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What are drivers of the tropospheric ozone reduction during spring 2020?

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We use the global Community Earth System Model to investigate the response of secondary pollutants (ozone O_3, secondary organic aerosols SOA) in different parts of the world in response to modified emissions of primary pollutants during the COVID□19 pandemic. We quantify the respective effects of the reductions in anthropogenic emissions and meteorological anomalies, including a discussion on long-term changes from the chemical climatology. We show that the level of NOx has been reduced by typically 40 % in China during February 2020 and by similar amounts in many areas of Europe and North America in mid-March to mid-April 2020. Relative to a situation in which the emission reductions are ignored and despite the calculated increase in hydroxyl and peroxy radicals, the ozone concentration increased only in a few NOx□saturated regions during the winter months of the pandemic when the titration of this molecule by NOx was reduced. In other regions, where ozone is NOx□controlled, the concentration of ozone decreased. Zonally averaged ozone concentrations in the free troposphere during Northern Hemisphere spring and summer were 5 to 15 % lower than 19-year climatological values, in good quantitative agreement with observations from ozonesondes and ground-based remote sensing from the Network for the Detection of Atmospheric Composition Change (NDACC). About one third of this anomaly is attributed to the drastic reduction in air traffic during the pandemic, another third to reductions in surface emissions, the remainder to 2020 meteorological conditions, including the exceptional springtime Arctic stratospheric ozone depletion. The overall COVID-19 reduction in mean northern hemisphere tropospheric ozone in June is less than 5 ppb below 400 hPa, but reaches 8 ppb at 250 hPa.