Diverse response of surface ozone to COVID-19 lockdown in China

Yiming Liu\textsuperscript{1,2}, Tao Wang\textsuperscript{2}, Trissevgeni Stavrakou\textsuperscript{3}, Nellie Elguindi\textsuperscript{4}, Thierno Doumbia\textsuperscript{4}, Claire Granier\textsuperscript{4,5}, Idir Bouarar\textsuperscript{6}, Benjamin Gaubert\textsuperscript{7}, and Guy P. Brasseur\textsuperscript{2,6,7}

\textsuperscript{1}School of Atmospheric Sciences, Sun Yat-Sen University, Zhuhai, China
\textsuperscript{2}Department of Civil and Environmental Engineering, The Hong Kong Polytechnic University, Hong Kong, China
\textsuperscript{3}Royal Belgian Institute for Space Aeronomy, Brussels, Belgium
\textsuperscript{4}Laboratoire d’Aérologie, Toulouse, France
\textsuperscript{5}NOAA Chemical Sciences Laboratory and CIRES/University of Colorado, Boulder, CO, USA
\textsuperscript{6}Environmental Modeling Group, Max Planck Institute for Meteorology, Hamburg, Germany
\textsuperscript{7}Atmospheric Chemistry Observations and Modeling Laboratory, National Center for Atmospheric Research, Boulder, CO, USA

Ozone (O\textsubscript{3}) is a key oxidant and pollutant in the lower atmosphere. Significant increases in surface O\textsubscript{3} have been reported in many cities during the COVID-19 lockdown. Here we conduct comprehensive observation and modeling analyses of surface O\textsubscript{3} across China for periods before and during the lockdown. We find that daytime O\textsubscript{3} decreased in the subtropical south, in contrast to increases in most other regions. Meteorological changes and emission reductions both contributed to the O\textsubscript{3} changes, with a larger impact from the former especially in central China. The southward-shifted wind with increased temperature, enhanced planetary boundary layer height, decreased cloud fraction and precipitation favored the O\textsubscript{3} increase in north and central China, while the northward-shifted wind with decreased temperature and then biogenic volatile organic compounds (VOCs) emissions, increased cloud fraction and precipitation reduced O\textsubscript{3} in south China. As for the emission reduction, the drop in nitrogen oxide (NO\textsubscript{x}) emission contributed to O\textsubscript{3} increases in populated regions, whereas the reduction in VOCs contributed to O\textsubscript{3} decreases across the country. Due to a decreasing level of NO\textsubscript{x} saturation from north to south, the emission reduction in NO\textsubscript{x} (46\%) and VOC (32\%) contributed to net O\textsubscript{3} increases in north China; the opposite effects of NO\textsubscript{x} decrease (49\%) and VOC decrease (24\%) balanced out in central China, whereas the comparable decreases (45-55\%) in the two precursors contributed to net O\textsubscript{3} declines in south China. Our study highlights the complex dependence of O\textsubscript{3} on its precursors and the importance of meteorology in the short-term O\textsubscript{3} variability.