4.16 AIR QUALITY DISPERSION MODELLING OF WOOD SMOKE EMISSIONS IN RESIDENTIAL AREAS IN SWEDEN.

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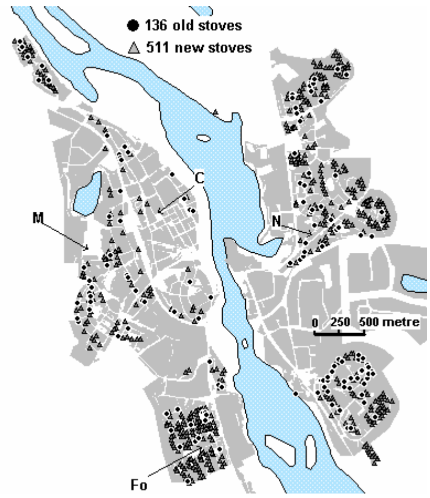
INTRODUCTION

An increased use of small-scale biofuel is one of the alternatives considered for the phasing out of fossil fuels. The Swedish Energy Agency has initiated and supported a three-year research programme (2001-2003) called Biomass Combustion Health and Environment. The aim of the programme has been to investigate the emissions from biofuel combustion and their effects on the environment and health. Although this information is sought for on a national scale, the project has been concentrated to two pilot towns where both ambient measurements and dispersion modelling have been performed.

EXPERIMENTAL SITES

The two pilot towns Lycksele and Växjö were selected because they represent a high use of bioful use, but also very different meteorological conditions. The results to be described here come mainly from the northernmost city, Lycksele. It is a small town with about 9000 inhabitants situated in the inland of northern Sweden (N64.6 E18.7). A river valley crosses the town, with typical height differences between the river and the surrounding hills of a couple of hundred meters. Wintertime inversions with cold ambient temperature, light winds and strong stable boundary layers are frequent. Växjö is a medium size town with about 50 000 inhabitants, located in the southern part of Sweden (N56.9, E14.8). In comparison to Lycksele, the air quality in Växjö is more influenced by long range transport of air pollution as well as traffic emissions. Moreover, the dispersion is expected to be less affected by strong wintertime inversions.

Figure 1 shows the locations of residential wood boilers and monitoring stations in Lycksele. About 136 of 647 wood boilers are old with an emission of combustion particles of about 35 ton/ year. The corresponding emission for the other wood boilers is about 1 ton/year.



Yearly PM emission in Lycksele: 66 ton/year	
Traffic exhaused	1
Old wood stoves	35
New wood stoves	1
Snowcats	1
Offroad mashines	12
Small scale oil	1.2
Thermal plant (bio)	15

Figure 1. Wood stove sources, monitoring stations and estimated PM10 emissions in Lycksele, Sweden. Air quality stations: Fo-Forsdala, N-Norrmalm,C- town Centre, M-meteorological station.

MODELS

For the modelling part of the project we used two Gaussian dispersion models (*Airviro* and *Dispersion*) and one Computational Fluid Dynamic model (CFD, *StarCD*). The meteorological inputs for the Gaussian models were local measurements. For the CFD model the meteorological model *HIRLAM* was used to produce meteorological data to the boundaries of the model.

RESULTS

Lycksele

Figure 2 gives an overview of some important results from the measurements. Local contributions were only important during cold ambient air conditions. The data were divided in two groups, one for conditions when the temperature was below –10 °C (group 1) and the other for temperatures above –10 °C (group 2). Local contributions were calculated as the differences between measured concentrations inside the town and those measured outside the town at the rural background station Vindeln (situated about 75 km from Lycksele). Local contributions were only important during cold conditions. The atmosphere was then very stable with wind speeds below 1 m/s. In the vertical, dispersion was limited by low mixing heights, estimated to be some tenth of meters. At the same time strong fluctuations in the horizontal wind directions were observed, resulting in relatively high lateral turbulence intensities and diffusion rates. For the Gaussian models these effects were included, directly by using measurements of the standard deviation of the wind directions (*Airviro*) or by modelling this effect using a method described by *Hanna*, 1983 (*Dispersion*). The mechanical wind anemometer used in the beginning of the experiment showed some problems related to these fluctuations during low wind speeds. Later in the project a sonic anemometer replaced the mechanical wind direction instrument.

