Quantifying the influence of local meteorology on air quality in Zagreb using generalized additive models

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1. Motivation and introduction
2. Measuring sites
3. Method
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5. Summary and conclusions

Motivation

- Elevated levels of concentration result of sudden emission and meteorological conditions
- A new approach for the urban area of Zagreb

Introduction

- GAMs well suited for quantifying and visualizing the pollutant- meteorological relationship
- The logarithm of hourly concentration modelled as a sum of non-linear functions of meteorological and time variables

- Partial effects

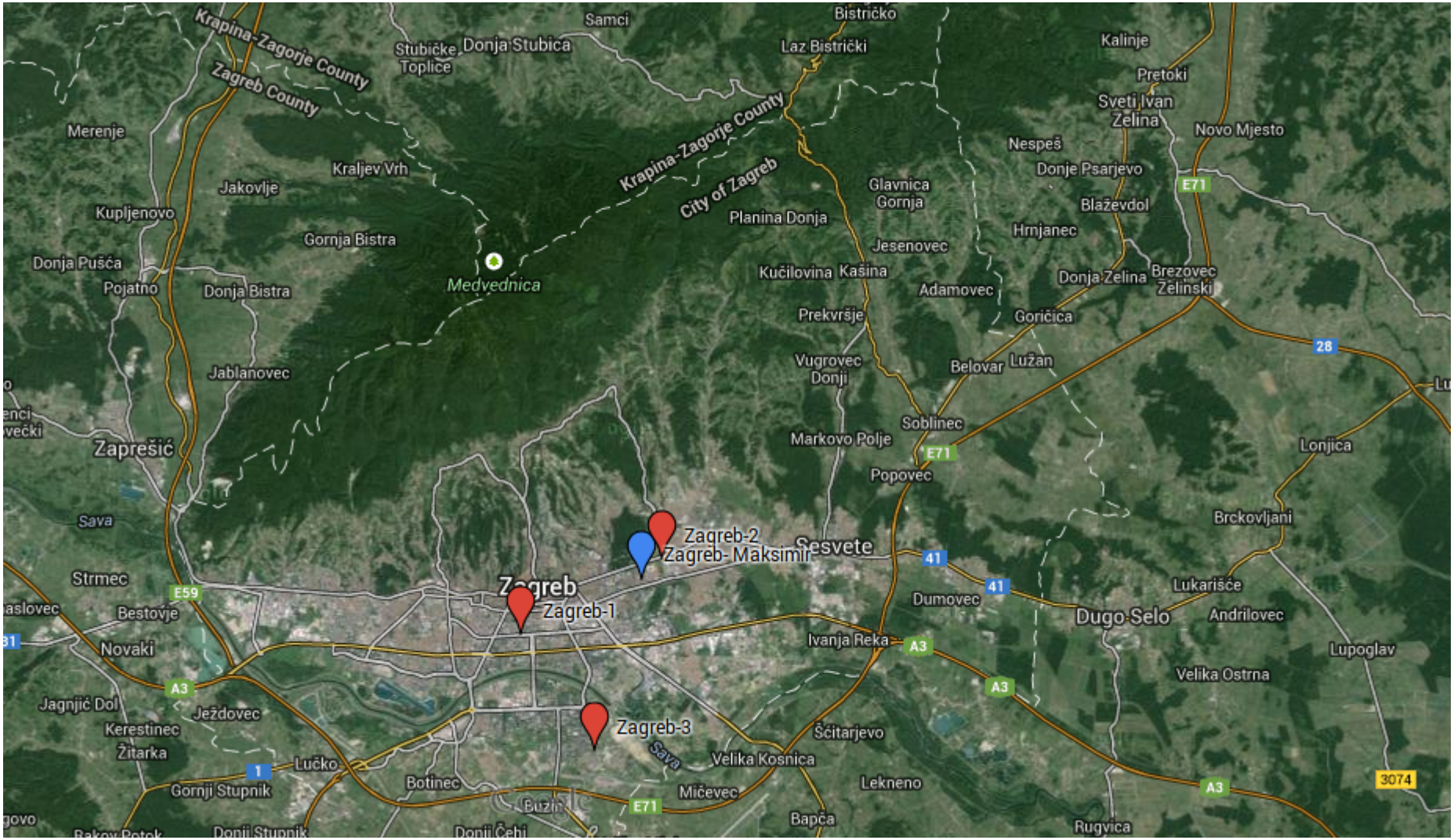

Figure 1 : Satellite view of the town Zagreb (source: Google Maps). Red bubbles indicate air pollution measuring sites and blue bubble indicates meteorological parameters measuring site.

Dataset

- Pollutants: CO, SO_2, NO_2 and $PM10$
- Meteorological data: temperature, pressure, relative humidity, precipitation last 4 h, precipitation last week, surface wind speed and direction
- Temporal variables: hour of day, day of week, day number
- Period: 1 Jan 2006 - 31 Dec 2012
- Sampling: Hourly

GAMs

- Regression models where smoothing splines are used instead of linear coefficients for covariates
- The logarithmic transformation

$$\begin{aligned} log(y_i) = s_0 &+ s(hd, k) + s(dw, k) \\ &+ s(dn, k) + s(temp, k) + s(press, k) \\ &+ s(rel.hum, k) + s(speed, k) + s(dir, k) \\ &+ s(prec.4h, k) + s(prec.week, k) + \epsilon_i \end{aligned} \tag{1}$$

R2

		r^2
$CO\ (mg/m^3)$	ZG3	0,60
$SO_2\ (\mu g/m^3)$	ZG3	0,51
$NO_2\ (\mu g/m^3)$	ZG3	0,43
$PM10\ (\mu g/m^3)$	ZG3	0,41

Table 1 : The explained variation, r^2, for each model on log scale at Zagreb-3.

