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Atmospheric Chemistry and Physics
Discussions

Interactive comment on "Elucidating the ozone pollution in Yangtze River Delta region during the 2016 G20 summit for MICS-Asia III" *by* Zhi-zhen Ni et al.

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1. While this is an interesting case study, the motivation of the paper is not clear to me. Specifically, the authors did not say whether [a] they want to study how surface ozone responded to the tropical cyclone during their study period or [b] if they are interested in understanding whether emergency control measures put in place for the G20 meeting helped reduce ozone levels or not? If their objective is [a], this study lacks novelty because it is now well understood that clear-sky stagnant conditions favor photochemical ozone formation and cloudy-skies suppress it. Thus, ozone variations reported and modeled before, during, and after the cyclone are expected and there

is no new knowledge gained here. If their objective is [b], the model experimental design is not appropriate. The authors did not modify their emission input to reflect emission control measures in their model simulations and no sensitivity experiment was performed to understand what would have happened in the absence of emergency emission control measures?

Reply: Thank you for this valuable comment. Accordingly, we have highlighted the motivation of the present study by rewriting the introduction with three additional paragraphs. The main objective of the present study is to understand the unique response of ozone increase to emission control measures during the 2016 G20 Summit in Hangzhou, while other pollutants had been significantly reduced (Li et al. 2019; Wu et al. 2019; Ji et al. 2018; Zheng et al. 2019). The title of the manuscript is also changed as "Spatial-temporal Variations and Process Analysis of O3 Pollution in Hangzhou during the G20 Summit" to reflect this motivation. For this purpose, a regional air quality model, within the framework of the Model Inter-Comparison Study for ASIA phase III (Li et al., 2019), is used to investigate the spatial-temporal variations of ozone pollution in Hangzhou during the G20 Summit. Process analysis is conducted to understand the chemical and physical factors that contribute to the local O3 abundance. It is worth noting that the base emission input has been modified to reflect emission control measures in our model simulations. Sensitivity experiments are not performed as previous surface observations (Li et al. 2019; Wu et al. 2019; Ji et al. 2018; Zheng et al. 2019) have suggested that the control measures took no immediate effect on local ozone formation, but significantly reduced other pollutants. The three added paragraphs are attached as below.

"Hangzhou, the capital of Zhejiang Province, is located in the center of the Yangtze River Delta which is one of the most developed areas in China. Resultant from local emissions (Wu et al. 2014, Hu et al. 2015) and transboundary transport of aerosol and trace gases transport (Liu et al. 2015; Ni et al. 2018; Zhang et al. 2018), air pollution in Hangzhou has become serious in the recent years. In 2016, Hangzhou city would host the 2016 G20 (Group of Twenty Finance Ministers and Central Bank Governors) summit during September 4-6. To improve air quality for this event, 14-day temporarily strict air pollution alleviation measures had been taken to reduce air pollutant emissions in Hangzhou and surrounding areas from August 24 to September 6, 2016. The emission control scheme includes a coal-fired power plant capacity 50% reduction since August 24, followed by an "odd-even" on-road vehicle restriction since August 28, and further emergent VOC reduction from industrial sectors since September 1 to 6 (Ji et al. 2018; Li et al. 2019; Wu et al. 2019). These short-term measures provide a valuable opportunity to investigate the response of air quality to the emission reduction, understand the formation mechanisms of air pollution, and explore effective policies for long-term air pollution control in the local or regional scale.

The effects of emission control on air pollutants during this G20 Summit have been investigated by several studies using field observations and numerical models. It is demonstrated that almost all major air pollutants including SO2, NOx (Li et al. 2019; Wu et al. 2019), fine particles (Ji et al. 2018; Li et al. 2019; Yu et al. 2018; Wu et al. 2019), and VOCs (Zheng et al. 2019) have been significantly reduced during the 14-day control period, except O3. Su et al. (2017) monitored the vertical profiles of ozone concentration in the lower troposphere of Hangzhou during the control period by using an ozone lidar. It was found that the ozone concentrations peaked near the top of the planetary boundary layer, and the temporary measures took no immediate effect on ozone pollution. Wu et al. (2019) investigated the variation of air pollution in Hangzhou and its surrounding areas during the G20 summit by using monitoring data from five sites, and reported that the air quality had been greatly improved by the implementation of the emission control. However, the average O3 concentration was increased by 19% compared to the same periods of the five preceding years. This unique response of ozone pollution to control measures is not well understood, and of great research interest for better control of ozone pollution in the future.