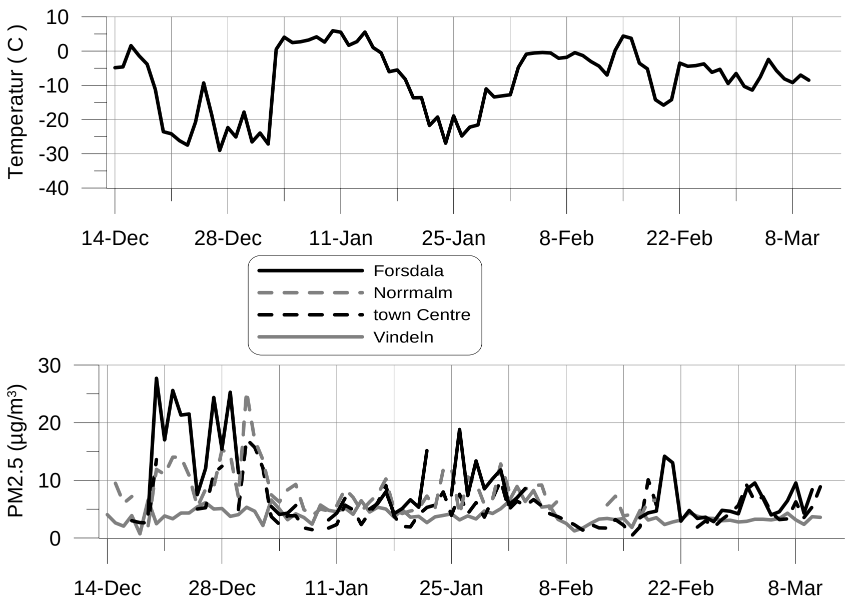


Figure 2. Daily mean of PM2.5 (µg/m³) from measurement stations in Lycksele (Forsdala, Normalm and town centre) and from the background station Vindeln. The upper figure shows daily mean temperatures.

For cold conditions (group 1), the Gaussian models gave reasonable results comparison to measurements of PM2.5, with slightly better results for *Dispersion* compared to *Airviro*. The later model showed some tendency of simulating too high concentrations, due to too narrow plumes modelled close to the sources. During warmer conditions (group 2), the models

systematically over-predicted the concentrations due to too simple description of the wood burning activity in the emission database.
The lack of information on the temporal variations in wood burning is a major problem. A way to handle this is to use measured concentrations and relate them to some basic ambient parameter like temperature. This was done by defining activity functions for wood burning, with the value of 1 for very cold conditions (data from group 1), and a small value for warm conditions (data from group 2). In fact wood burning was mainly used during cold conditions to heat the houses. In figure 3 a comparison is done between measured and calculated concentrations for all data. The model *Dispersion* simulated measured concentrations reasonably well.

