# Supplementary Materials: Black carbon along a highway and in a residential neighborhood during rush hour traffic in cold climate"

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**Text S1. Correlation between BC and external conditions**

The Pearson correlation coefficient between BC and reference weather, traffic and ambient air quality data is presented for the stationary and walking highway campaigns in **Tables S1 and S2**, respectively. Traffic volume, the atmospheric lapse rate (dT/dz) and wind speed were the three most important drivers of hourly BC variability at the stationary site, seen by the high correlation coefficient and a high statistical significance ($p<0.001$, **Table S1**). BC was, however, most strongly correlated to $NO_2$ measured at the same site, suggesting roadside $NO_2$ can be used as an indicator for roadside BC. The correlation analyses also demonstrate that many of the reference data were intercorrelated. For example, air temperature correlated at a statistically significant level to all reference parameters except snowfall. While some of the relationships are physical (e.g. higher humidity during warm weather), others may be coincidental (e.g. high traffic midday when solar heating is highest). The two ambient air quality parameters monitored at the HRI site, $NO_2$ and $PM_{10}$, were also intercorrelated ($r = 0.35$, $p<0.001$).

The mobile campaigns were all conducted during rush hour targeting dry days with high traffic related pollution. Traffic was not identified as a strong indicator during rush hour. Instead, the atmospheric stability was the key predictor for high BC concentration (high dT/dz, **Table S2**), followed by low wind speed. As expected with a shorter dataset of 20 observations, the level of significance of the linear relationships was lower.

**Text S2. Regression slopes and intercepts**

The linear regression coefficients, the intercept and slope, are presented in **Table S3** for traffic volume and publicly available ambient air quality parameters monitored real time by local authorities. First notice that both the intercepts and slopes were consistent throughout the three-week monitoring period. Secondly, the 95% confidence interval (CI) of the intercept was centered around zero both for traffic volume and $NO_2$, suggesting it could be set to zero. This allows for an easier interpretation of results, providing a direct ratio of BC concentration with traffic or ambient air pollution. Therefore, for simplicity, the final presentation of **Table 3** and **Figure 6a** in main text portrayed the linear regression lines forced through zero. The apparent correlation between BC and PM is predominantly because it is intercorrelated with $NO_2$ (**Table S1**), as it did not improve the predictive power of the linear regression model (model 1: $BC = \alpha_0 + \alpha_0 NO_2 + \alpha_0 PM_{10}$; **Table S5**).

Median BC from the start to end of each mobile campaign was significantly correlated with $NO_2$. The intercepts were centered around zero during the walk highway and walk residential campaigns (**Table S4**), consistent with the stationary campaign (**Table S3**). However, the intercept during the drive highway campaign had a positive value. Median BC during was not significantly correlated to $PM_{10}$ and $PM_{2.5}$ when considering the entire dataset. When separating winter and spring campaigns walking along highway, more statistically significant relationships emerged ($p \sim 0.08$) with intercepts centered around zero (**Table S4**). This is interpreted as there are significant sources of non-combustion related particles (such as local road dust or long-range transported dust), particularly in spring. Therefore, these seasonal relationships (winter and spring) are highlighted in **Figure 6b,c** in the main text.

Lastly, incorporating weather conditions, such as the near surface atmospheric lapse rate and wind speed, improved the predictive power of the linear regression model (model 2, **Table S5**), confirming that they are both important factors in moderating traffic related BC as hinted by the mobile campaigns (**Table S2**). Adding precipitation, however, did not improve the model, suggesting it has limited effect on BC concentration.

