PM10 SOURCE APPORTIONMENTS WITHIN THE CITY OF KLAGENFURT, AUSTRIA

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INTRODUCTION

Currently, PM10 is the most critical pollutant in the EU as the air quality standard for the allowed 35 days with an average PM10 concentration above 50 µg m^{-3} is not met in many cities. In Austria and Italy even in smaller cities south of the Alps this air quality standard is violated. One reason are bad dispersion conditions in alpine basins, where smaller cities are situated. For instance, at kerb site air quality monitoring stations within the city of Graz, owing a population of 250,000, more than 130 days with daily mean PM10 concentrations above 50 µg m^{-3} are observed.

Within the frame of a European funded LIFE Project (KAPA GS) launched in summer 2004, it is intended to perform PM10 source apportionments within the cities Klagenfurt (Austria), Graz (Austria), and Bolzano (Italy). In November 2004 a dense network of monitoring stations (GRIMM) for PM10, PM2.5 and PM1 were installed in Klagenfurt. In addition, chemical analysis of daily PM10 samples are being made at four monitoring stations for a period of one year. Unfortunately, these results were not available for this presentation yet. Based on the existing emission inventory, simulations for the spatial distribution of PM10 are currently performed using the Lagrangian particle model GRAL (Graz Lagrangian Model) by using a horizontal resolution of 10 m x 10 m. First results for the city of Klagenfurt are outlined in the following sections.

METHODOLOGY

A total of 12 air quality monitoring stations were installed in the city of Klagenfurt owing a population of 90,000. The topography, street network and the monitoring stations for PM are shown in Figure 1. Four monitoring stations were placed close to major streets, whereby two of them were situated near the same road on both sides to assess PM emissions from this road. Five urban background stations were mounted to get an idea about spatial gradients of PM concentrations within the city, and three stations were placed outside of the city to observe the background concentrations of PM.

There exist several possibilities to obtain modelled pollutant concentrations, which meet the requirements of environmental impact assessments. One of the most appealing ways to model air pollution in areas with complex terrain is to compute time series of 3-dimensional wind-, turbulence-, and concentration fields (e.g. Nanni et al., 1996). In order to be able to account for the influences of topography on the flow field (e.g. mountain-valley breeze, slope wind) models are initialized by a large scale model, such as ECMWF, and subsequently nested until the required horizontal resolution of the terrain and meteorological fields is reached. Due to very sharp concentration gradients usually found near highways and construction features like bridges, viaducts, dams, etc. (e.g. transit routes through alpine valleys) it is necessary to go down to say 200 m x 200 m horizontal grid spacing (Oettl et al., 2003a). Thus, mostly four times nesting is required. Clearly, the main disadvantage of this common approach is the extremely high demand on computer resources. Consequently, it is neither possible now nor in the near future to perform simulations in this way for periods of one year and more in the frame of practical applications. A current solution to overcome this basic problem is to select certain shorter periods of one year, which all together represent the concentration statistics for a whole year in terms of annual mean, percentiles, maximum concentrations etc. In fact, some uncertainty arises by this procedure as the selected periods will never perfectly match all necessary statistics for all pollutants in consideration. Moreover, if the periods were selected by analyzing concentration and meteorological data of one monitoring station it is not sure that this station is representative for a larger area too. The major advantages of this method are it's scientifically soundness and basically the independence on meteorological measurements (apart for evaluation of model results). Besides the high demand for computer capacities of this approach there is also a high demand for comprehensive input data to run such prognostic non-hydrostatic wind field models. As many of these parameters like soil moisture, soil temperature, snow cover, etc. are not well known on all spatial scales and as some variables can not be modelled exactly (e.g. cloudiness, precipitation, horizontal diffusion, heat fluxes, etc.) it is a very challenging task to model wind fields on the regional and local scale. At this stage it might be important to remember a hypothesis stated by Hanna (1989) regarding uncertainty related with air pollution models. Very simple models own uncertainties mainly because of errors in the physics, while very sophisticated models own increasing errors due to badly known input data. We may conclude that there should an optimal model/method exist with the best performance for today's scientific knowledge. Such can only be found by comprehensive model/method comparisons.

