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Relative impact of short-term emissions controls on gas and particle-phase oxidative potential during the 2015 China Victory Day Parade in Beijing, China

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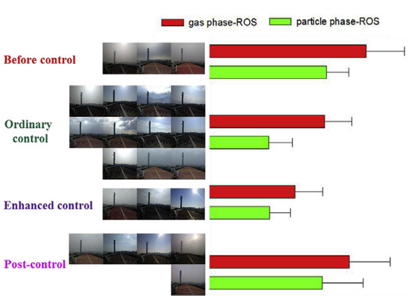
GRAPHICAL ABSTRACT



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ABSTRACT

A field observation focusing on reactive oxygen species (ROS) was conducted before, during, and after the 2015 China Victory Day Parade to understand the influence of short-term emissions controls on atmospheric oxidative activity. The hourly average concentrations of $PM_{2.5}$, SO_2, NO, NO_2, CO, O_3, as well as gas and particle-phase ROS, were measured using a series of online instruments. $PM_{2.5}$ concentrations during control days were significantly lower than non-control days, which directly lead to the “Parade Blue”, yet reductions of most gaseous pollutants except SO_2 were not so obvious as PM. Similarly, the control measures also led to a great loss of particle-phase ROS throughout the control period, while the reduction of ROS in gas phase was not obvious until the more stringent measures implemented since September 1. Furthermore, only weak positive correlations were observed among ROS and some other measured species, indicating ROS concentrations were affected by a number of comprehensive factors that single marker could not capture. Meanwhile, meteorological condition and regional transportation were also shown to be the minor factors affecting atmospheric oxidizing capacity. The results of this observation mainly revealed the control measures were conducive to reducing particle-related ROS. However, the reduction of gas-phase ROS activity was less effective given the menu of controls employed for the 2015 China Victory Day Parade. Therefore, short-term emissions controls only aimed to PM reduction and

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visibility improvement will produce the blue sky but will not equivalently reduce the gas-phase ROS. Supplemental control measures will be needed to further reduce gas-phase ROS concentrations.

1. Introduction

Air quality issue has become a very big concern in megacities of China following the rapid economic growth and urbanization nationwide (Chan and Yao, 2008; Fang et al., 2009; Zhao, 2012). In consideration of the adverse effects on eco-environment and human health attributed to air pollution (Ayres et al., 2008; Gauderman et al., 2007; Peters et al., 2006; Pope et al., 2004; Schwartz et al., 2002), a series of air quality control measures were implemented during the 11th and 12th Five Year Plan (2006–2010 and 2011–2015), including afforestation, traffic restriction, and energy upgrading for motor vehicles (eg: upgrading the quality of gasoline product and application of new energy vehicles) (Wang and Hao, 2012; Zhang et al., 2016). In addition to these long-term measures, short-term policies with more stringent measures were also conducted to ensure the air quality during some specific periods, such as the 2008 Beijing Olympic Games (Guo et al., 2012; Huang et al., 2010), 2010 Shanghai World Expo (Huang et al., 2012, 2013), 2010 Guangzhou Asian Games (Ting-Yuan et al., 2012; Yao et al., 2013), and 2014 Asia-Pacific Economic Cooperation (APEC) conference (Huang et al., 2015; Wang and Dai, 2016).

Using the successful experiences of previous policies as the references, Beijing government and China's Ministry of Environmental Protection enacted similar air pollution mitigation measures to improve air quality during the 2015 China Victory Day Parade. These measures were implemented between August 20 and September 3, including the odd-and-even license plate rule for vehicle use, polluting industry restriction, construction sites shutdown, delay of school opening, vacation days off for the public, and more frequent road sprinkling (BMPC, 2015). The efficiency of the control measures has been demonstrated by “Parade Blue” and the results of some field observations (Wang et al., 2017; Xu et al., 2017). Gui et al. (2016) investigated aerosol optical properties in Beijing from August 6 to September 17 using a series of ground-based monitors, revealing significant reductions in aerosol optical depth (AOD) and $PM_{2.5}$ mass concentration. Han et al. (2016) and Shen et al. (2016) observed similar results about PM concentrations, as well as some other pollution parameters like particle number concentration and water-soluble ions.