**Table S1.** Pearson correlation coefficients (r) between hourly BC monitored at stationary HRI site, weather conditions monitored at KEF and IMO sites, and ambient air quality monitored at HRI site, unless otherwise noticed. The number of observations were 563.

| | **BC** (µg/m³) | **dT/dz** (°C/m) | **$T_{air}$** (°C) | **WS** (m/s) | **WD** (°) | **RH** (%) | **Rad** (W/m²) | **Prec.** (mm/h) | **Rain** (mm/h) | **Snow** (mm/h) | **Traffic** (1000 veh/hr) | **$NO_2$** (µg/m³) | **$PM_{10}$** (µg/m³) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **BC** | 1 | | | | | | | | | | | | |
| **dT/dz** | 0.17*** | 1 | | | | | | | | | | | |
| **$T_{air}$** | -0.09* | -0.62*** | 1 | | | | | | | | | | |
| **WS** | -0.36*** | -0.34*** | 0.36*** | 1 | | | | | | | | | |
| **WD** | 0.04 | -0.12** | 0.24*** | 0.08 | 1 | | | | | | | | |
| **RH** | 0.04 | -0.23*** | 0.25*** | 0.01 | 0.11** | 1 | | | | | | | |
| **Rad** | 0.11* | -0.10* | 0.20*** | 0.00 | 0.06 | -0.23*** | 1 | | | | | | |
| **P** | -0.10* | -0.13** | 0.12** | 0.53*** | -0.04 | 0.24*** | -0.07 | 1 | | | | | |
| **Rain** | -0.13** | -0.13** | 0.16*** | 0.57*** | -0.02 | 0.18*** | -0.06 | 0.92*** | 1 | | | | |
| **Snow** | 0.04 | -0.04 | -0.07 | -0.01 | -0.07 | 0.18*** | -0.04 | 0.35*** | -0.04 | 1 | | | |
| **Traffic** | 0.55*** | -0.11* | 0.12** | -0.03 | 0.14*** | -0.08 | 0.36*** | 0.00 | -0.03 | 0.06 | 1 | | |
| **$NO_2$** | 0.84*** | 0.34*** | -0.31*** | -0.49*** | -0.10* | 0.02 | 0.10* | -0.12** | -0.15*** | 0.04 | 0.47*** | 1 | |
| **$PM_{10}$** | 0.40*** | 0.04 | 0.19*** | -0.12** | 0.03 | -0.22*** | 0.14** | -0.16*** | -0.15*** | -0.05 | 0.24*** | 0.35*** | 1 |
| **$PM_{2.5}$**(1) | 0.15** | 0.03 | -0.08 | -0.01 | -0.04 | -0.28*** | 0.15*** | -0.10* | -0.09* | -0.05 | 0.13** | 0.14** | 0.44*** |

Notes: Statistical significance is given as * p<0.05 ** p<0.01 *** p<0.001.
(1) Air quality monitored at stationary GRE urban traffic site, 3.7 km southeast of HRI site.

**Table S2.** Pearson Correlation coefficients (r) between median BC monitored during the twenty Walk Highway (WH) mobile campaigns, weather conditions monitored at KEF and IMO sites, and ambient air quality at the GRE urban traffic site.

| | **BC** (µg/m³) | **dT/dz** (°C/m) | **$T_{air}$** (°C) | **WS** (m/s) | **WD** (°) | **RH** (%) | **Rad** (W/m²) | **Time**(1) (1/2) | **Traffic** (1000 veh/hr) | **$NO_2$** (µg/m³) | **$PM_{10}$** (µg/m³) | **$SO_2$** (µg/m³) | **$H_2S$** (µg/m³) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **BC** | 1 | | | | | | | | | | | | |
| **dT/dz** | 0.80*** | 1 | | | | | | | | | | | |
| **$T_{air}$** | -0.40 | -0.60** | 1 | | | | | | | | | | |
| **WS** | -0.67** | -0.46 | 0.40 | 1 | | | | | | | | | |
| **WD** | -0.05 | -0.22 | 0.32 | -0.12 | 1 | | | | | | | | |
| **RH** | 0.40 | 0.40 | -0.27 | -0.31 | 0.16 | 1 | | | | | | | |
| **Rad** | -0.46* | -0.49* | 0.66** | 0.36 | 0.19 | -0.67** | 1.00 | | | | | | |
| **Time**(1) | 0.13 | -0.10 | 0.24 | 0.14 | 0.14 | -0.37 | 0.51* | 1 | | | | | |
| **Traffic** | 0.09 | -0.10 | 0.39 | 0.08 | 0.23 | -0.41 | 0.62** | 0.87 | 1 | | | | |
| **$NO_2$** | 0.96*** | 0.79*** | -0.50* | -0.72*** | 0.05 | 0.41 | -0.51* | 0.05*** | -0.01 | 1 | | | |
| **$PM_{10}$** | -0.02 | -0.38 | 0.22 | -0.18 | 0.18 | -0.31 | 0.25 | 0.01 | 0.19 | 0.04 | 1 | | |
| **$SO_2$** | 0.94*** | 0.79*** | -0.31 | -0.63** | 0.04 | 0.33 | -0.42 | 0.09 | 0.04 | 0.94*** | -0.01 | 1 | |
| **$H_2S$** | 0.57** | 0.55* | -0.45* | -0.32 | 0.04 | 0.26 | -0.42 | 0.04 | -0.08 | 0.58** | -0.28 | 0.58** | 1 |
| **$PM_{2.5}$** | 0.03 | -0.47 | 0.31 | -0.14 | 0.05 | -0.41 | 0.35 | 0.02 | 0.25 | 0.08 | 0.90*** | 0.01 | -0.41 |

