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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. The authors mentioned emergency emission control measures. Were emissions perturbated to represent these measures? How did emission control measures contribute to the ozone episode?

Reply: Yes, emissions are perturbated to represent these measures. We have added two paragraphs (lines 84-122) to introduce the background of emergency emission control measures and the effects on pollutant emissions during the G20 summit. Previous studies have 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. It was found that the temporary measures took no immediate effect on ozone pollution (Su et al. 2017), or even the average O3 concentration was increased by 19% compared to the same periods of the five preceding years (Wu et al. 2019). 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, which motives the present work. To obtain the quantitative effect of emission control measures on the ozone episode, scenario simulations and sensitivity analysis are required, which is beyond the scope of the current work.

2. The authors claimed that this study revealed notable background O3 concentrations, but it is very confusing how this conclusion was drawn. How much does it contribute to O3 levels in the YRD?

Reply: Thank you for pointing out this issue. The background O3 means the O3 that vertically distributes within the planetary boundary layer. High ozone concentrations, temporarily during most day time of the emission control period and spatially from the surface to the top of the planetary boundary layer, are observed in Hangzhou and even the whole YRD region. This can be seen from Figs. 5, 7, and 8 in the revised manuscript. The background O3 essentially influences the surface O3 concentration through vertical diffusion. Its quantitative contribution to the surface O3 level in Hangzhou is different from day to day, as demonstrated in Figs 8 and 9.

3. It is not convincing that current categorization of process analysis can provide any useful information. Concluding photochemistry dominated O3 generation does not provide any indications for O3 pollution control. Which precursor or process are important? More in-depth analyses are needed.

Reply: 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. It 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, to understand the underlying mechanism of O3 formation, individual physical and chemical processes of O3 formation are investigated by using the IPR. The gas chemistry, vertical diffusion, horizontal and vertical advections are considered 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.

Through the IPR analysis, interesting horizontal and vertical advection circulations of O3 are observed during several short periods, and the effects of these processes are nearly cancelled out, as indicated in Figs. 8 and 9 in the revised manuscript. As a result, the ozone pollution is mainly attributed to the local photochemical reactions which are not obviously influenced by the emission reduction measures. In addition, the vertical diffusion from the upper-air background O3 also plays an important role in shaping the surface ozone concentration.

Following the reviewer's suggestion, the discussion section has been rewritten and some more in-depth discussions on the precursors of ozone formation have been added into the revised manuscript, as attached below.

"Chemical generation of O3 is the net effect of photochemical generation and titration consumption. VOC oxidation (Jenkin et al., 1997; Sillman, 1999) in photochemical reactions provides critical oxidants (i.e., RO2) that efficiently convert NO to NO2, resulting in further accumulation of O3 (Wang et al., 2017). The chemical generation of O3 is controlled by NOx and VOCs depending on which substance is lack in the reactions. As a consequence, there are two sensitivity regimes of O3 production, namely, the NOx-limited and VOC-limited regimes. Previous studies have shown that the sensitivity pattern of surface O3 formation in Hangzhou is dominant by the VOCs-limited regime (Yan et al. 2016; Li et al., 2017; Su et al., 2017). In this regime, if the regional reduction of VOCs is much higher than that of NOx, the O3 concentration can be re-

duced, otherwise if the regional reduction of VOCs is much less than that of NOx, the inhibitory effect of NOx on O3 generation will be weakened, and the O3 concentration will increase remarkably (Wang et al. 2015). According to the studies of Su et al. (2017), Zheng et al. (2019), and Wu et al. (2019), it can be deduced that NOx has been significantly reduced by about 60%, at least two times of the reduction of VOCs in Hangzhou. The influence of stringent emission control measures on VOCs is not as immediate and effect as that on NOx, which is associated with the fact that there was a large amount of biogenic VOC emission in Hangzhou and surrounding regions (Liu et al. 2018; Wu et al. 2020). In fact, the average temperature during the study period is as high as around 31°C (Fig. 4c), which facilitates the biogenic VOC emissions and photochemical reactions. As a result, the photochemical generation of O3 was not under control and high concentration of ozone appeared. However, it is worth noting that after the emergent VOCs control measures had been implemented in the area during the third stage, the net generation rate of O3 gradually reduces since September 2, 2016, leading to a period of relatively low ozone concentration together with other meteorological effects. These discussions implicate that to alleviate ozone pollution, the ratio of reduction of VOCs to that of NOx is the key parameter based on the O3-NOx-VOCs sensitivity analysis. As the biogenic VOCs are important sources of the total VOCs in the YRD region, it is necessary to balance the reduction of NOx to make the ratio within effective regime in the future."

Minor comments:

1) Fig. 1a does not show domain 1.

Reply: Domain 1 has been marked in Fig. 1a.

2) Line 119: it is confusing if assimilation of meteorological variables were used or not, and how?

Reply: Assimilation of meteorological variables are not used in this study. To avoid confusion, "assimilated" has been corrected as "mapped" in Line 145.

3) Line 143: In June, July, and August, biomass burning emissions are important in east China, why do you ignore it?

Reply: Biomass burning emissions have already been included in the emission inventory we used (2016 Multiresolution Emission Inventory for China (MEIC, $0.25^\circ \times 0.25^\circ$; http://www.meicmodel.org/)). Thus, their effect has been considered.

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