Generally, most of the short-term control measures were aimed to PM and visibility which were directly associated with “blue sky”, and the related literature also mainly focused on the reductions of $PM_{2.5}$ and its chemical compositions (Han et al., 2016; Yang et al., 2016). Therefore, the excellent efficiencies of such short-term policies were always obtained in the form of PM reduction and visibility improvement. However, considering the lack of monitoring parameters which can reflect the health impact related to air quality, it cannot be concluded that the adverse health risks exerted by air pollutants were largely reduced. Since oxidative stress in the lung caused by reactive oxygen species (ROS) is believed to be a major contributor to air pollutant-related adverse health effects (Fischer and Maier, 2015; Gupta et al., 2014; Li et al., 2003; Seifried et al., 2007), ROS can be regarded as an important indicator to evaluate the health risks of air pollution. For this reason, ROS, whether directly inhaled from ambient air (exogenous ROS) or formed within cells when stimulated by introduced air pollutants (endogenous ROS), has gradually gained more and more attention among atmospheric researchers (Chen et al., 2011; Chung et al., 2006; Lin and Yu, 2011; Verma et al., 2012; Zhang et al., 2008).

Atmospheric ROS, a series of oxygen-containing species with strong oxidizing abilities containing hydroxyl radical ($HO^{\cdot}$), superoxide anion ($O_2^{\cdot-}$), and hydrogen peroxide (H_2O_2) (Halliwell and Cross, 1994), can be formed in gas and particle phases. The traditional methods for ROS measurement, including dithiothreitol (DTT) assay (Lin and Yu, 2011; Verma et al., 2012), 2′,7′-dichlorofluorescin (DCFH) assay (See et al., 2007; Venkatachari et al., 2005), and respiratory tract lining fluid (RTLF) assay (Mudway et al., 2005), were usually performed after the longtime sampling and pretreatment, which may lead to an underestimation of true ROS concentration due to the great loss of short-life species. To avoid the artifacts associated with these offline methods, a few ROS online systems were developed recently based on DCFH assay (Fuller et al., 2014; Huang et al., 2016b; King and Weber, 2013; Venkatachari and Hopke, 2008; Wang et al., 2011). Among these online instruments, the GAC-ROS which refers to a ROS analysis system equipped with a GAC (gas and aerosol collector) sampler was the first to realize the simultaneous measurement of gas and particle-phase ROS (Huang et al., 2016b), while others can only analyze ROS related with particulate matter (PM).

In this study, a field observation was conducted during the 2015 China Victory Day Parade to characterize the concentration of atmospheric ROS using GAC-ROS and investigate the effects of short-term control measures on atmospheric oxidative activity. Meanwhile, PM and some gaseous pollutants were observed to reveal the influential factors of ROS concentration. This study was the first time to simultaneously obtain the concentrations of both gas and particle-phase ROS during the field observation associated with short-term air quality control measures, which will give applicable suggestions for future short-term policies.

2. Experimental methods

2.1. Study design

Field observation was conducted from August 16 through September 10, 2015 at the Institute of Remote Sensing and Digital Earth

Table 1
Control measures implemented in different phases. “✓” means the control measure was implemented in this period.

		Phase I	Phase II	Phase III	Phase IV
long-term routine measures		✓	✓	✓	✓
short-term routine measures	odd-and-even license plate rule for vehicle use		✓	✓	
	polluting industry restriction		✓	✓	
	construction sites shutdown		✓	✓	
	delay of school opening		✓	✓	
	vacation days off			✓	
	more frequent road sprinkling		✓	✓	
	road traffic control around Tiananmen Square			✓	
	museum and tourist attraction closedowns			✓	
	enhanced measures in surrounding cities			✓	