**Title**

Decoupling of urban $CO_2$ and air pollutant emission reductions during the European SARS-CoV2 lockdown

**Authors**

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**Supplementary Information:**

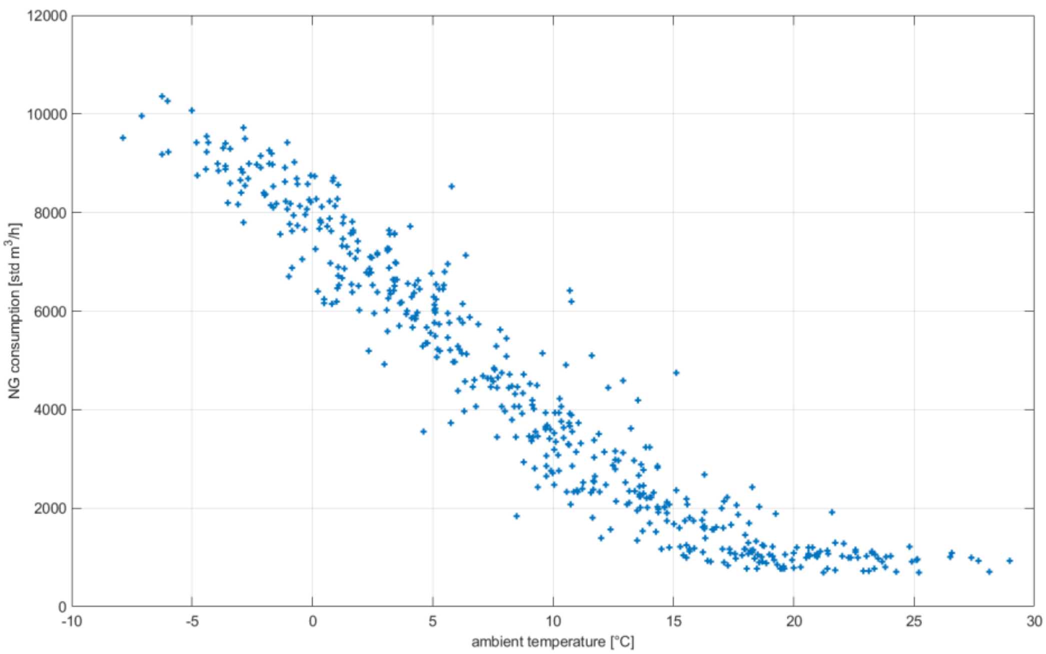


**Fig. S1:** Degree heating days vs natural gas consumption from 01/01/2019 to 01/05/2020 (data source: TIGAS, Tirol, www.tigas.at)

## Eddy covariance analysis

For stationary conditions and neglecting horizontal advection the surface atmosphere flux is defined as.

$$F = \langle w'c' \rangle \qquad \text{(Seq. 1)}$$

where w' represents the vertical fluctuation of wind speed, and c' the concentration fluctuation. Brackets denote the averaging interval. The ensemble average used here is 30 minutes. Eddy covariance fluxes were calculated as the covariance between the rotated vertical wind speed and the tracer mole fraction. All flux data were analysed with the innFLUX eddy covariance code and proceedures described within the work of Striednig et al., (2020).

**Boosted regression tree model:**

Three methods are used to validate the regression model. The first approach (method 1: pre-lockdown) is based on long-term measurements of $NO_2$/NO, $NO_x$, $CO_2$ and traffic data, where the model is trained up to Feb. 29$^{th}$ 2020, and the prediction is then tested for the first two weeks in March 2020 before SARS-CoV2 lockdown measures were implemented. The second approach (method 2: bootstrapping) includes all chemical species. Here, the regression model is trained with 2019 data, when an air quality campaign was conducted during a similar timeframe (March-April 2019) as the SARS-CoV2 lock-down period in 2020. The regression model is then tested using bootstrapping based on 1000 randomized samples. The third approach (method 3: cross validation) is a variation where the model is trained on a subset of the 2019 period (March-April 2019), and tested against data that were not used to train the model. Table S1 summarizes respective model verification and initiation dates. Table S2 captures statistical parameters of the model output verification. Importance values of individual predictors of the regression model for key chemical species are shown in Fig. S3. The most important predictors are wind direction, time of day, radiation and temperature.

