5 m s-1} and replace with ... during the observationS, while wind speeds of

L19: ...based on THE Beer-Lambert Law...

L25: ..for all the retrievals to determine {retrieve} slant ...

P8, L2: ...The Ring structure ...

L12-L13: add brackets (and measured in a small sun zenith angle 90 elevation around noon).

P9, L16: .. VCDs ..

L17: ... are obtained from the ..

P11, L1: {is it T5 or T255?}

L2-L3: change to 00:00, 06:00, 12:00, 18:00 UTC.

L15: ...show that THE cloud coefficient ...
P12, L1: {I would reduce to 1 decimal, e.g. 2.2%, -23.5% etc.}
L4: ...and a dominant southerly wind flow with a speed of more than 2.0 m/s, during the two days ...
L24: {keep significant figures constant, 17%, 16%, 12% ...}
P14, L10: ... the effects of the control measures, ...
L14: ... considerably lower than 10.3 or 9.20 ...
L16: significant figures please
P15, L2: Equation 1
L9: ..could be the dominant ..
L9:... during other periods ...
L13: .. replace obviously with statistically {or significantly} depending on what you mean
P16, L7: ..other VOCs could be the ...
L12: (Figure 15a)?
L14: (Figure 15c)?
P17, L7: ... the economy near the UCAS has grown rapidly ...
L16: {statistically significant?}
P18, L2: .. and the CAMS model becomes larger or ...and the CAMS model becomes more pronounced.
P19, L12: ...on HCHO were evaluated...
L16: significant figures

Response to above: Thank you very much for your suggestion. We have considered your advice, it is changed in the manuscript.

2. Questions and advices:

P2, L1 {suggest 38% and 31%, as I don't think 4 significant figures is appropriate}

Response: Thank you very much for your suggestion. We considered the errors attributed to them and the correct number of significant figures. It was changed as ~40% and ~30%.

Changes in manuscript: During the period of the APEC conference, the average HCHO VCDs were ~40% and ~30% lower than that during the pre-APEC and post-APEC periods, respectively.

P2, L15: ...emission reduction measurements {is it measurements or strategies or maybe measurement strategies? I would use emission reduction strategies in accordance...}

Response: Thank you very much for your advice. We used emission reduction strategies here.

Changes in manuscript: Some provinces, including Beijing, Tianjin, Hebei, Shanxi, Inner Mongolia, and Shandong implemented different emission reduction strategies in accordance with the air quality assurance plan (Wang et al., 2016a).

P3, L4-L7: {So the O3 increased by 101%, you could also say that the O3 level approximately doubled over this period then, right?}

Response: Thank you for your question. The O3 increased by 101%, which means the O3 level approximately doubled over this period then the same period over the last five years. It was changed in the manuscript.

Changes in manuscript: Wang et al, (2016a) selected five representative *in situ* stations in different locations in Beijing and found that average concentrations of SO₂, NO₂, PM₁₀, and PM_{2.5} decreased by 62%, 41%, etc, respectively, whereas the average O₃ level approximately doubled over this period than the same period over the last five years (PM_{2.5} since 2013)

L9 : {do you mean that there is less O₃ titration due to NO_x, if so re-word this? Not sure if inhibition of O₃ is the best wording here?}

Response: Thank you for your advice. We re-worded this to make it clear.

Changes in manuscript: O₃ production rate depends on the ratios of volatile organic carbon (VOC) and NO_x. The urban and suburban areas of Beijing are controlled by the NO_x saturated condition of O₃ production. Since emission control measures are mainly focus on NO_x, but not VOCs, decrease of NO_x can cause significant increases of O₃ concentration (Wang et al., 2016a).

L10-12: {sorry but I am not sure what the difference is between traffic, urban, suburban and regional stations, define it or at least reference it please }

Response: Thank you for your question. At the beginning we introduced five representative in suit station, which were City Background Station, Regional Station, Suburban Station, City Station, and Transport Station. We defined it to make it clear.

Changes in manuscript: Wang et al, (2016a) selected five representative *in situ* stations in different locations in Beijing, which were Miyun Reservoir Station (City Background Station), Yuzhan Station (Regional Station), Changping Station (Suburban Station), Olympic Sports Center Station (City Station) and Xizhimen North Street Station (Transport Station), and found that average concentrations of SO₂, NO₂, PM₁₀, and PM_{2.5} decreased by 62%, 41%, etc, respectively, whereas the average O₃ level approximately doubled over this period than the same period over the last five years (PM_{2.5} since 2013).

Although the traffic and urban stations produce a lot of pollution due to motor vehicle emissions, the NO₂ concentrations of suburban and regional stations significantly dropped (47%) compared with the traffic and urban stations (23%) as a result of the control measures.

L22-23: .. experiencing significant decreases of 47% and 68% versus what? {...versus the average 2008 values, state what you mean here }

Response: Thank you for your question. It is comparison between before, during and after APEC. It was added in the manuscript to make it clear.

