Atmos. Chem. Phys. Discuss.,
https://doi.org/10.5194/acp-2017-1063-AC2, 2018

Atmospheric Chemistry and Physics Discussions
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Interactive comment

Interactive comment on "Assessment of Air Pollution in Bangkok Metropolitan Region, Thailand" *by* Pornpan Uttamang et al.

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Received and published: 5 June 2018

We wish to thank the reviewer for the careful and thoughtful review of our manuscript. We appreciate the reviewer' s comments "Overall, the article is well written and examines the interaction of Ozone with NOx regime. The analysis was well done." All the comments and suggestions are now incorporated in the manuscript.

Line 12: the statement is made, "On average, the number of hourly O3 exceedences ranged from 1 - 60 hours a year." This line is confusing. The overall average should be a value, not a range. If you wish to express it as a range, then do it by year, such as 2010 that average was XX hours, 2011, the average was XX hours. This range of 1-60 hours makes no sense.

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Discussion paper

Authors' response: Thank you. We have now incorporated the change in the modified manuscript.

"Abstract. Analysis of gaseous criteria pollutants in Bangkok Metropolitan Region (BMR), Thailand, during 2010 to 2014 reveals that while the hourly concentrations of CO, SO2 and NO2 were mostly in the National Ambient Air Quality Standards (NAAQs) of Thailand, the hourly concentrations of O3 frequently exceeded the standard. The results reveal that the problem of high O3 concentration continuously persisted in this area. Interconversion between O3, NO and NO2 indicates crossover points between the species occur when the concentration of NOx (= NO + NO2) is $\sim$60 ppb. Under low NOx regime ([NOx] < 60 ppb), O3 is the dominant species, while, under high NOx regime ([NOx] > 60 ppb), NO dominates. Linear regression analysis between the concentrations of Ox (= O3 + NO2) and NOx provides the role of local and regional contributions to Ox. During O3 episodes ([O3]hourly > 100 ppb), the values of the local and regional contributions were nearly double of those during non-episodes. Ratio analysis suggests that the major contributors of primary pollutants over BMR are mobile sources. The Air Quality Index (AQI) for BMR was predominantly between good to moderate, however, unhealthy O3 categories were observed during episode conditions in the region."

Section 2, Methodology line 12: When you express a range (this applies throughout, do not mix the units and values. In Section 2, Methodology line 12 you state the temperature is (âĹij35C - 40C). This appears to read that it ranges from 35 degrees to - (minus) 40 degrees. Do this instead: (35 - 40 C).

Authors' response: Thank you. We have now incorporated the change in the modified manuscript.

"2.1 Study Area Figure 1 shows a map of BMR, the location of the monitoring stations in this study and major monsoon winds over the region. BMR refers to BKK and the five adjacent provinces, including Nakhon Pathom, Pathum Thani, Nonthaburi, Samut

Prakan, and Samut Sakhon. These provinces are closely linked to BKK in terms of traffic and industrial development (Zhang and Oanh, 2002). Thailand has three official seasons–local summer (February to May), rainy (May to October) and local winter (October to February) as per the Thai Meteorological Department (TMD) (TMD, 2015). During the rainy season, this region's weather is influenced by Southwest monsoon wind that travels from the Indian Ocean to Thailand. This marine air mass contains high moisture, resulting in the wet season in Thailand. During this season, Thailand is characterized by cloudy weather with high precipitation and high humidity. From October to April, this region is influenced by Northeast monsoon wind that travels from the north-eastern and the northern parts of Asia (China and Mongolia). This monsoon wind brings a cold and dry air mass, which leads to the dry season (local summer and local winter) in Thailand. The local winter in Thailand is characterized by cool and dry weather, while the local summer is characterized by hot (35 to 40 âĎČ) to extremely hot weather (> 40 âĎČ) due to strong solar radiation. During the dry season, storms may occur during the seasonal transition (TMD, 2015). Transportation and industrial sectors are considered to be the major sources of air pollutants in the study area (Watcharavitoon et al., 2013). For example, in 2014, ∼36 million new vehicles were registered in Thailand and 29 % of these cars were registered in BKK (DLT, 2015). About 56 % and 28 % of the registered vehicles in BKK were gasoline and diesel engines. The remaining 16 % were Compressed Natural Gas (CNG) (DLT, 2017). In fact, the outskirts of BKK are populated with a variety of metal, auto parts, paper, plastic, food and chemical manufacturing facilities and power plants (DIW, 2016, 2016a, 2016b, 2016c, 2016d). "

