A comparison of ambient measurements of NO\textsubscript{2}, CO, PM\textsubscript{2.5}, and O\textsubscript{3} during the COVID-19 pandemic with a climatological multiple linear regression model for various U.S. cities

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1. Introduction

- U.S. air quality monitoring network data are used to
- inform the public of the extent and magnitude of pollution
- evaluate the effectiveness of emission controls
- constrain air quality models
- During the COVID-19 pandemic, state and local governments implemented lockdowns to reduce the spread of the disease, resulting in reduced traffic and on-road emissions beginning in Spring 2020
- We use measurements of NO\textsubscript{2}, CO, PM\textsubscript{2.5}, and O\textsubscript{3} and a multiple linear regression model to predict pollution levels, controlled for meteorology, in 9 U.S. cities and compare the model to observations to determine how emissions and atmospheric chemistry may have changed during the pandemic.

2. Data

- Air quality monitoring data for CO, NO\textsubscript{2}, O\textsubscript{3}, and PM\textsubscript{2.5} were downloaded from the Environmental Protection Agency’s Air Quality System (https://www.epa.gov/airnow)
- when possible, the Core Based Statistical Area (CBSA) dataset is used, which includes multiple measurement sites
- Meteorological data were downloaded from NOAA’s National Center for Environmental Information’s Integrated Surface Data (ISD) for the nearest large airport (https://www.nci.noaa.gov/pub/data/noaa/isd-led)
- The Stringency Index (SI) is used as a metric to determine the severity of the lockdowns (Hale et al., 2021)

3. Multiple Linear Regression (MLR) model

We use a multiple linear regression (MLR) model (similar to de Foy & Schauer, 2019) to account for decadal trends and meteorological factors:

\[ x_i = c_0 + c_1 y + c_2 T + c_3 P + c_4 W + c_5 H + c_6 WE + e_i \]

where \( x_i \) is a fit of daily max. 8-hr O\textsubscript{3} (PMDAB) or daily avg. CO, NO\textsubscript{2} or ln(PM\textsubscript{2.5}) for each month, \( i \) from 2010-2019

\( y \) is the year

\( T \) is the daily avg. temperature

\( P \) is the daily avg. precipitation

\( W \) is the daily avg. wind speed

\( H \) is the daily avg. relative humidity

\( e_i \) is the residual

Example: Denver carbon monoxide

4. Comparison of measurements with modeled predictions in the absence of COVID for 2020

Observed and predicted NO\textsubscript{2} and O\textsubscript{3} are plotted for 9 U.S. cities, as are state-level stringency indices, the FIVE inventory ratio of 2020 vs. 2019 for NO\textsubscript{x} (see panel 6 for details), and a ratio of the 2020 observed to predicted concentration.

A two-sided t-test was run each week. Using a 10% confidence interval, observations significantly lower than the predictions are plotted in blue, significantly higher in red.

5. Model Results

Lockdown effects for all cities from March 29 – April 11:
- most cities experienced a decrease in NO\textsubscript{2} and CO
- many had decreases in PM\textsubscript{2.5}; all cities had lower O\textsubscript{3}
- avg. changes: NO\textsubscript{2} –18%, CO –13%, PM\textsubscript{2.5} –7%, O\textsubscript{3} –8%

6. Comparison of Modeled Effects with Inventory

Consistent with North American results from Gkatzelis et al. (2021), who analyzed 150 published studies of 6 continents:

Comparison of observed/model-predicted ratios with ratios for 2020/2019 of a fuel-based primary emissions inventory, FIVE (Harkins et al., 2021), for March 29 – April 11. A CO background has been subtracted from the observed and predicted values for a comparison with emissions. Markers for cities with only one monitoring location are outlined in gray.

7. Conclusions and Future Work

- A multiple linear regression model that accounts for meteorology is used to determine daily lockdown effects for all cities
- Results are consistent with studies summarized by Gkatzelis et al. (2021) and mostly consistent with a fuel-based inventory (FIVE)
- Emissions reductions generally led to decreases in O\textsubscript{3} and PM\textsubscript{2.5}. While the reasons for such decreases are not definitive, our model could help guide where the application of a more sophisticated chemistry model that relates NO\textsubscript{x} and VOC reductions to O\textsubscript{3} and PM\textsubscript{2.5} formation may be of value to air quality managers.

References

De Foy, B. and Schauer, J. (2019), Changes in spatially resolved PM\textsubscript{2.5} concentrations in Fresno, California, due to NO\textsubscript{x} reductions and variations in diurnal emission profiles by day of week, Elements, doi:10.1038/s41978-019-00554-4


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