Analysis and Prediction of Particulate Matter in Graz

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1 What is Particulate Matter?

Mixture of midget dust particles.

Primary particles

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

Secondary particles

- arise from aerially pollutants.

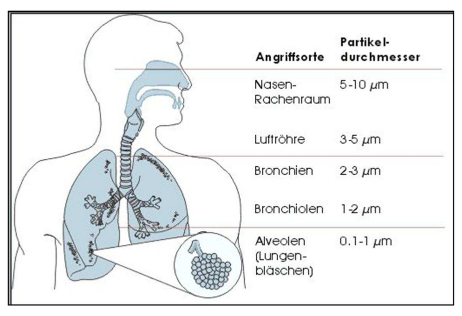
1.1 Measuring

Particulate **M**atter is classified according to its size. We distinguish between *PM10* , *PM2.5* and *PM1*, particles with a diameter of $10\mu m$, $2.5\mu m$ respectively $1\mu m$. The concentration in the air is measured in $\mu g/m^3$.

1.2 Health Effects

The harmful externality of *PM10* depends on the size of the particles :

Size	Increasing neg. health effects
$PM_{2.5}$	• overall mortality rate • heart-/lung diseases
PM10	• dyspnea • allergic coryza • acute respiratory disease • COPD
PM_{15}	• bronchitis • chronic cough



1.3 EU Directive

The threshold value for the daily average in the EU is $50\mu g/m^3$. According to IG−L this limit must not be exceeded on more than 30 days per year. The corresponding threshold for the annual average is $40\mu g/m^3$.

2 The Situation in Graz

Since 2001 the *PM10*-concentration in and around the city of Graz is measured at different gaging stations.

Figure 2.1: Graz at meteorological inversion.

Mainly the adverse meteorological conditions are responsible for the high *PM10*-loads in Graz.

- low wind velocities
- low precipitation
- many days with temperature inversion (i.e. temperature increases with the altitude.)

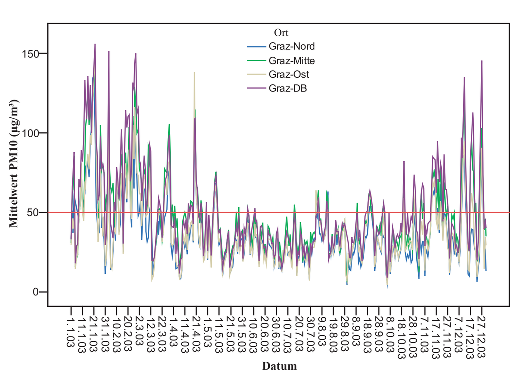


Figure 2.2: Most exceedances occur in the winter season (October to March). At the gaging station Graz Mitte (near the inner city) 136 exceedances were observed in 2003 with an annual average exceeding $50\mu g/m^3$.

2.1 Exploratory Analysis

2.1.1 Inversion

The strongest impact on *PM10* in Graz comes from inversion. It implies a bad air circulation. We measure inversion by the temperature difference of Graz ($350m$ sea level) and Kalkleiten ($700m$ sea level).

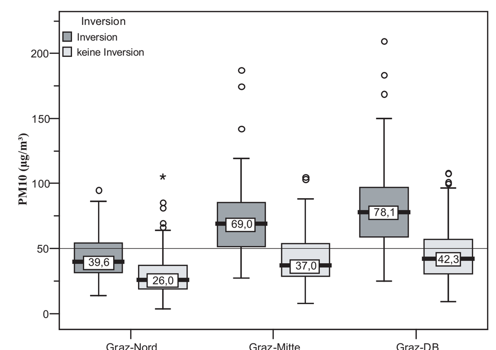


Figure 2.3: We describe Inversion by the average temperature difference between Graz and Kalkleiten. Inversion means that the average of the daily difference is below $0°C$.

