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Atmospheric Measurement Techniques Discussions

Interactive comment on "Analysis of spatial and temporal patterns of on-road NO_2 concentrations in Hong Kong" *by* Ying Zhu et al.

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We thank reviewer #2 for careful reading our manuscript and the very detailed comments. They certainly helped us to improve the manuscript. We understand that the comments are positive on the scientific content of the manuscript while appropriate revisions and clarifications are necessary. We have addressed the reviewer's comments on a point to point basis as below for consideration.

In this manuscript, Zhu et al. report on measurements of boundary layer NO2 in Hong Kong using different techniques. In two campaigns, car-based measurements with a CE-DOAS instrument were performed for several days at different times of the day, covering both rush-hour and normal conditions. These measurements are complemented

by data from the in-situ measurement network, a long path DOAS instrument operating during and in between campaigns, and OMI satellite data. Data were analysed for their temporal trend, the diurnal profile, the week-end effect, their spatial distribution and the NO2 / NOx ratio.

The paper reports interesting measurement results from a highly polluted city enforcing strict emission controls and highlights some nice local effects such as changes in pollution levels around metro stations. The manuscript is overall well written but focuses on reporting measurement results and a qualitative interpretation. It therefore does not fit well into the scope of AMT ("The main subject areas comprise the development, intercomparison, and validation of measurement instruments and techniques of data processing and information retrieval for gases, aerosols, and clouds.") but should rather have been submitted to ACP in my opinion. It would also benefit from a more quantitative discussion including error bars.

Nevertheless, I recommend it for publication after the following points have been fully addressed.

Response: Before we submitted our manuscript to AMT, we carefully thought about the choice of journals and we chose AMT because our manuscript reports the application of mobile CE-DOAS, the data analysis method of the mobile measurements and the measurement results. We also compared our mobile measurements with in-situ monitor data. Therefore, we think the work represented fits well with the scope of AMT especially the specially issue of "Advances in cavity-based techniques for measurements of atmospheric aerosol and trace gases". We hope the manuscript is of interests for the general audience of the journal.

1. Was any correction applied to the in-situ chemiluminescence NOx analysers for cross-sensitivities?

Response: Cross-sensitivities correction is not applied to the chemiluminescence NOx analyzer measurements. However, the in-situ monitor operated by EPD have under-

goes a series of calibration and verification procedures. The quality of the measurement data is proofed to meet the measurement standard.

2. I'm not yet convinced by the discussion of the NO2 to NOx ratios. While I can understand that the ratio is driven by the fraction of NOx emitted as NO close to the source, and therefore a change in technology used in the car fleet can have an impact on NO2 to NOx ratios at roadside stations, I'm surprised to see that this is also the case at ambient stations. Is this because of the increase in ozone concentrations, and if so, does this match quantitatively with model results/ stationary state estimates?

Response: The increase of ambient ozone certainly has an effect on the NO2 to NOx ratio. However, it is very difficult to quantify the contribution of increase of ozone on the increase of NO2 to NOx ratio even with chemical transport model. In addition, the focus of this section is to analysis the long term change of on-road and ambient NO2. Model study of the interaction between ambient O3 and NOx is certainly interesting but beyond of the scope of the paper. We have supplemented the information in the revised manuscript (page 16, line 3-5).

The values given in Fig. 9 are also not in good agreement with the number of 0.7 given for the NO2/NOx ratio in section 2.3. Clearly, this ratio is not constant over the measurement period and varies strongly within the area. How will that impact on the results?

Response: The NO2/NOx ratio given in section 2.3 reflects the general condition in Hong Kong and of course this number could vary in a wide range depending the local situation. The value indicated in section 2.3 is more representative for the ambient station measurements Fig 9b. The ratio provided is only supplementary information and not our focus of the study. In order to avoid confusion, we have removed the calculation of NO2/NOx ratio in section 2.3.

3. I do not see what I can learn from Fig. 7 which is not already shown in Fig. 6.

Response: We would like to show the decrease of NO2 level is not only happening in Hong Kong, but also in the surrounding areas. Therefore, we provided the satellite images of NO2 spatial distribution over Pearl River Delta in both 2010 and 2017.

4. In section 3.2.1, a filtering of the data for congestion situations is described, and I can see the reason why the authors apply this filter. On the other hand, isn't there a risk of introducing a low bias, as the most busy (and thus most polluted) parts of the roads which have the highest risk of congestion will be removed from the data?