Section 2, Methodology line 21: it states, " It is assumed that the monitoring sites used were representative of BMR specific patterns and trends." I think it goes without stating this that the professionals at the PCD would have done this and this does not need to be stated, but you would hope you would infer this. Remove this statement.

Authors' response: Thank you. We have now incorporated the change in the modified manuscript and the statement has been removed.

Section 2, Methodology, line 27 -29: you list the sites (19T, 20T, etc...) which mean absolutely nothing to the reader then you state in line 29 that the figure shows these. The statement that mentions the figure should be the first line to the paragraph, not the last line. Move this line to the front so the reader can go get the figure look at it while you read the information.

Authors' response: Thank you. We have now modified the manuscript by removing site lists and referring the figure earlier in the section.

Section 2.2, line 2: you mention wind speed and direction. Is this average or vector data? Please state. This is important when calculating direction from which winds are blowing.

Authors' response: Thank you. The wind speed and wind direction are hourly averages.

Section 2.2, line 10: it is mentioned that equipment and monitoring station are calibrated every year. This is vague and could cast a shadow on validity of data. does this mean that this is done only once per year? Pollution instruments and met, or only met instruments. I am sure the PCD does calibrations more often than once annually. Please clarify this statement.

Authors' response: Thank you. As indicated in the manuscript, the data were collected, and after QA/QC, were provided to us by the Pollution Control Department (PCD), Thailand. Data loggers are calibrated/ checked at least every 15 days. Air inlets are cleaned at least every 15 days. Equipment is single-point calibrated and multi-point calibrated at least every 15 days and at least every 3 months. Monitoring stations and equipment are audited by external auditors every year. We have modified our manuscript to make a clarification.

".2 Data Collection and Data Analysis Over the four-year period, January 1, 2010 to

December 31, 2014, hourly observations from 15 Pollution Control Department (PCD) monitoring stations were analysed. The monitoring stations are categorized into three categories: BKK sites, roadside sites, and BKK suburb sites. BKK sites refer to the monitoring stations that are located within BKK's residential, commercial, industrial and mixed areas. They are within ∼50 to 100 m away from the road. Roadside sites refer to the monitoring stations that are located in BKK within 2 to 5 m from the road (Zhang and Oanh, 2002). BKK suburb sites refer to the monitoring stations that are located in provinces adjacent to BKK (Figure 1). Quality assurance and quality control on the data set were performed by PCD prior to receiving the data. Hourly observations of the gaseous pollutants and meteorological parameters were automatically collected with auto calibration at the monitoring stations. Manual quality control was performed when unusual observations were found. External audit of the equipment and monitoring stations were done every year. Data availability is provided in Figure I, supplement material. Gaseous species were measured at 3m above ground level (AGL). CO was measured using non-dispersive infrared detection (Thermo Scientific 48i). NO and NO2 were measured using chemiluminescence detection (Thermo Scientific 42i). SO2 was measured using ultraviolet (UV) fluorescence detection (Thermo Scientific 43i) and O3 is measured by using UV absorption photometry detection (Thermo Scientific 49i). The meteorological parameters including wind speed (WS) and wind direction (WD) were measured at 10 m AGL by cup propeller and potentiometer wind vanes. Temperature (T) and relative humidity (RH) were measured at 2 m AGL by thermistor and thin film capacitor, respectively (Watchravitoon et al., 2013). All the meteorological measurements were made by Met One or equivalent method. Data analysis, statistical analysis and plots are performed using Excel 2016. Predominant wind directions related to O3 concentrations are performed using Openair package (tool for the analysis of air pollution data) on RStudio program. "

Section 3.3 line 24: you use the term "atmospheric boundary layer." Is this the same as planetary boundary layer that was used previously? If it is the same term, then be consistent. If it isn't then please explain what this term means on how it differs from the

PBL.

