Machine learning application to quantify the impact of the 2020 COVID-19 lockdown on urban air quality in Leipzig, Germany

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Drastic measures to combat the COVID-19 pandemic have led to strongly reduced anthropogenic activities during the spring 2020 lockdown in Germany, especially in the traffic sector. A corresponding decrease of air pollutants could, however, not always be directly observed from measurements at urban monitoring stations, because of changing weather patterns and the strong impact meteorological variables like wind speed, wind direction, or mixing layer height can have on the local enrichment or dispersion of urban emissions. One of the most advanced approaches to account for such impacts in a quantitative way is training algorithms to learn complex influences and interactions between air pollutant concentrations and meteorological variables and then apply such a machine learning model to predict business-as-usual concentrations during the COVID-19 lockdown. A few studies, mainly for NO_2 and O_3 (e.g. Grange et al., 2021; Petetin et al., 2020) indicated that such predictions have sufficient accuracy to yield reasonable estimates of air quality changes due to the lockdown intervention.

Here, we apply tree-based boosting models (xgboost) to predict business-as-usual concentrations for air pollutants including NO_x, O_3, eBC, and PM_{10} in the city of Leipzig, Germany, during the lockdown from 16 March – 17 May 2020. Air quality data from traffic and urban background sites were provided by the Saxonian environmental agency LfULG and complemented by our own measurements. The models were trained with 4 years (2016-2019) of hourly data, including the respective pollutant concentrations, meteorological measurements, time variables like hour of day as a proxy for traffic densities and day of year as a proxy for seasonal effects, as well as back-trajectory data related to larger-scale inflow sectors and residence times above different land covers. Model predictions for the weeks before the lockdown in 2020 were used as benchmark for model quality and mean differences between model predictions and actual observed values were calculated to derive quantitative estimates of air quality changes during the lockdown.

The results for NO_x and eBC at two traffic-impacted sites are shown in Figure 1. From the observational data alone, a clear impact of the lockdown on air pollutant concentrations could not be discerned. In fact, both measured NO_x and eBC concentrations seemed to have slightly increased with the beginning of the lockdown period, which is likely related to different background concentrations caused by a change in synoptic conditions from windy and precipitation-intensive western advection to dry and calm continental eastern air mass inflow with the beginning of the lockdown.

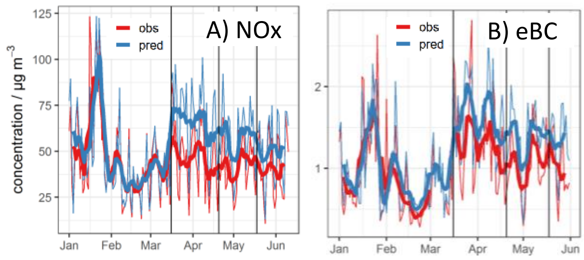

Figure 1: Observed (red) and predicted business-as-usual (blue) concentrations for A) NOx and B) eBC at two traffic sites. Vertical black lines show two phases of the lockdown with more strict measures in the first period.

Only when the predicted business-as-usual concentrations are compared with the observed concentrations, a reduction of 20 $\mu g\ m^{-3}$ for NO_x and 0.3 $\mu g\ m^{-3}$ for eBC during the first 5 weeks of the lockdown can be derived. These correspond relative decreases of 30% and 20% for NO_x and eBC, respectively, at the two sites, which is in line with counted reductions of traffic densities in the city.

Impacts for PM_{10} at the traffic site and NO_x, O_3, and eBC at the urban background sites were much smaller and also depended on the location of the site with respect to the main wind direction. Downwind of the urban plume small concentration differences were seen, while upwind the effects were negligible.

Overall, our results are broadly consistent with previous studies from other European cities, emphasizing the importance of correctly accounting for meteorological conditions in quantitative intervention studies and demonstrating the potential of machine learning model to do so, even so many of the details in such implementations will still need to be further assessed for robust routine applications in the future.

References

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