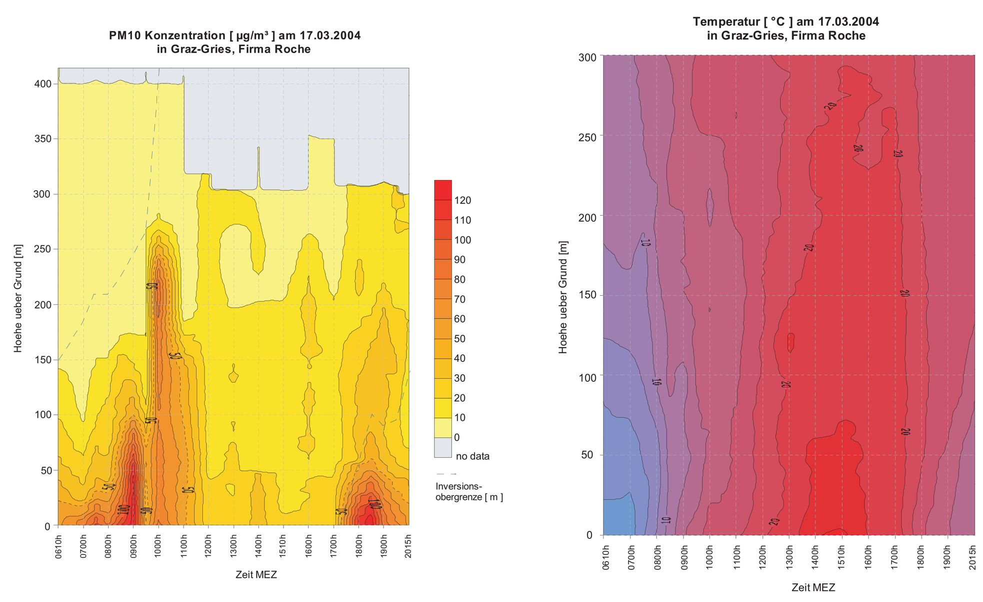


Figure 2.4: The balloon probe shows to what extent the dissolution of inversion yields a decline of PM10.

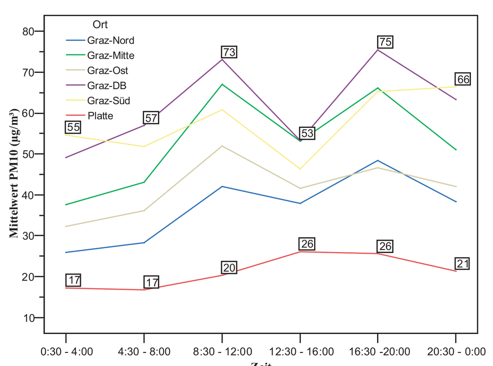


Figure 2.5: We observe a decrease of PM10 between 12 and 16 o'clock. This results from the meteorological fact that inversion often ends at noon and starts again in the evening.

During this time we find a slight increase of the PM10-load at "Graz Platte"($661m$ sea level).

2.1.2 Traffic

Traffic is probably the most important polluter (besides domestic fuel, industry, etc.)

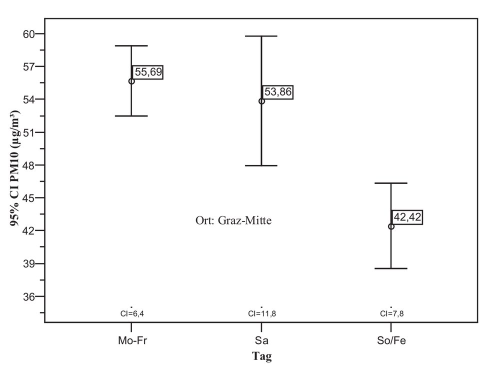
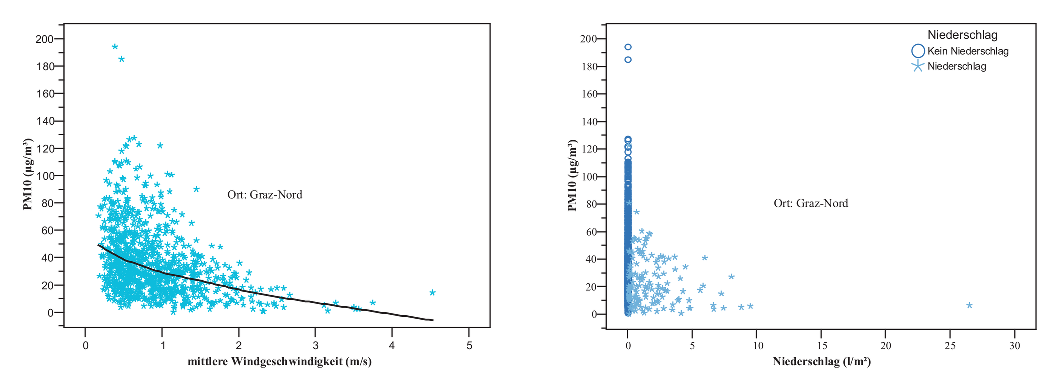


Figure 2.6: On Sundays the volume of traffic reduces to about 60% of working days. Simultaneously the PM10-average on Sundays in the winter season is about 30% below that on working days.