Comparison

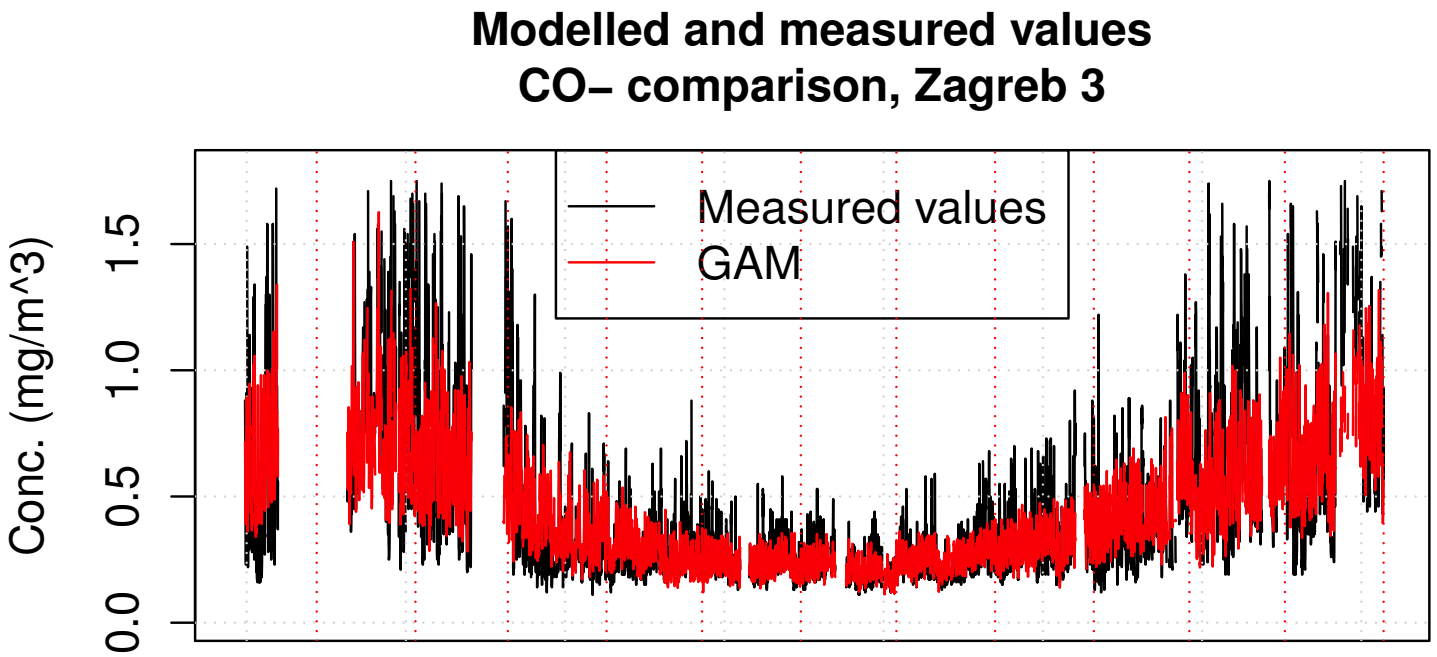

Figure 2 : The difference between the measured values of concentration (black) and modelled values (red) for CO at Zagreb-3, 2012.

