Analysis and Prediction of Particulate Matter PM10 in Bolzano, Klagenfurt and Graz

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1 What is Particulate Matter?

Mixture of midget dust particles ($\varnothing < 10\mu m$).

Primary particles

Emerge from burning processes, mechanical abrasion of tyres, brakes, tarmac, etc. or natural sources (pollen, crushing rock, soil, etc.)

Secondary particles

Arise from aerially pollutants.

1.1 EU Directive

According to the EU framework directive 96/62/EC the limit value for the daily average is $50\mu g/m^3$ and must not be exceeded on more than 30 days a year. The corresponding threshold for the annual average is $40\mu g/m^3$.

2 The PM10 Problem

For several years the PM10 concentration has been measured and analyzed in Europe.

Figure 2.1: Graz at a period of stationary temperature inversion.

Mainly the adverse meteorological conditions are responsible for the high PM10 loads in basin areas south of the Alps.

- **low wind velocities**
- **rare days with precipitation**
- **stationary temperature inversions**

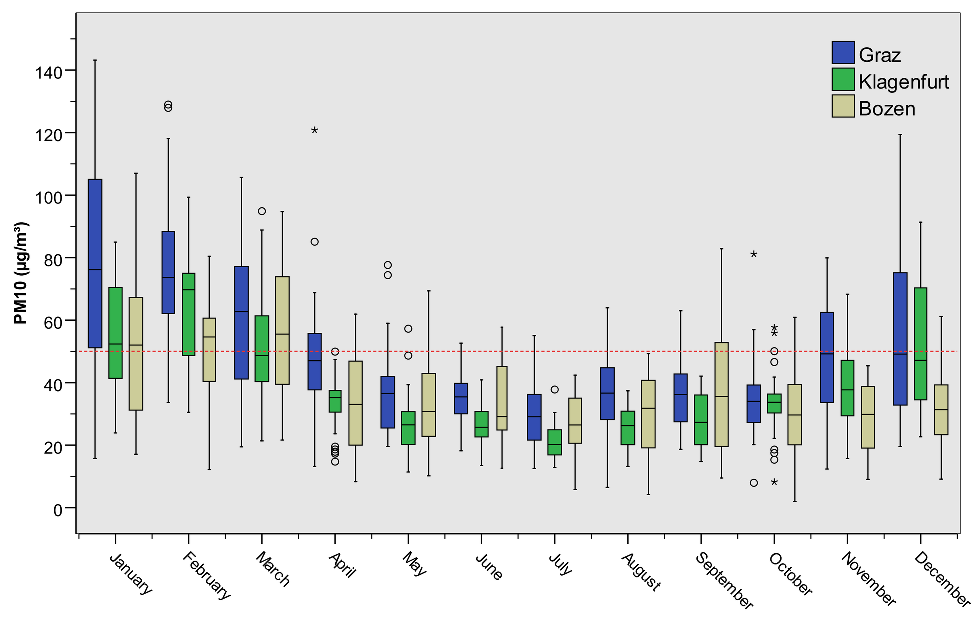

Figure 2.2: Most exceedances of the limit value occur during the winter period (October till March).

2.1 Exploratory Analysis

2.1.1 Temperature Inversion

Due to the reduced air exchange we observe the highest PM10 concentration at stationary temperature inversions.

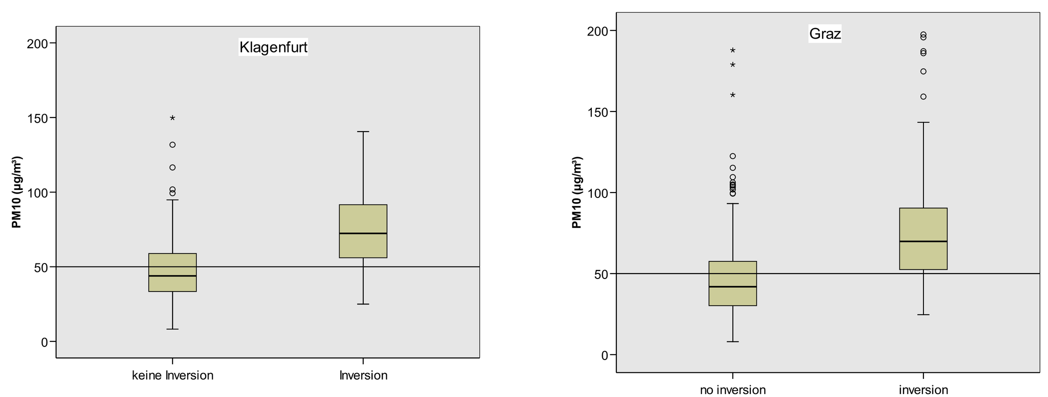

Figure 2.3: We measure temperature inversion with respect to Göriach and Kalkleiten (390/360m above ground). Temperature inversion is indicated if temp(Klagenfurt)-temp(Göriach) respectively temp(Graz)-temp(Kalkleiten) is negative.