Notes: Statistical significance is given as * p<0.05 ** p<0.01 *** p<0.01. (1) MRH = 1; ARH = 2

**Table S3.** Single linear regression relationships between hourly BC (μg/m$^3$), traffic volumes (unit: 1000 vehicles per hour), and ambient roadside air quality (unit: μg/m$^3$) at the stationary HRI site, unless otherwise specified.

| | | Slope (μg BC/m$^3$ / unit) | | Intercept (μg BC/m$^3$) | | | |
|---|---|---|---|---|---|---|---|
| **Data** | **Parameter** | Value | 95% CI | Value | 95% CI | **$R^2$** | **p-value** |
| **All** | Traffic vol. | 0.5373 | [0.4681, 0.6064] | 0.108 | [-0.029, 0.246] | 0.306 | 0 |
| **N = 563** | $NO_2$ | 0.0408 | [0.0386, 0.0431] | -0.026 | [-0.100, 0.049] | 0.712 | 0 |
| | $PM_{10}$ | 0.0379 | [0.0304, 0.0454] | 0.484 | [0.351, 0.617] | 0.160 | 0 |
| | $PM_{2.5}$(1) | 0.0125 | [0.0049, 0.0200] | 0.855 | [0.737, 0.974] | 0.022 | 0.0013 |
| **9AM-7PM** | Traffic vol. | 0.5089 | [0.2974, 0.7204] | 0.210 | [-0.355, 0.776] | 0.085 | 0 |
| **N = 259** | $NO_2$ | 0.0428 | [0.0389, 0.0466] | 0.055 | [-0.103, 0.214] | 0.665 | 0 |
| | $PM_{10}$ | 0.0389 | [0.0264, 0.0514] | 0.950 | [0.713, 1.187] | 0.136 | 0 |
| | $PM_{2.5}$(1) | -0.0025 | [-0.0123, 0.0073] | 1.504 | [1.312, 1.696] | 0.001 | 0.62 |
| **<Nov.6** | Traffic vol. | 0.592 | [0.4944, 0.6896] | -0.051 | [-0.242, 0.141] | 0.380 | 0 |
| **N = 235** | $NO_2$ | 0.0504 | [0.0480, 0.0528] | -0.103 | [-0.171, -0.035] | 0.878 | 0 |
| | $PM_{10}$ | 0.0385 | [0.0307, 0.0463] | 0.218 | [0.037, 0.400] | 0.288 | 0 |
| | $PM_{2.5}$(1) | 0.011 | [0.0026, 0.0194] | 0.793 | [0.616, 0.970] | 0.029 | 0.0106 |
| **Nov. 6-12** | Traffic vol. | 0.4309 | [0.2790, 0.5827] | 0.340 | [0.033, 0.647] | 0.171 | 0 |
| **N = 155** | $NO_2$ | 0.0417 | [0.0378, 0.0456] | -0.321 | [-0.481, -0.162] | 0.746 | 0 |
| | $PM_{10}$ | 0.1076 | [0.0806, 0.1346] | 0.000 | [-0.317, 0.316] | 0.297 | 0 |
| | $PM_{2.5}$(1) | 0.0658 | [0.0296, 0.1020] | 0.475 | [0.167, 0.784] | 0.103 | 0.0005 |
| **Nov.14-20** | Traffic vol. | 0.5539 | [0.4347, 0.6731] | 0.142 | [-0.096, 0.381] | 0.376 | 0 |
| **N = 142** | $NO_2$ | 0.0339 | [0.0286, 0.0391] | 0.245 | [0.074, 0.416] | 0.537 | 0 |
| | $PM_{10}$ | 0.0545 | [0.0234, 0.0856] | 0.502 | [0.139, 0.865] | 0.080 | 0.0007 |
| | $PM_{2.5}$(1) | 0.0341 | [-0.0032, 0.0715] | 0.869 | [0.575, 1.163] | 0.025 | 0.073 |