Temperature

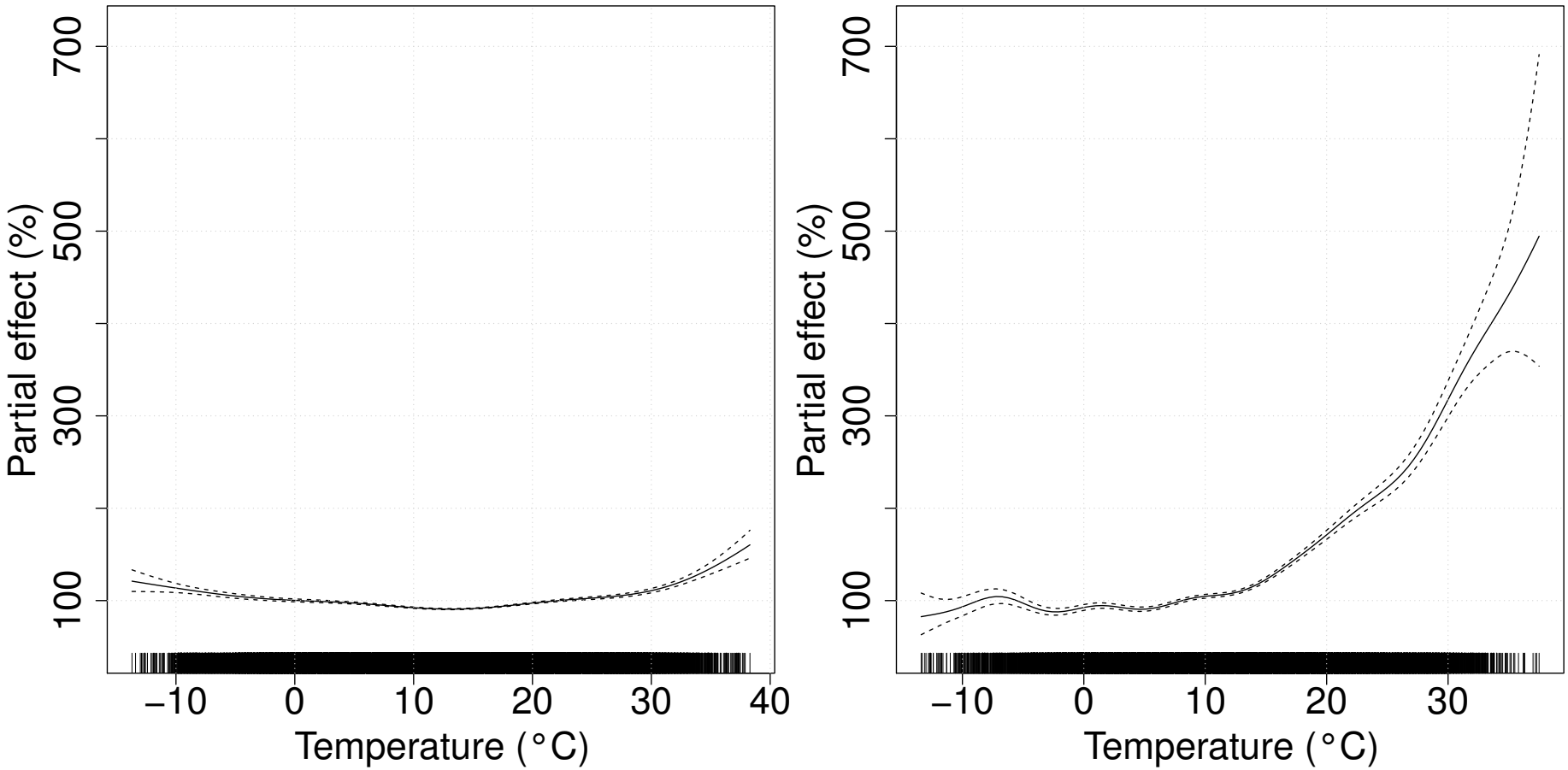

Figure 3 : *CO* and *PM*10

Mean sea level pressure

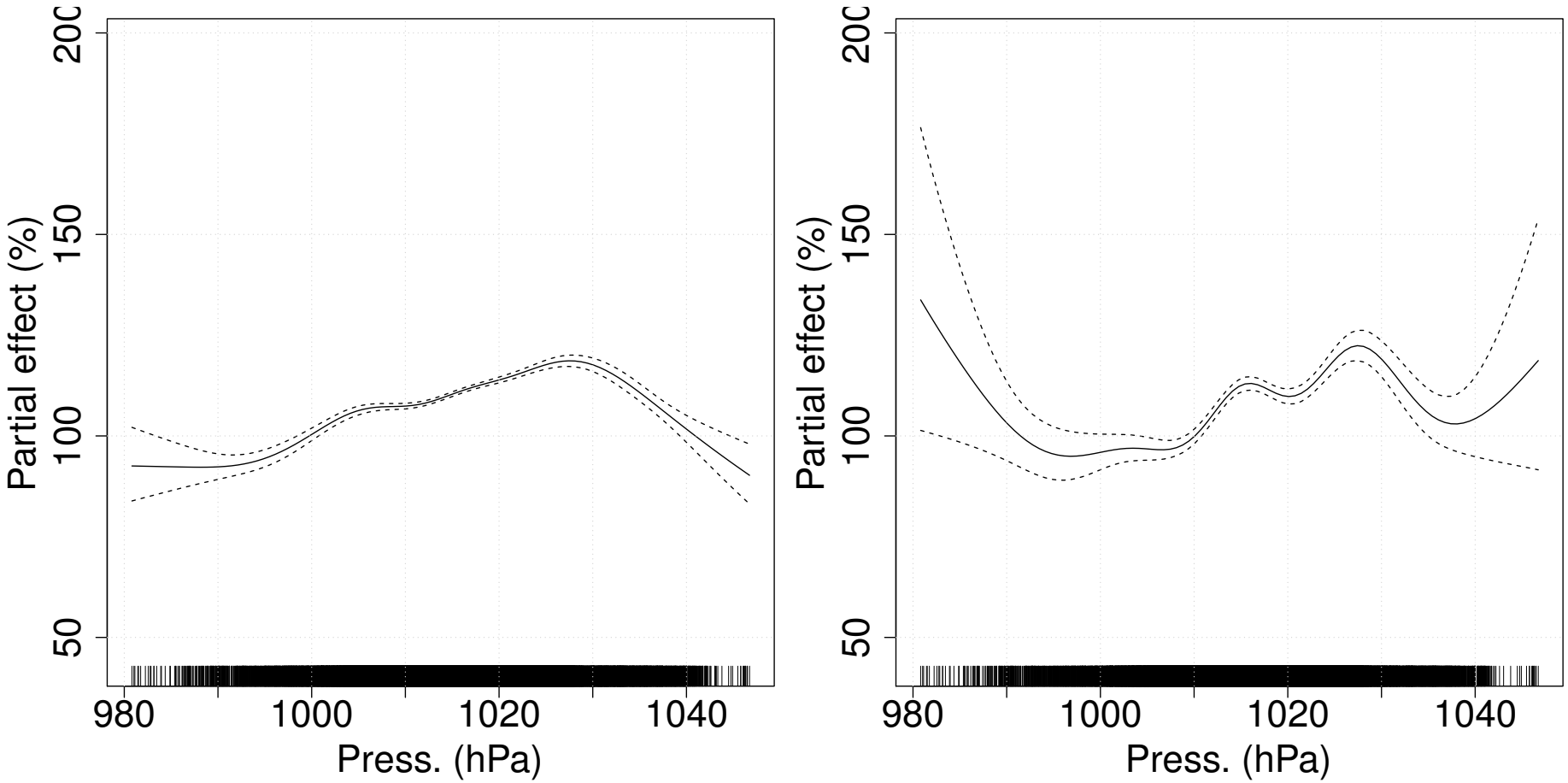

Figure 4 : CO and SO_2

Relative humidity

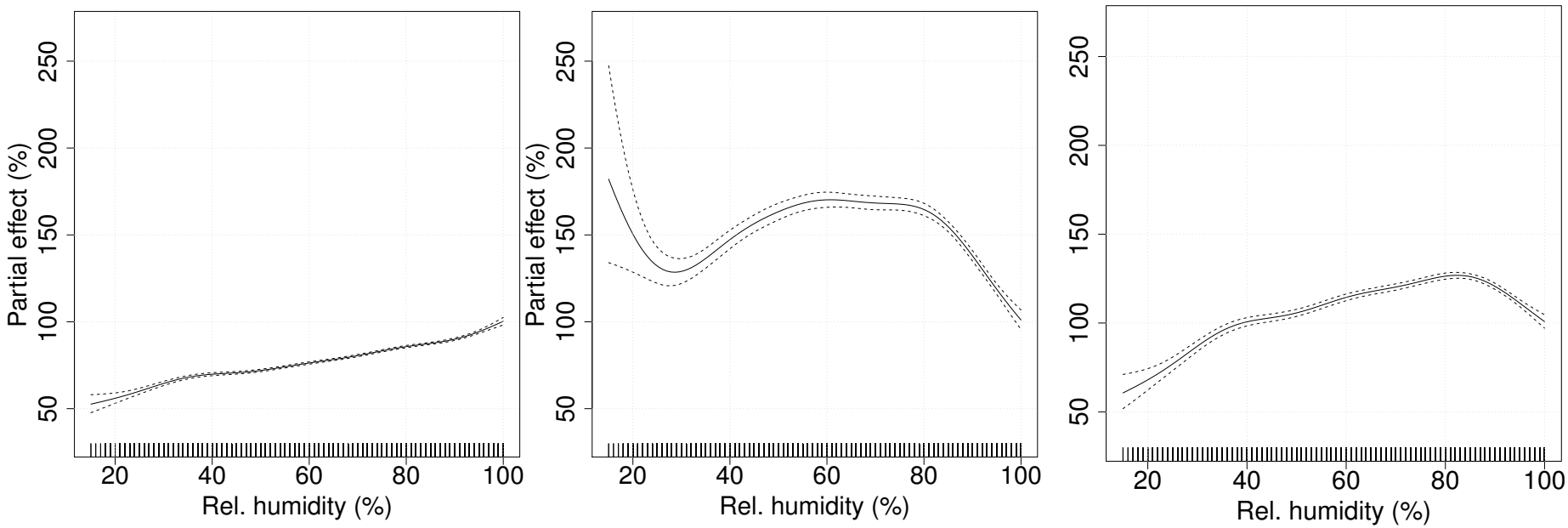

Figure 5 : CO, SO_2 and NO_2