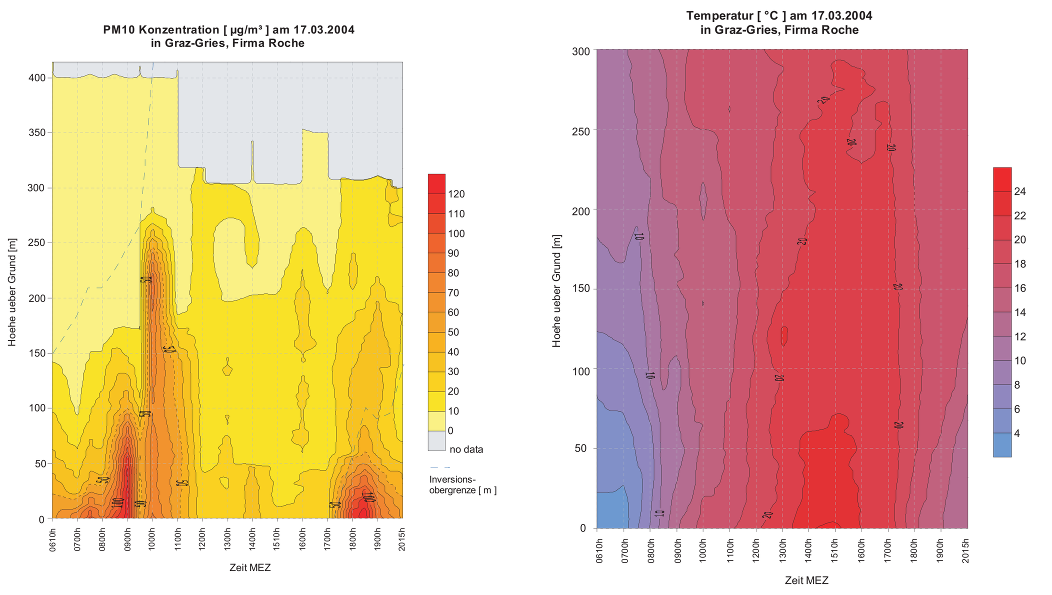

Figure 2.4: The balloon probe shows to what extent the dissolution of inversion yields a decline of PM10. (Source ZAMG Styria.)

2.1.2 Traffic

Traffic plays a crucial role for the PM10 problem (exhaust, abrasion, dispersion of dust).

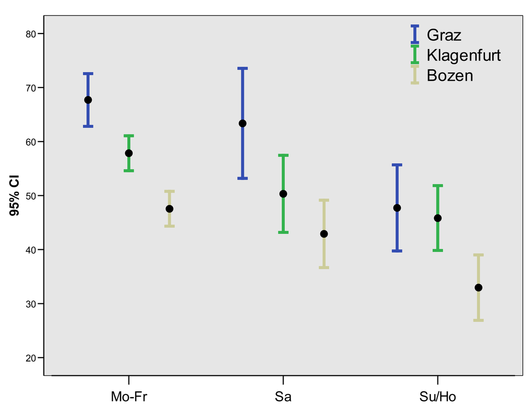

Figure 2.5: On Sun- and Holidays the PM10 concentration is considerably lower than on working days (25–30%). This may be explained by the reduced traffic loads at the three sites.

2.1.3 Wind, Precipitation and Frost

The emergence of wind and precipitation have positive effects on the PM10 concentration. Contrarily frost causes an increase of the PM10 values. This may be explained via heightened domestic fuel.