Wind field simulations for the rather complex nocturnal wind field of the city of Graz, Austria, first brought up the idea of a much simpler method to compute wind fields in complex terrain with a high horizontal resolution. In the study of Oettl et al. (2000) the Froude number dependent flow in the Graz basin could successfully modelled and explained by simply initializing the prognostic non-hydrostatic wind field model GRAMM (Graz Mesoscale Model) with a single point measurement of wind and simple assumptions about the vertical wind- and temperature profile. In other words, the wind field model was initialized with a horizontally homogenous wind field and then a steady-state wind field was computed by solving the Navier-Stokes equations (RANS). It has to be mentioned that this is the current way of computing building influenced flows in the microscale. The most important point is of course to find or mount a meteorological wind station, which is representative for the large scale wind (e.g. the mountain/valley breeze). This leads already to the main disadvantage of the method, as it is based on local wind observations, which are often not available for practical applications. Another disadvantage is that the wind field might be captured only well in the surface layer but not in the whole boundary layer. However, provided that one representative point measurement of wind is available, the method offers distinctive advantages compared to the method described before:

When using a locally observed atmospheric "stability" parameter (e.g. radiation balance) then some simple assumption can also be made about the vertical temperature and wind profiles in that area. This means that the model can already be fully initialized by the use of three locally observed input parameters, namely wind speed, wind direction, and a kind of atmospheric "stability". Due to this limited number of required input parameters it is still possible to establish a simple classification of the meteorological conditions. For instance, in this study 36 wind sectors, 5 wind speed classes, and 3 stability classes where used resulting in 322 different meteorological situations. The meteorological monitoring site here fore is located northwest of the city at the airport. As locally observed wind directions and speeds are used as input to the model, the main characteristics of the pollutant advection is already captured (frequency distribution of wind speed, wind direction). The main assumption is that all other parameters in a mesoscale model are of minor importance once the large scale wind is used as input. The subsequent computation of a steady-state flow field for each classified meteorological condition using constant boundary conditions derived from the locally observed large scale wind aims mainly at the simulation of very local topographical influences on the large scale wind (e.g. development of eddies in the wake of mountains).

Detailed descriptions of the models GRAMM and GRAL are given in Almbauer et al. (2000), and Oettl et al. (2000, 2002, 2003a,b,c). The main new developments in the model GRAL concern the used stochastic differential equations for the horizontal turbulent velocities. These are described in detail in Anfossi et al. (2005) and account for meandering in low wind speed conditions. This is an important issue as more than 70 % of the time wind speeds below 1.5 m s^{-1} prevail in the basin of Klagenfurt.

PM10 emissions for domestic heating, trade and industry where retrieved from the existing emission inventory for Klagenfurt. Exhaust traffic emissions were calculated applying the model NEMO (Network emission model, Rexeis M. and S. Hausberger 2005) and non-exhaust traffic emissions were estimated on the basis of the study by Gehrig et al. (2003). Finally, PM10 emissions from agricultural operations were estimated using emission factors derived by Oettl et al. (2005).

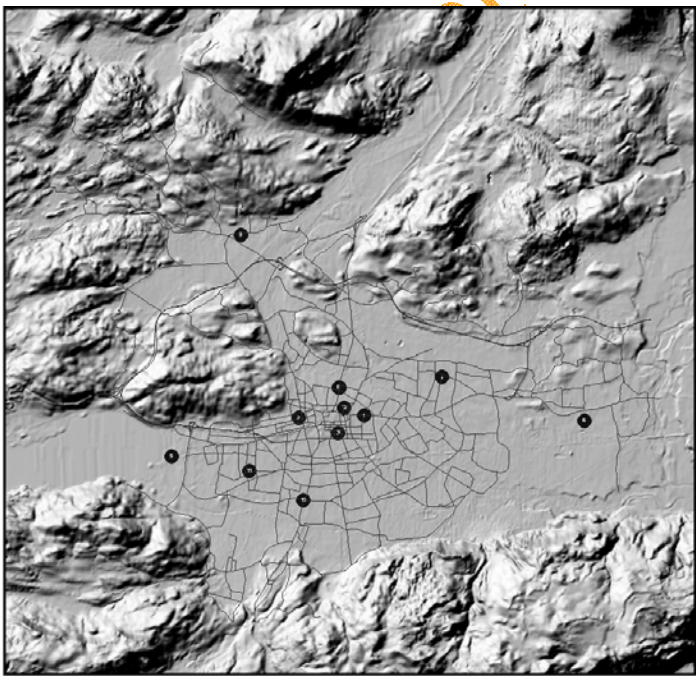

Fig. 25; Topography, street network and PM monitoring stations in the city of Klagenfurt.