Wind direction

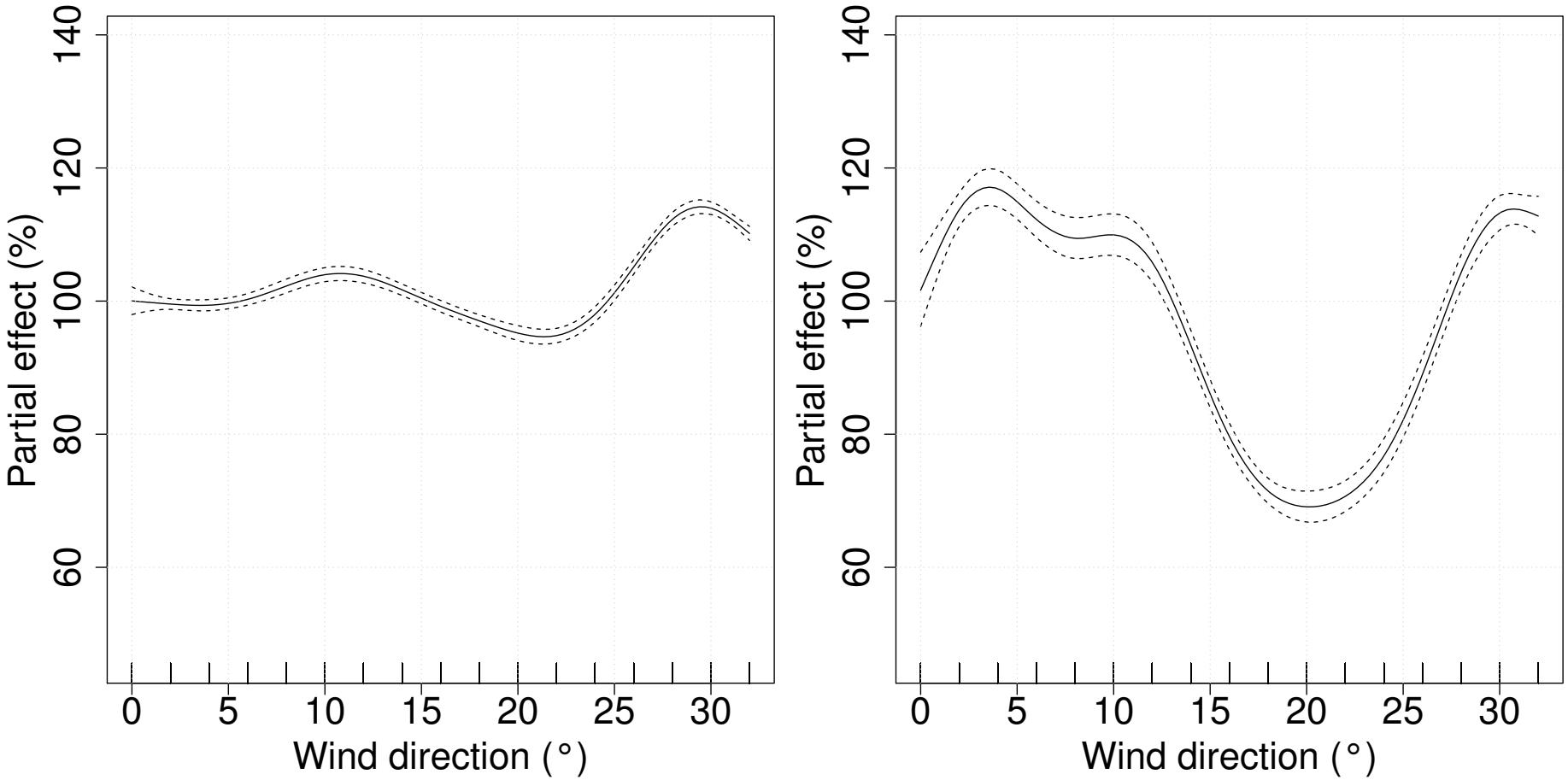

Figure 6 : CO and SO_2

Wind speed

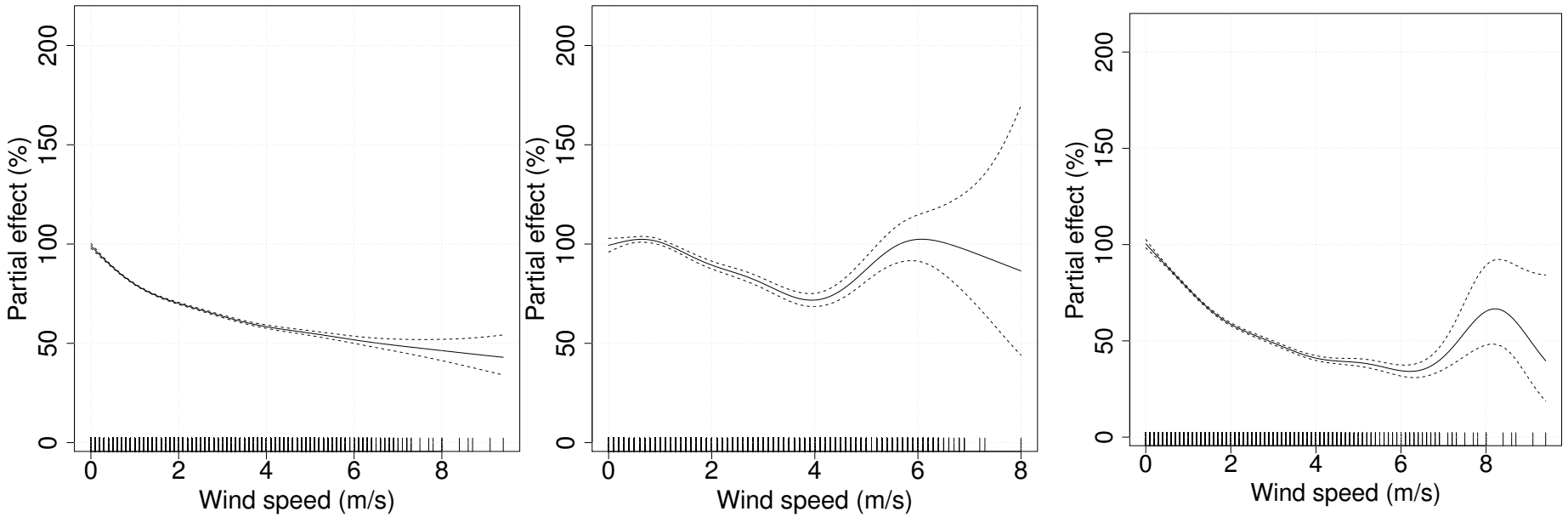

Figure 7 : CO, SO_2 and NO_2

Precipitation last 4 h

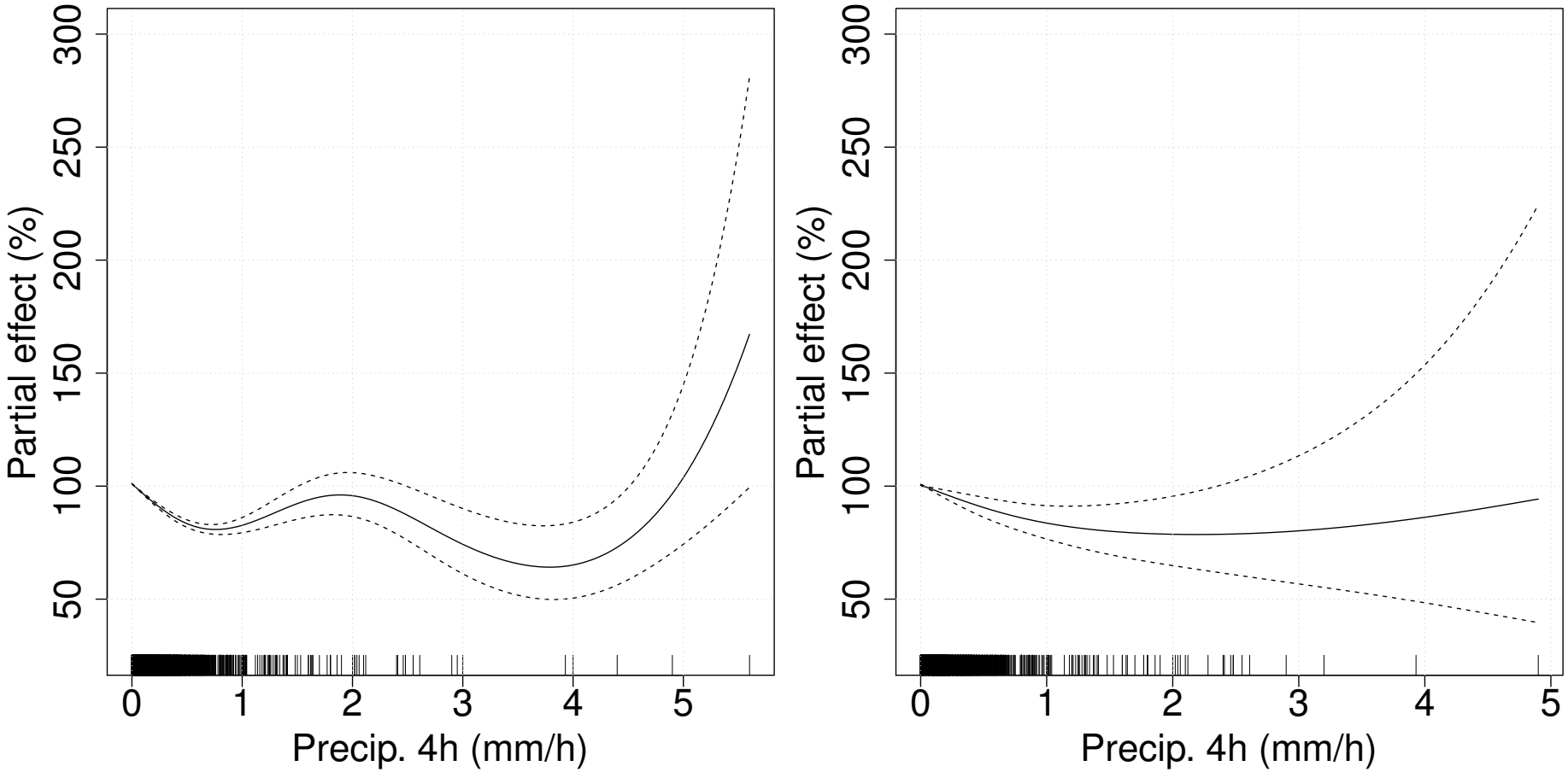

Figure 8 : CO and SO_2

Hour of day