Changes in manuscript: Particles with larger sizes were better controlled during the APEC period, with the number concentration of accumulation mode and coarse mode particles experiencing more significant decreases of 47% and 68% than before and after the APEC period (Zhang et al., 2017).

P8, L5-L6: {define what large RMS values are, what was your threshold please?}

Response: Thank you very much for your advice. The threshold $>10^{-2}$ was added to make it clear.

Changes in manuscript: Data with a large root mean square (RMS) of the residuals ($>10^{-2}$) and large relative intensity offset were also excluded.

P9, L7: {do your lower EAs have obstacles in their paths, if so, what is the use of them? what about using the geometric approximation for the lower EAs, that doesn't work either right? You have a lot of

unused data in your data set (ie. 3, 5, 10 degrees). Perhaps later to get a VCD from RTM?}

Response: Thanks for the suggestion! We checked the data and found the lower EAs are not obstructed. However the sensitivity height at a lower EA is too close to the surface. In order to derive the HCHO VCD in the boundary layer, the geometric light path at 15 ° is a good approximation in the boundary layer. In a following study, we will try to retrieve HCHO profiles from the full sequence for the comparisons with model simulations.

Changes in manuscript: This study used the geometric approximation method to determine HCHO VCDs at an elevation angle of 15 °. **The geometric light paths at 15 ° and 30 ° are good approximations in the boundary layer. However lower** systematic errors were achieved at 15 ° than at 30 ° by using the geometrical approximation (discussed in Section 2.3 below).

L15: {what is TG?}

Response: Thank you very much for your question. The TGs here means **trace gases**. It was changed in the manuscript.

Changes in manuscript: The systematic error of the HCHO VCDs calculated by the geometric approximation depends on the layer height of the **trace gases** and aerosols.

P9-10, I23-11 : {from your figure 6, it appears that the VCD_{geo} > VCD_{amf} for 30 degrees, but VCD_{amf}>VCD_{geo} at 15 degrees, is there any explanation for this?}

Response: Thanks for the asking! The effect shown in Fig. 6 is from RTM simulations and consistent with the previous researches based on RTM simulations (Wang et al., 2017c, Ma et al., 2013, and Shaiganfar et al., Atmos. Chem. Phys., 11, 10871–10887, 2011).

This phenomenon is mainly due to the layer height of HCHO and aerosol, and relative azimuth angles.

L6: {any explanation for the large range in the fitting error?}

Response: Thanks for the question. The absolute fit error is almost constant value of (1.2×10^{15}) molecules cm^{-2} at different HCHO dSCDs. The relative error is given here. The relative error also depends on the HCHO dSCDs. The large variation range of the relative error is due to the variation of HCHO dSCD. In order to clarify this point, we add the absolute fit error in the manuscript.

Changes in manuscript: and the hourly average of the HCHO VCD fitting error was from **4% to 27%** for the entire period **with the absolute fit error is $\sim 1.2 \times 10^{15}$** .

L12: {if the total error is 12% on average, what is the range?}

Response: Thank you very much for your suggestion. The range of the total error is **3%-21%**. It was added in the manuscript

Changes in manuscript: Since the three errors are mainly independent, the total error can be calculated by combining all the above error sources, adding up to about **3% - 21% with 12%** on average.

L16: {you defined what CAMS stands for in the intro, but I would also repeat it here since it has been 9 pages since you introduced it}

Response: Thank you very much for your suggestion. It was added in the manuscript

Changes in manuscript: **Copernicus Atmosphere Monitoring Service (CAMS)**, which is managed by

ECMWF, publicly provides generally reliable atmospheric information.

L23 : TM5 chemical transport model (CTM)?

Response: Thank you very much for your advice. It was added in the manuscript to make it clear.

Changes in manuscript: In the simulation of HCHO, chemistry originating from the **Transport Model 5 (TM5)** had been fully integrated into the C-IFS, in which only gas phase reactions of HCHO are included.

L21: {it looks like 3 peaks to me?}

Response: Thank you for your question. The increasing process of HCHO VCDs is in the periods of 3-5 and 6-9 November. And the peaks appeared on November 4, 2014 and November 7, 2014, in the two periods, respectively.

P13, L5: ... correspond to a minimum in the average HCHO VCDs (6.64×10^{15} molec cm⁻²).

Response: Thank you very much for your advice. We considered the correct number of significant figures. It was changed as 6.6×10^{15} molec cm⁻².

Changes in manuscript: In contrast, the northeast and north directions correspond to a minimum in the average HCHO VCDs (6.6×10^{15} molec cm⁻²).