Authors' response: Thank you. We have now corrected the manuscript by using "planetary boundary layer" instead of "atmospheric boundary layer" to provide consistency in the manuscript.

Page 8, line 11: Please explain why the ratios of NO2 and NO show significant difference. You make the statement but you don't say why. this is an important claim that you make in this paper.

Authors' response: Thank you. As suggested by the reviewer, we have now removed this from our manuscript.

Page 9, line 9: you state, "In conclusion, the titration of O3 and NO is perhaps one of the most important processes..." Please elaborate about why this is so important.

Authors' response: Thank you. The titration of O3 by NO is perhaps one of the most important processes to reduce O3 concentration at roadside sites, due to this monitoring station type is more affected by fresh NO emitted from vehicles than the other monitoring station types. Several studies reported the effect of the titration of O3 by NO, for example, Chan et al., (1998) studied surface ozone pattern in Hong Kong and reported that "In fact, this O3 sink is a common feature observed in many countries in the Northern Hemisphere, such as in Great Britain and Canada. In these two countries, the urban stations in central London (Bower et al. 1989; UKPORG 1990) and Alberta (Angle and Sandhu 1988) show lower O3 concentrations than their counterparts in the rural areas. This can be explained by the fact that the fresh precursor emissions from traffic and other sources cause direct chemical scavenging of O3." And "Indeed, Bell et al. (1970, 1977) has shown that even under light wind conditions, pollutants generated from local sources will be dispersed within 2–3 h. Thus, the titration effect of the fresh O3 precursors, especially NO, emitted from the metropolitan area of Hong Kong leads to the lower O3 levels in the urban stations in our study." Ghim and Chang (2002) studied ground-level ozone distribution in Korea and reported that "many studies reveal that background ozone concentrations in the Northern Hemisphere are around 3 5-40 ppb [Akimoto et al., 1996; Husar, 1998]. However, even in summer, monthly mean ozone levels in Korea are lower than this background level. . ..This could be primarily due to local effects of titration of O3 by fresh NOx emissions, since most ozone monitoring stations are located in or near major cities [Fuentes and Dann, 1994]". Munir et al., (2014) studied the diurnal variations of O3 in the UK and reported that "the lowest ozone concentrations are exhibited by Marylebone monitoring site which is located approximately 1 m from the edge of Marylebone road. This road has six lanes and has a flow of 80,000 vehicles per day. Most probably titration of ozone by fresh NO emitted by road transport keeps ozone concentrations low at this site." Chan, L. Y., Chan, C. Y. and Qin, Y.: Surface Ozone Pattern in Hong Kong, Journal of Applied Meteorology, 37, 1153-1165, 1998. Ghim, Y. S., and Chang, Y-. S.: Ground-level ozone distribution in Korea, Journal of Geographical Research, 105(7), 8877-8890, 2000. Munir, S., Chen, H., and Ropkins, K: Characterising the temporal variations of ground-level ozone and its relationship with traffic-related air pollutants in the United Kingdom: a quantile regression approach, Int. J. Sus. Dev. Plann, 9(1), 29-41, 2014.

However, we have removed this from the manuscript.

Page 11, line 5: you state, "However, a negative delta O3 may be negative. However, it appears that the data doesn't support this in the paragraph. Why is this statement made?

Authors' response: Thank you. We put this statement to clarify that a negative delta O3 was possibly to be observed due to O3 deposition and/or O3 consummation. Our analysis, negative values of delta O3 were observed several times, however, the average of those was positive.

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