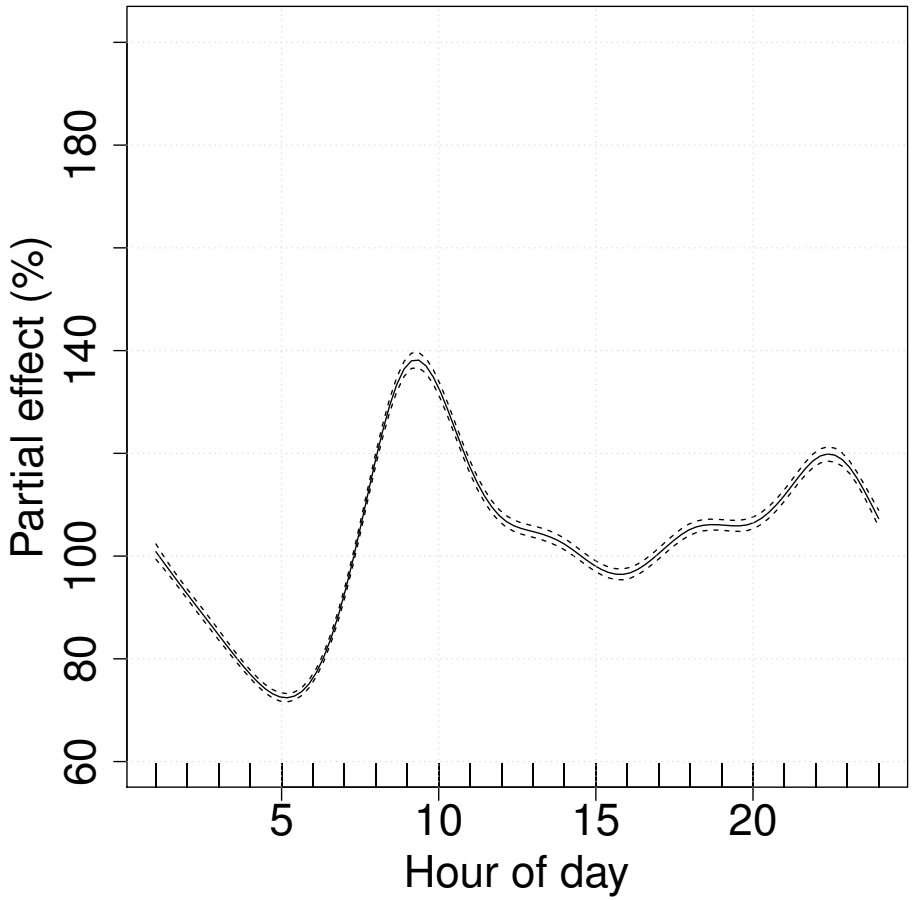

Figure 9 : *CO*

Day number

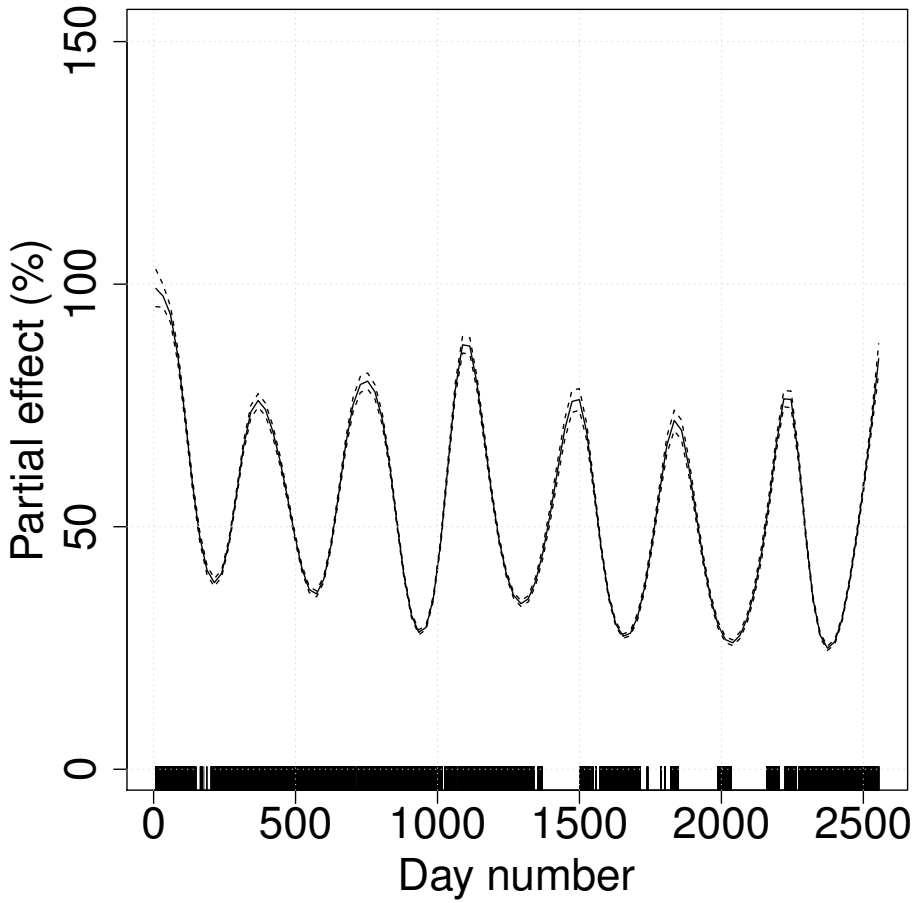

Figure 10 : *CO*

Day of week

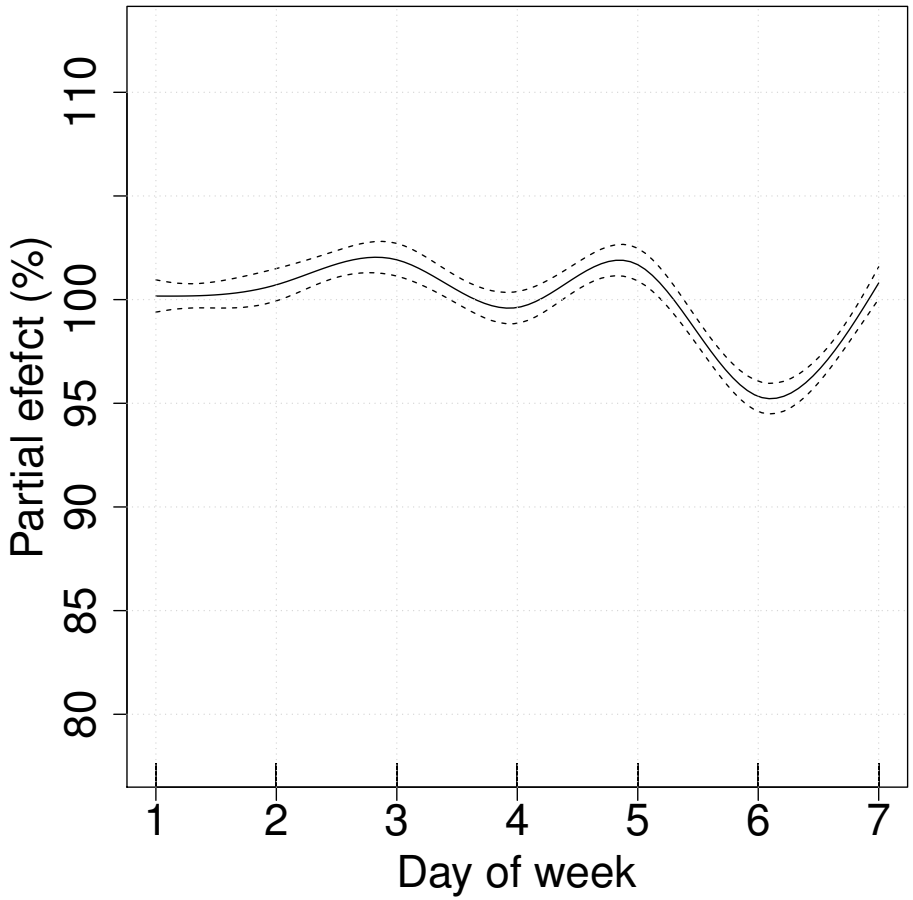

Figure 11 : *CO*

Summary and conclusions

- Emissions have the largest and clear impact on air quality