Notes: (1) Air quality monitored at stationary GRE urban traffic site, 3.7 km southeast of HRI site.

**Table S4.** Single linear regression relationships between median BC (μg/m$^3$) and ambient air quality (unit: μg/m$^3$) at the stationary GRE site 80 m from centerline of the highway during mobile campaigns.

| **Mobile** | | Slope (μg BC/ μg $NO_2$) | | Intercept (μg BC/m$^3$) | | | | |
|---|---|---|---|---|---|---|---|---|
| **Campaign** | **Parameter** | Value | 95% CI | Value | 95% CI | **$R^2$** | **p-value** | **N** |
| **WH – All** | $NO_2$ | 0.033 | [0.0283, 0.0377] | -0.189 | [-0.735, 0.357] | 0.923 | 0 | 20 |
| **WR – All** | $NO_2$ | 0.0172 | [0.0124, 0.0220] | -0.235 | [-0.772, 0.303] | 0.770 | 0 | 19 |
| **DH – All** | $NO_2$ | 0.0252 | [0.0140, 0.0363] | 1.389 | [0.129, 2.648] | 0.556 | 0.0002 | 20 |
| **WH – Winter** | $PM_{10}$ | 0.0032 | [-0.0004, 0.0068] | -7.152 | [-19.795, 5.490] | 0.278 | 0.078 | 12 |
| **WH – Summer** | $PM_{10}$ | -0.0008 | [-0.0030, 0.0015] | 4.269 | [-4.077, 12.615] | 0.105 | 0.43 | 8 |
| **WH – Winter** | $PM_{2.5}$ | 0.0515 | [-0.4295, 0.5325] | 2.068 | [-2.060, 6.196] | 0.022 | 0.78 | 12 |
| **WH – Summer** | $PM_{2.5}$ | 0.0171 | [-0.0014, 0.0355] | 0.541 | [-0.616, 1.698] | 0.460 | 0.06 | 8 |

Notes: Statistical significance is given as * $p<0.05$ ** $p<0.01$ *** $p<0.001$.
WH = Walk Highway, WR = Walk Residential, DH = Drive Highway.

**Table S5.** Multi-regression analyses for BC and key external drivers at stationary HRI site (N = 563).

| Model | Parameter | Unit | Regr. Coeffs µg BC/m³/unit | SE | p-value | $R^2$ | $\Delta R^2$ |
|---|---|---|---|---|---|---|---|
| **1** | Intercept | - | -0.12 | 0.04 | 0.005 | | |
| | $NO_2$ | µg/m³ | 0.039 | 0.001 | <0.001 | 0.712 | |
| | $PM_{10}$ | µg/m³ | 0.011 | 0.002 | <0.001 | 0.725 | +0.01 |
| **2** | Intercept | - | 0.49 | 0.09 | <0.001 | | |
| | Traffic | 1000 veh. / h | 0.56 | 0.03 | <0.001 | 0.31 | |
| | dT/dz | °C/m | 2.53 | 0.78 | 0.001 | 0.38 | +0.07 |
| | WS | m/s | -0.17 | 0.02 | <0.001 | 0.47 | +0.09 |
| | Precipitation | mm/h | 0.25 | 0.08 | 0.003 | 0.48 | +0.01 |

Notes: Statistical significance is given as * $p<0.05$ ** $p<0.01$ *** $p<0.001$.