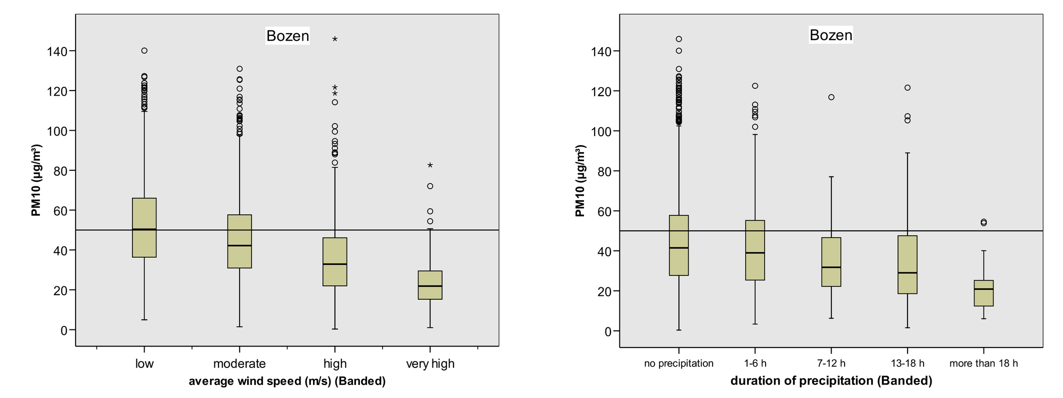

Figure 2.6: The influence of wind (left) and precipitation (right) in Bolzano. Here the wind velocity has the biggest influence on PM10.

2.1.4 'Saturation Effect'

Under constant meteorological conditions the PM10 values become considerably higher in course of the winter period. A possible explanation might be that the defilement of deposited road grit is increasing during the winter months.

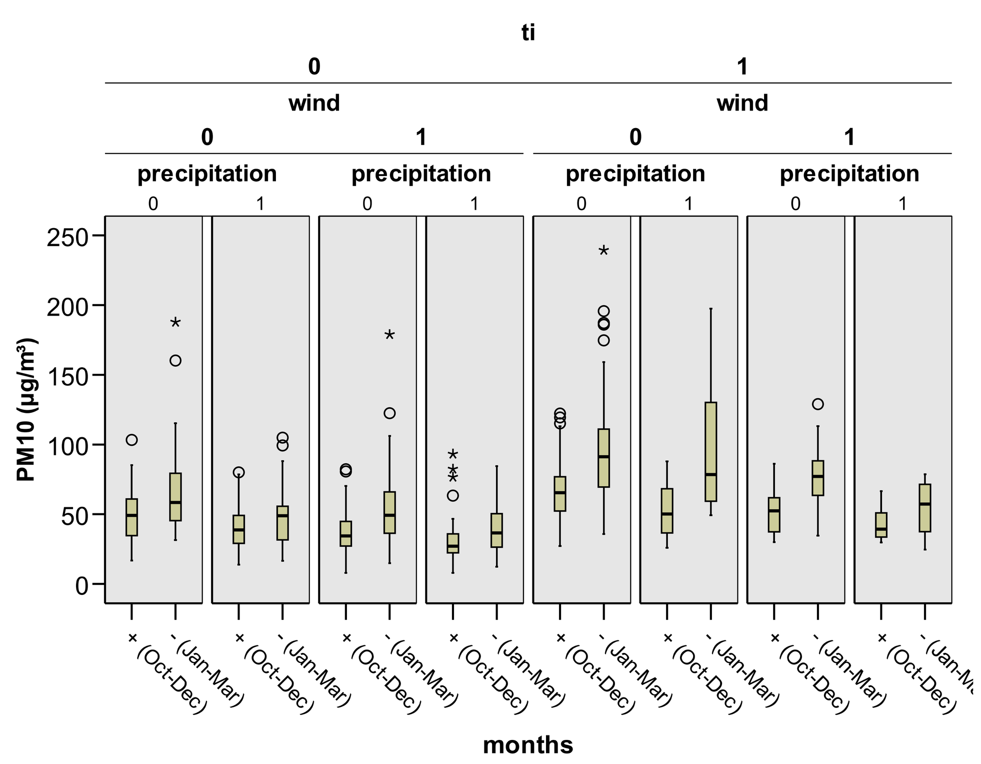

Figure 2.7: PM10 load in Graz under specific meteorological scenarios: Inversion: 0=no inversion; Wind: 0=wind speed below median; Precipitation: 0=no precipitation. Value=1 describes the complements.