- Stable atmospheric conditions increase the concentration and have the negative impact on human health
- Changes in concentration quite well estimated

Improvements

- Traffic density data
- Vertical cross section
- Interactions

Thank You!

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Dataset

- Precipitation last 4 h:

$$\frac{1}{10}(4P_t + 3P_{t-1} + 2P_{t-2} + P_{t-3}) \tag{2}$$

- Precipitation last week:

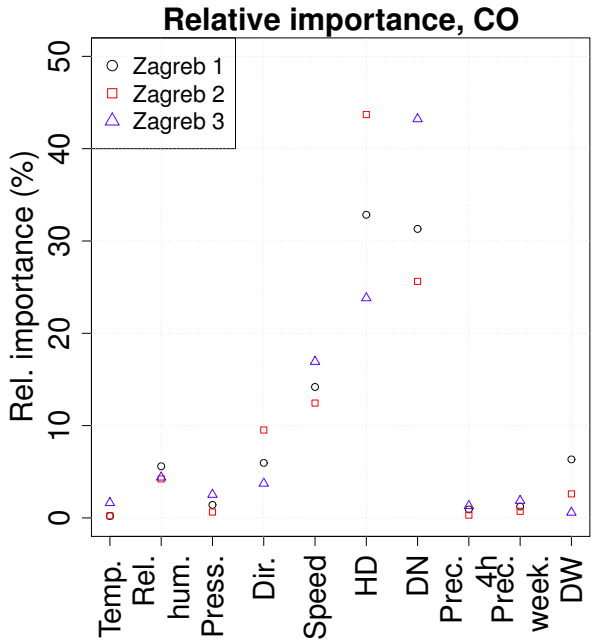
$$\frac{1}{\sum_{j=1}^{168} w_j} \sum_{j=1}^{168} w_j P_{t-3-j} \tag{3}$$