Response: The reviewer is right that the filter implemented would remove more data from busy roads where congestions happen more frequently. The filter is only applied to the maps for comparison (Figure 8), so that the maps are focus on NO2 concentrations instead of congestion patterns, since the congestion patterns could be very different due to road constructions and traffic accidents. The interpretation of the data is based on the difference between these maps, which they are analyzed in the same way. Therefore, the biases are very likely to be cancelled out with each other. On the other hand, this filter was not applied to the NO2 spatial distribution analysis (Figure 12), so it will not affect the interpretation of the spatial pattern of NO2. In order to avoid confusion, we have added a sentence in section 3.2.1 to clarify that the filter is only applied the maps for comparison (page 8, line 8).

5. If I understood the diurnal normalization discussed in section 3.2.2 right, not the actual diurnal profile from the LP DOAS is used but rather the mean profile for that day of week, scaled to the actual LP DOAS measurements. As can be seen in Figure 5, the match is not very good between these two curves, and I'm wondering what that implies for the validity of the correction and the remaining bias from non-coincidence of measurements.

Response: In this study, the mean profile of the day of week is scaled to fit the actual LP-DOAS measurement and the resulting profile is used for diurnal variation correction. Although the LP-DOAS measures along an optical path of 2km, the results may

still not be fully representative for the general condition of the entire Hong Kong. Figure 5 shows the LP-DOAS and 7 EPD monitor stations NO2 measurements. The result shows the scaled LP-DOAS data matches better the general condition of Hong Kong. Therefore, we use the scaled mean profile instead of the actual coinciding data. We have included a more detailed explanation of the use of scaled profiles instead of coinciding measurement in the revised manuscript (page 9, line 6-8).

6. In Figure 8 and the discussion in the text, the measurements taken in March 2017and December 2010 are used to characterise the long-term evolution of NO2 in Hong Kong. While the differences are large enough to be convincing, I still think that some discussion is needed here to exclude and quantify other effects such as weather, season or sampling.

Response: The measurement campaigns were held in different seasons, we tried to organize the campaigns in the similar time of year, but due to certain limitations, we can only measure in these two time frames. The two measurement campaigns were performed in winter (December) and early spring (March). We have analyzed the meteorological parameters including temperature, humidity, wind speed and wind direction taken during the two measurement campaigns. The results show that the meteorological conditions are quite similar during the two campaigns. We have supplemented the information in the revised manuscript (page 12, line 24-26).

7. In section 3.4, the differences between the magnitude of the NO2 concentrations measured by EPD ambient stations and on-road CE-DOAS is discussed in the context of Figure 11. However, already in Fig. 6 it can be seen that CE-DOAS values are on average clearly (much) higher than the station data, although measured within 100 m. I assume that this is mainly due to the different measurement altitudes and the steep vertical profile of NO2 in this urban environment (see also the earlier paper on the LP-DOAS measurements by Chan et al., 2012). In my opinion, this asks for some discussion with respect to the representativity of the CE-DOAS measurements and the station data, for example for human health and compliance with environmental

legislation.

Response: The vertical distribution of NO2 under on-road/road side conditions varies in a wide range. The EPD ambient stations are located at different altitude and in general above 10m a.g.l., while the road side stations are measuring at 3m a.g.l.. The inlet of our on-road mobile measurement is setup at 1.5m a.g.l, which is much closer to the pedestrians breathing height. As the tail pipes of vehicles are usually at 10-30cm a.g.l., our mobile measurement inlet is much closer to the emission sources and therefore in general measure higher NO2 concentrations. We have supplemented the description of the EPD stations (page 5, line 11-12) and the explanation of much higher on-road NO2 measured by the mobile CE-DOAS (page 12, line 5-9) in the revised manuscript.

8. In order to put Figure 12 to use in other studies, it is important to know if this is a snapshot or an average over many observations. If the latter is true, the number of individual measurements that go into these averages and also the RMS are relevant so that the reader can get an idea of how representative the mean value is.

Response: The spatial distribution of NO2 shown in Figure 12 is an average of all available measurements. The standard route measurement was performed 3 times per day, while other locations only have single or few overpasses during the two campaigns. Therefore, the resulting map can be regards as a consistent snapshot. In order to have a better overview, the data are corrected for diurnal variation using the LP-DOAS measurements (Figure 12b). To avoid confusion, we have extended the description of the figure capture of Figure 12 (page 20).

9. I'm missing a statement on the availability of data – as the high resolution NO2 map is one of the main outcomes of the study, readers should know how to access it.

Response: We have now included a statement on the availability of data. The mobile measurement data is available on request from the corresponding author (ka.chan@dlr.de).

10. The text is overall well written and clear, but there are several shorter sections which need careful proof reading for grammar. Response: We have carefully proofread the manuscript again and corrected the typing and grammatical errors.

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