3 Prediction Model

The aim of the prediction model is to give a forecast of the average PM10 load of the subsequent day. Multiple linear regression proved to be a reliable approach.

3.1 Regression Models

Our prediction models are based on linear regressions.

$$\sqrt{PM_{10}} = \sum_k b_k \cdot x_k + \sum_l b_l \cdot p_l + \epsilon \quad \text{with} \quad \epsilon \sim N(0, \sigma^2).$$

A square root transformation of the response PM10 is necessary in order to assure that the model assumptions are not violated. For our models we use up to 7 input variables:

variable	type	explanation
x_1	metric	PM10 24-h moving average from 12.00–12.00
x_2	categorial	Mo–Fr, Sa, Su/Ho
x_3	0/1	average temperature $> 0, \leq 0$
x_4	categorial	October – March
p_1	metric	average wind speed of the subsequent day (to be forecasted)
p_2	0/1	precipitation of the subsequent day (to be forecasted)
p_3	metric	average temperature difference to a 300–400m higher reference test point (to be forecasted)

The variables $x_1 - x_4$ are available at the assigned time for prediction. The variables $p_1 - p_3$ have to be forecasted.

3.2 Quality of the model

The models show a corrected R^2 between 54% and 64%. The input variables have been selected via a stepwise procedure.

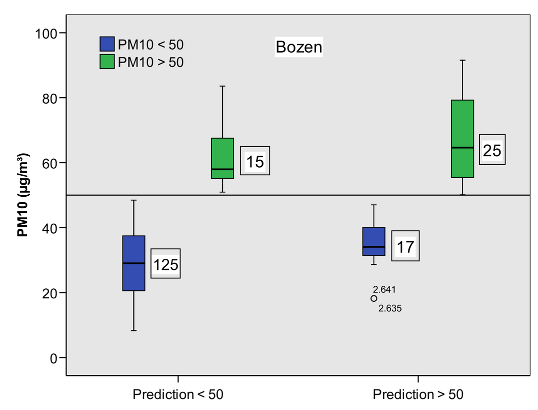

Figure 3.1: From 1.10.2005–31.3.2006 150 (=82%) out of 182 predictions have been categorized correctly (exceedance/no exceedance). The misclassified values were still close the classification limit ($50\mu g/m^3$).

3.3 Test Run in Graz

Our prediction model for Graz has been tested within three winter periods (2004/05–2006/07). The necessary meteorological forecasts were provided by the ZAMG Steiermark.

The forecasts can be found on http://www.feinstaubfrei.at/htm/ampel.php. Thereby our prediction model proved its worth as reliable monitoring tool.

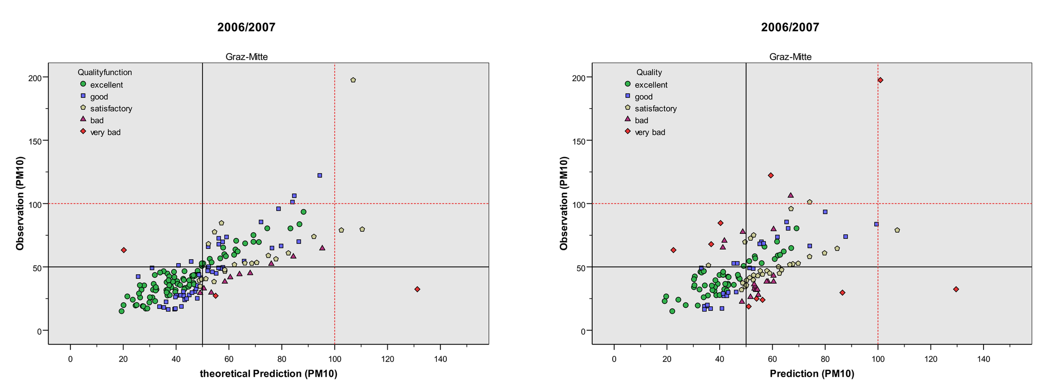

Figure 3.2: Comparison between observation and prediction. If the meteorological parameters are known the predictions are satisfactory in about 90% of the cases (left panal). During the test run where we used the meteorological forecasts approximately 80% (right panel) met our demands.

Literature

Hörmann, S., Pfeiler, B., Stadlober, E. (2005): *Analysis and Prediction of Particulate Matter PM10 for the Winter Season in Graz*, Austrian Journal of Statistics (34) 307–326.

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