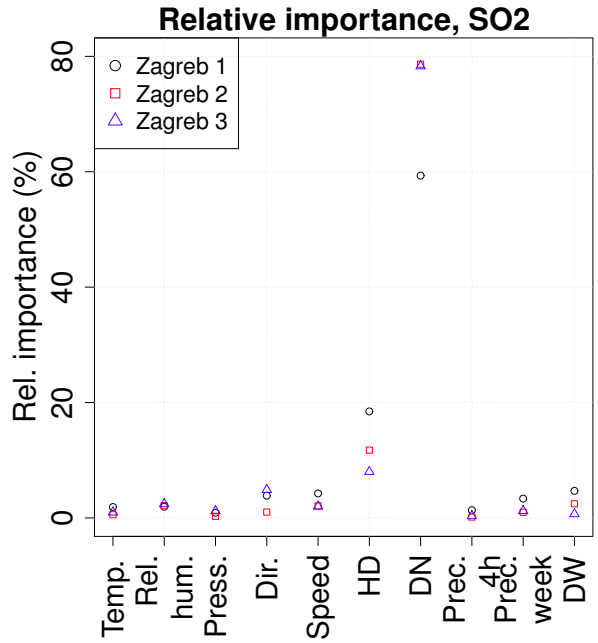
$$
\begin{aligned}
log(y_i) = s_0 &+ s(hd, k = 12) + s(dw, k = 7) \\
&+ s(dn, k = 28) + s(temp, k = 9) + s(press, k = 9) \\
&+ s(rel.hum, k = 9) + s(speed, k = 9) + s(dir, k = 9) \\
&+ s(prec.4h, k = 5) + s(prec.week, k = 5) + \epsilon_i
\end{aligned}
\tag{4}
$$

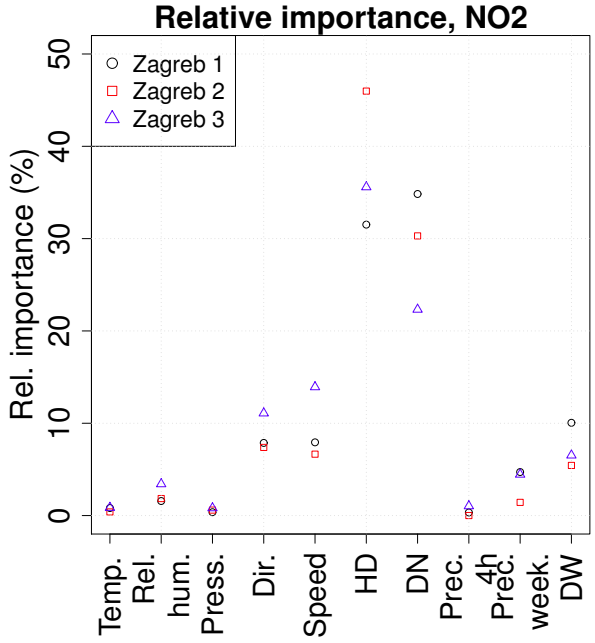
Relative importance

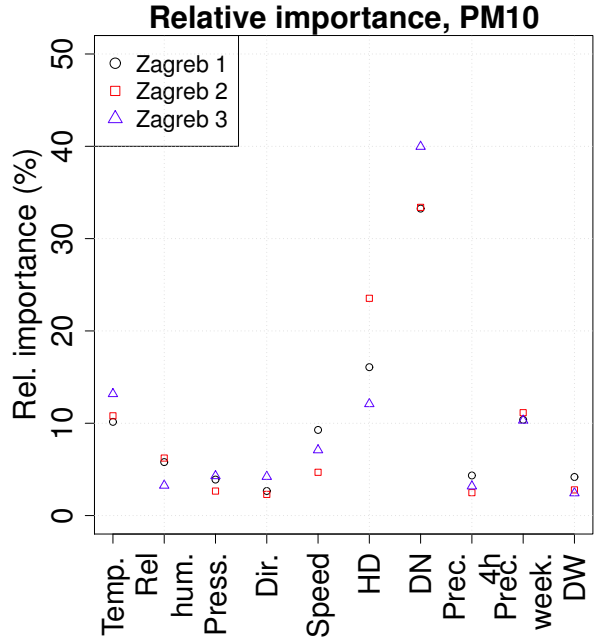
- The proportion (in %) of the variation explained by the j-th predictor variable in the model:

$$100 \frac{\hat{\sigma_{-j}}^2 - \hat{\sigma}^2}{\sum_{i=1}^{p} \hat{\sigma_{-j}}^2 - p\hat{\sigma}^2} \tag{5}$$


Relative importance, CO
Zagreb 1
Zagreb 2
Zagreb 3
Rel. importance (%)
0
10
20
30
40
50
Temp.
Rel. hum.
Press.
Dir.
Speed
HD
DN
Prec.
4h Prec.
week.
DW


Relative importance, SO2
Zagreb 1
Zagreb 2
Zagreb 3
Rel. importance (%)
0
20
40
60
80
Temp.
Rel. hum.
Press.
Dir.
Speed
HD
DN
Prec.
4h Prec.
week
DW


Relative importance, NO2
Zagreb 1
Zagreb 2
Zagreb 3
Rel. importance (%)
0
10
20
30
40
50
Temp.
Rel. hum.
Press.
Dir.
Speed
HD
DN
Prec.
4h Prec.
week.
DW


Relative importance, PM10
Zagreb 1
Zagreb 2
Zagreb 3
Rel. importance (%)
0
10
20
30
40
50
Temp.
Rel
hum.
Press.
Dir.
Speed
HD
DN
Prec.
4h Prec.
week.
DW

Partial effects

- The actual estimated non-linear smooth curves

$$100\frac{S_j(x_j)}{S_j(x_{j,ref})} \tag{6}$$

Model evaluation

i.e. CO:

- Measurement standard deviation: 0,30 mg/m^3
- Model standard deviation: 0,23 mg/m^3
- Measurement mean: 0,47 mg/m^3
- Model mean: 0,47 mg/m^3