RESULTS

Figure 2 displays a comparison of modelled annual mean PM10 concentration without adding a background concentration and the observed concentrations. The linear regression analysis suggests a background concentration of 21 µg m^{-3}, which is in good agreement with rural monitoring sites in the southern part of Austria. The coefficient of determination is satisfying and confirms the reliability of the method to assess the spatial PM10 concentrations in Klagenfurt.

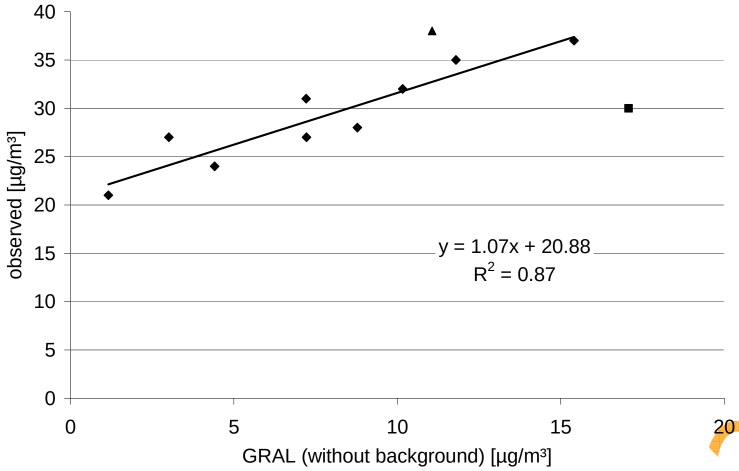

Fig. 2; Scatter plot of modelled annual mean PM10 concentrations without background vs. observed ones.

Figure 3 depicts the modelled contributions of different sources to the observed total annual mean PM10 concentration at a kerb site and an urban background site. The major source for PM10 within the city is at both locations traffic with shares between roughly 30 % and 15 %. It is interesting to note that the non-exhaust shares are remarkable higher than the exhaust ones, which calls for measures to reduce re-suspension of PM10 as well as road, tire, and break wear. Significant contributions are also given by domestic heating with about 10 %. Chemical analysis in the city of Vienna (Puxbaum et al., 2005) suggested also a similar value. Another important result is the high share of the so-called background concentration defined as contribution of all other sources outside of the model domain (Fig. 1), all sources not considered in the emission inventory, and secondary aerosols generated within the city. The latter leads to the conclusion, that it is almost impossible for cities like Klagenfurt to implement reduction measures to meet the air quality standards for PM10. Thus, efforts have also to be undertaken to reduce the background concentration itself, which consists to a large extent of secondary aerosols (ammonium nitrate and ammonium sulphate). At the moment it is not clear, whether the high background concentration results mainly from local emissions or if long-range transport (e.g. from eastern European countries) plays an important role, too.

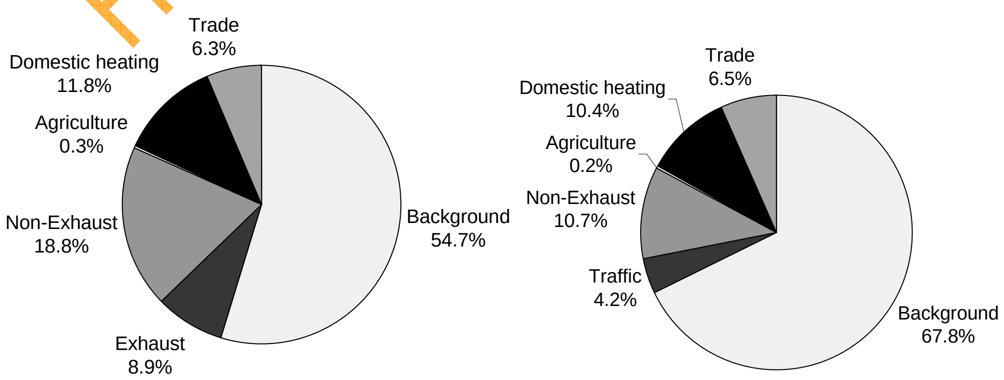

Fig. 3, Modelled contributions of different emission sources to the total annual mean PM10 concentration at a kerb site (left) and an urban background site (right).

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