**Table S1:** Regression model setup

| **Species** | **Model training** | **Model verification** | **Model run initiated** |
|---|---|---|---|
| $NO_x$, $CO_2$ | 1.9.2018 – 29.2.2020 | 1.3.2020-13.3.2020 | 13/3/2020 |
| $NO_x$, $CO_2$ | 11.3.2019 – 9.4.2019 | 11.3.2019 – 9.4.2019 | 13/3/2020 |
| NMVOC | 11.3.2019 – 9.4.2019 | 11.3.2019 – 9.4.2019 | 13/3/2020 |
| Traffic | 1.9.2018 – 29.2.2020 | 1.3.2020-13.3.2020 | 13/3/2020 |

**Uncertainty Analysis:**

**Regression model:**

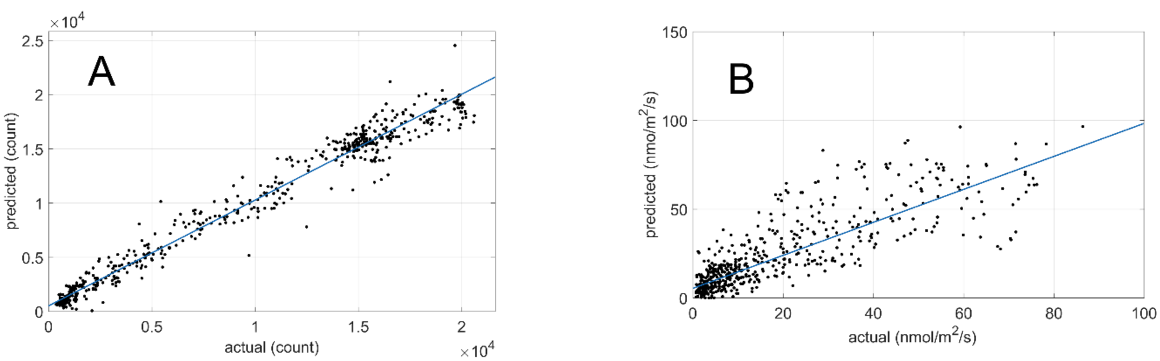


**Fig. S2:** (A) Regression model prediction for traffic during pre-lockdown (method 1). (B) Regression model prediction for $NO_x$ during pre-lockdown. The regression slopes are represented by the blue lines and are used to calculate the average bias of the fit (see Table S2)