2.1.3 Wind and Precipitation

Wind and precipitation help to reduce the load of *PM10*.



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. From October 2004 to April 2005 we carried out a test run with our prediction model. The necessary meteorological forecasts were provided by the ZAMG Steiermark.

3.1 Regression Model

Our prediction model is based on a linear regression model. We use five variables:

Variable	Var	Type	Description
pm_10_lag	x_1	numerical	*PM10* 24−h average of preceding day
tag	x_2	numerical	1 =Mo−Fr, 2 = Sa, 3 =Su/Ho
$wige$	p_1	numerical	mean wind velocity of the subsequent day (Forecast)
$nied$	p_2	0/1	precipitation of the subsequent day (Forecast)
$ltusg$	p_3	numerical	temperature difference Graz−Kalkleiten (Forecast)

A square root transformation of the response *PM10* is necessary in order to assure that the model assumptions are not violated.

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

3.2 Properties of our Model

The adjusted R^2 is 67%. All model variables selected above have a significant impact on the response.

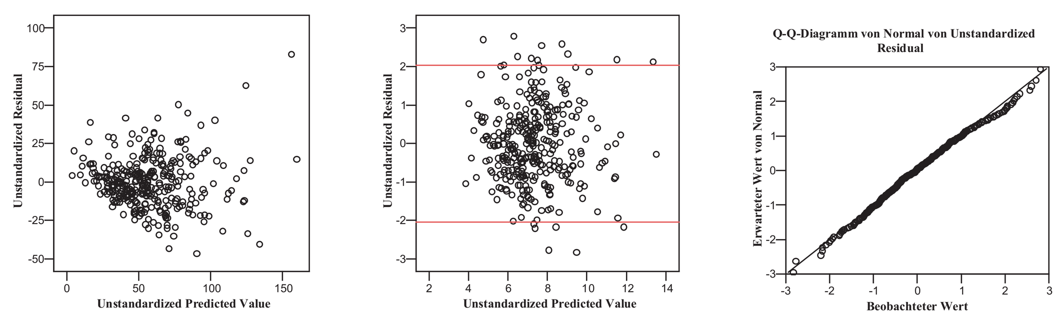
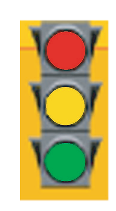


Figure 3.1: Without square root transformation the scatter plot of the residuals vs. the predicted values is funnel shaped (left graphic). After the transformation we see no specific shape of the pattern (middle graphic). The QQ−Plot against the normal distribution is a further indication that our assumptions are not violated.

3.3 Test Run

On the website `www.feinstaubfrei.at/htm/ampel_f.htm` the *PM10*−load is displayed as a traffic light system (green=low, orange=middle, red=high). The prediction model proved its worth as reliable monitoring tool.

	Prediction	$< 75\mu g/m^3$	$\geq 75\mu g/m^3$	Total
$PM10 \leq 75\mu g/m^3$	Count	87	6	93
	% within Category	93.5%	6.5%	
$75\mu g/m^3 < PM10 \leq 100\mu g/m^3$	Count	13	9	22
	% within Category	59.1%	40.9%	
$PM10 \geq 100\mu g/m^3$	Count	1	5	6
	% within Category	16.7%	83.3%	
Total	Count	101	20	121
	% within Category	83.5%	16.5%	100%



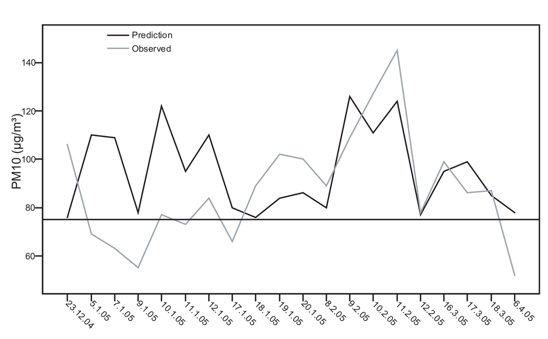


Figure 3.2: On days with prediction $> 75\mu g/m^3$ the actual measurement was always higher than the PM10-threshold value.

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 (in press).