To this end, a regional air quality model, within the framework of the Model Inter-

Comparison Study for ASIA phase III (Li et al., 2019), is used to investigate the spatial-temporal characteristics of ozone pollution in Hangzhou during the G20 Summit in the present work. Process analysis is conducted to understand the chemical and physical factors that contribute to O3 abundance. It is found that the serious ozone pollution happened, mainly resultant from the local photochemical reactions which are not under good control by the emission reduction measures."

2. There was no analysis of whether or not the observations at 96 sites violated the ozone standard during the G20 meeting?

Reply: Following the reviewer's suggestion, the observations at 96 sites are analyzed. Fig. 3c shows that during the 14-day emission control period of G20 summit, 52% of the observed ozone samples from the 96 sites are above the China's national level-II standard (160μg/m3). This result confirms that regional ozone pollution appears in the YRD region during the study period. Relevant statement has been added into the revised manuscript (Line 309-312), and attached as below.

"This phenomenon is consistent with the satellite-derived tropospheric O3 distribution in the area (Su et al. 2017), and is also supported by the observed ozone data from the 96 sites in the YRD region as shown in Fig. 3c. During the 14-day emission control period of G20 summit, 52% of the observed ozone samples from the 96 sites are above the China's national level-II standard (160μg/m3), suggesting that regional ozone pollution appears in the YRD region during the study period."

3. The choice of Hangzhou as the analysis site is also not clear. Authors say that they selected the site based on evaluation but no evaluation metric was presented to justify their decision to focus on Hangzhou. Why not use all the observations from 96 sites in your analysis to get a regional picture?

Reply: We have added two paragraphs (lines 84-122 see reply to the first comment) in the introduction to indicate why Hangzhou is chosen as the focus. Basically, the main objective of the present study is to understand the unique response of ozone increase to emission control measures while other pollutants had been significantly reduced (Li et al. 2019; Wu et al. 2019; Ji et al. 2018; Zheng et al. 2019) during the 2016 G20 Summit which was held in Hangzhou. Observations from 96 sites are also analyzed to give a regional picture (Fig. 3c), together with the model results.

In addition to these major concerns, below are some other specific concerns that the authors might find useful in their revision.

1) Section 2:3: Can you be a little more specific about the IPR here? Did you save the tendency terms before and after the call to each process is made in the code? For example, did you save ozone concentrations before and after the call the chemistry solver and used the difference in the process analysis?

Reply: Yes, you are right. The IPR analysis is integrated into the WRF-Chem model and all the tendency terms are saved before and after the call to each process. The difference is then used for quantitative analysis of each process. For more details, please refer to the study of Jfffries and Tonnesen (Atmospheric Environment, 1994, 28(18): 2991-3003) and the user guide of WRF-Chem. Following the reviewer's suggestion, we have added relevant description on the IPR analysis in lines 174-183. The description is also attached as below.

"To understand the underlying mechanism of O3 formation, individual physical and chemical processes of O3 formation are investigated by using the integrated process rate (IPR) analysis in the WRF-Chem model (Jfffries and Tonnesen, 1994). The IPR analysis differentiates changes in pollutant concentrations from individual atmospheric process which quantitatively elucidates the contributions of each process, mainly including advection, diffusion, emission, deposition, clouds process, aerosol and gaseous chemistry. The IPR analysis has been widely applied and demonstrated to be an effective tool for investigating the relative importance of individual processes and interpreting O3 concentrations (Goncalves et al., 2009; Tang et al., 2017; Shu et al., 2016). In the present work, we consider gas chemistry, vertical diffusion, horizontal

and vertical advections as the main atmospheric processes for O3 formation. Other processes, such as cloud process and horizontal diffusion, play minor roles and are thus not considered."

2) Table S1: For some reason, the equations did not appear correctly in the Table. Please correct.

Reply: Revised as suggested.

3) Section 2.4: Are the observations from air quality monitoring network quality controlled or did you apply any quality control procedure to the measurements before using those for evaluation?

Reply: The quality of all the observations from air quality monitoring network has been controlled by the data provider.

4) Line 255: Change "supply raw material" to "transport ozone precursors"

Reply: Revised as suggested.

5) Figure 8 shows that horizontal advection contributes much larger to the ozone increase on most of the days but in the abstract the authors say "vertical diffusion and chemical production" are the main drivers. I did not understand how the authors concluded this in the abstract.

Reply: Sorry for the confusion. Although horizontal advection contributes much larger to the ozone increase on most of the days, the contribution of vertical advection is also larger. The effects of these two processes have been cancelled out during several circulations. As a result, photochemical production and vertical diffusion from the upper-air background ozone are the main drivers for the local ozone. To be clear, we have modified the relevant statements in the abstract and discussions.

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