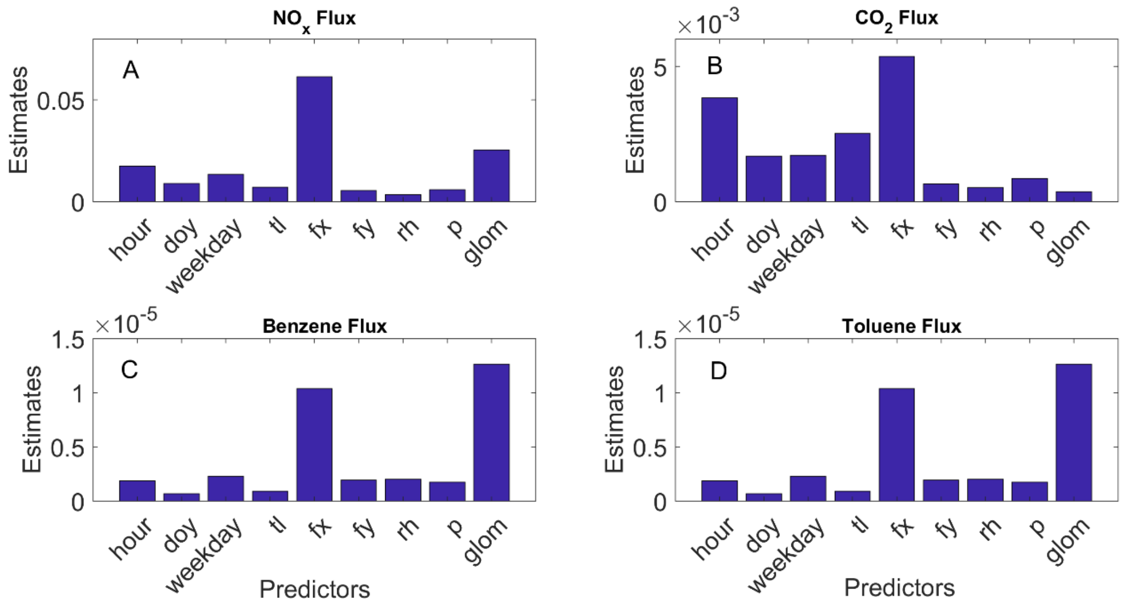


**Fig. S3:** Importance of individual predictors from the boosted regression tree model. (A) $NO_x$ flux, (B) $CO_2$ flux, (C) benzene flux, and (D) toluene flux. Predictors are hour of the day (hour), day of year (doy), day of the week (weekday), ambient temperature (tl), longitudinal wind speed (fx), latitudinal windspeed (fy), relative humidity (rh), pressure (p), and global radiation (glom).

**Table S2:** Statistical results (bias, standard error and $R^2$) of the model verification methods for individual quantities.

| Species | Bias | SE | R2 | Verification method |
|---|---|---|---|---|
| NOx | -7% | 0.04 | 0.80 | Pre-lockdown |
| CO2 | -25% | 0.05 | 0.62 | Pre-lockdown |
| traffic | -2% | 0.01 | 0.97 | Pre-lockdown |
| NOx | -2% | 0.03 | 0.79 | Bootstrapping |
| CO2 | -1% | 0.03 | 0.75 | Bootstrapping |
| traffic | -1% | 0.001 | 0.97 | Bootstrapping |
| NOx | -6% | 0.02 | 0.93 | Cross-validation |
| CO2 | -6% | 0.01 | 0.86 | Cross-validation |
| traffic | -1% | 0.004 | 0.99 | Cross-validation |
| Benzene | -1% | 0.01 | 0.86 | Bootstrapping |
| Toluene | -1% | 0.01 | 0.83 | Bootstrapping |
| Benzene | -13% | 0.03 | 0.87 | Cross-validation |
| Toluene | -21% | 0.02 | 0.92 | Cross-validation |

**Instrumental uncertainty:** Errors arising from analytical uncertainty mainly stem from calibration proceedures. For NMVOC these are estimated as 10% for aromatic NMVOC compounds based on a calibration standard (Apel & Riemer, USA), similarly the uncertainty of $NO_x$ is 2%, and for $CO_2$ 5%, respectively.

**Two end member pollutant model – uncertainty estimation:**

Errors for coefficients $a_s$ and $b_s$ (eq 6.) can be calculated based on error propagation, where by definition $\Delta a_s = \Delta b_s$. Lets define $b_s := b$, $\frac{\delta T}{T} := t$, $\frac{\delta R}{R} \coloneqq r$, and $\frac{\delta F}{F} := f$, then

$\Delta b = \frac{\partial b}{\partial f}\Delta f + \frac{\partial b}{\partial t}\Delta t + \frac{\partial b}{\partial r}\Delta r$, and $b = \frac{f-t}{r-t}$ (Seq. 2a, b)

Uncertainties of relative flux, traffic and RCP activity variations are taken as $\Delta f = 7\%$, $\Delta t = 2\%$, and $\Delta r = 50\%$. This leads to a combined uncertainty of $\Delta a = \Delta b = 0.11$. $\Delta f$ represents the average bias obtained from the boosted tree regression model verification analysis. $\Delta t$ is based on counting statistics of traffic observations. $\Delta r$ is the least certain and estimated based on the constraints estimated for the RCP sector.

**Supplementary References:**

Striednig, M., Graus, M., Märk, T., & T.Karl, InnFLUX – an open-source code for conventional and disjunct eddy covariance analysis of trace gas measurements: an urban test case, *Atmos. Meas. Tech.*, **13**, 1447–1465, (2020)