L6-7: {what about VOCs from natural sources?}

Response: Thank you for your advice. The nature sources of VOC should be much lower than the anthropogenic sources, especially in the winter season. We clarify the point in the manuscript as " the nature sources of VOC in the north should be much lower than the anthropogenic sources in the winter season. "

Changes in manuscript: The northern cities are clean with low VOC emissions, and **the nature sources of VOC in the north should be much lower than the anthropogenic sources in the winter season.** Thus few precursors of HCHO were transported to the measurement station in the north wind.

P14, L1: {I would say 38% and 31% here, be consistent in your significant figures please.}

Response: Thank you very much for your suggestion. According to P2.L1, we considered the errors attributed to them and the correct number of significant figures. It was changed as **~40% and ~30%**.

Changes in manuscript: The average HCHO VCDs were 10×10^{15} , 6×10^{15} , and 9×10^{15} molec cm⁻² before, during, and after APEC, with fitting errors of **9.4%, 10.1%, and 9.7%**, respectively. A noticeable decrease of **~40%, and ~30%** during APEC was found compared with before and after APEC.

L10-L12: {how do you know this, what is your proof? }

Response: Thank you very much for your suggestion. We considered your advice, and the references were added.

As the measurement station is located in the northern suburban area of Beijing, the effects of the control **measures**, which were mainly implemented in the urban areas, on HCHO were only observed at the station when dominant southerly winds occurred (**Fan et al., 2016, Li et al., 2015**).

Li, W.T., G, Q.X., Liu, J.R., Li, L., Gao, W.K., Su, B.D.: Comparative Analysis on the Improvement of Air Quality in Beijing During APEC, 36(12), 4340-4347, 2015.

L19-L20: the O₃ is surface but the NO₂ is VCD, is this a potential source of error? If so, mention it somewhere.

Response: Thank you very much for your advice. We clarified the point as the following:

Here it needs to clarify that the O₃ data is from the surface measurements, but NO₂ and HCHO are the tropospheric VCD. Since NO₂ and HCHO are mostly in the boundary layer, the effect of the discrepancy of measured layers on the correlation analysis is not significant.

Changes in manuscript: Here it needs to clarify that the O₃ data is from the surface measurements, but NO₂ and HCHO are the tropospheric VCD. Since NO₂ and HCHO are mostly in the boundary layer, the effect of the discrepancy of measured layers on the correlation analysis is not significant

P19. L23: {could state the per cent error here instead of exact value, since you did that earlier, but it is your choice}

Response: Thank you very much for your suggestion. We have considered your advice, and the per cent error is instead of exact value. It is changed in the manuscript.

Changes in manuscript: The CAMS model underestimated HCHO VCD by about 24% on average compared to the MAX-DOAS measurements.

Thank you for your valuable comments!

Kind regards,

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Response to Co-editor

Dear editors,

Thank you very much for your decision "Publish subject to minor revisions" on our manuscript. We have carefully considered your comment and comments from the reviewer. And we made corresponding revisions (marked in red) in the revised manuscript and wrote a point-to-point response to all the comments.

Changing in the manuscript is following:

P1-2, L27-L1: During the period of the APEC conference, the average HCHO VCDs were **~40% and ~30%** lower than that during the pre-APEC and post-APEC periods, respectively.

P13, L1: HCHO VCDs considerably depend on wind directions, and the average HCHO VCDs were **8×10^{15}** molecules cm^{-2} under the southerly wind (including southwest and southeast).

P13, L4-5: In contrast, the northeast and north directions correspond to a minimum in **the average HCHO VCDs (6.6×10^{15} molec cm^{-2})**.

P14, L1-3: The average HCHO VCDs were **10×10^{15} , 6×10^{15} , and 9×10^{15}** molec cm^{-2} before, during, and after APEC, with fitting errors of **9.4%, 10.1%, and 9.7%**, respectively. A noticeable decrease of **~40%, and ~30%** during APEC was found compared with before and after APEC.

P14, L14-18: **Fig. 12d–f** indicate that the averaged HCHO VCDs under south winds during APEC were about **6.5×10^{15}** molec cm^{-2} , which was considerably lower than **10.3, or 9.2×10^{15}** molec cm^{-2} in the pre-APEC and post-APEC periods. In addition the peak values due to transport from the south urban area on November 4, 2014 and November 7, 2014 during APEC shown in **Fig. 11** were **25% and 18%** lower than the peak values under similar wind fields in the pre-APEC and post-APEC periods.

P16, L16-17: On average, the CAMS model underestimated HCHO VCDs by **$1.6\text{--}2.0 \times 10^{15}$ molec cm^{-2} and $1.3\text{--}2.1 \times 10^{15}$ molec cm^{-2}** compared to the MAX-DOAS measurements at 8:00 LT and 14:00 LT, respectively, due to different grid-sizes.

P17, L16-17: During the period of the APEC conference, the average HCHO was **6×10^{15}** molec cm^{-2} , which was **~40% and ~30%** lower than that during the pre-APEC and post-APEC periods, respectively.

Thank you for taking care of our manuscript.

Kind regards,

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