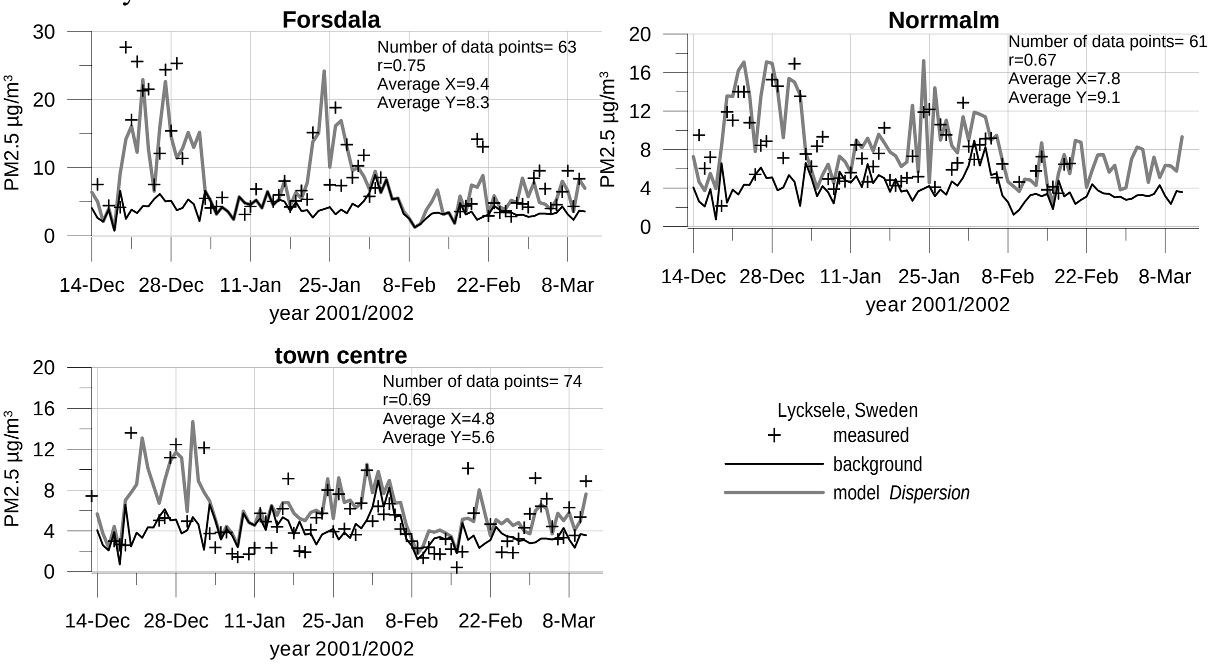


Figure 3. Measured (cross), simulated (grey line) and background (black line) daily average PM2.5 concentrations for the measuring campaign in Lycksele, Sweden. r is the correlation coefficient.

The model has then been used for calculation of air quality standards according to new EU legislation (Council Directive 1999/30/EC). Some important findings related to wood burning in residential areas are that:

1. The 98-percentile levels often exceed 50 µg/m^3 closed to the sources using old wood stoves.
2. The influence area is small with a horizontal extension of less then a few hundred metres.

The CFD-modelling part of the project aimed at understanding the dispersion processes related to the topography. The model was therefore set up for the whole city. An example of results is given in figure 4. The CFD model showed that during very cold conditions, a thin surface layer – a few meters thick – develops in which the dispersion takes place without influences from the synoptic wind higher up in the atmosphere. The drainage flow takes low level emissions downwards towards the river and other low-level areas. It is therefore likely that the Gaussian models will underestimate the PM concentrations in low and emission free areas. Still the highest concentrations are found close to the sources (houses with wood stoves), which justifies the use of Gaussian model results for regulatory purposes.

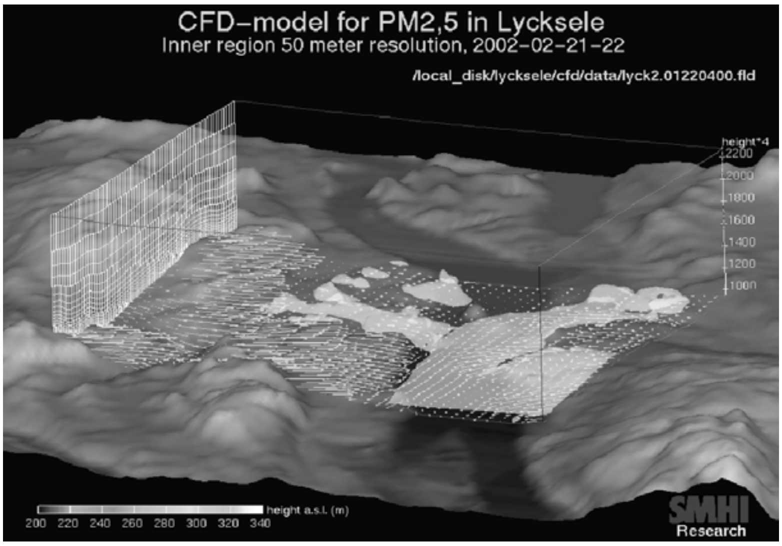


Figure 4. Example of results from the CFD-model showing calculated PM2.5 (µg/m^3) and wind arrows at 2 meters level at 2002-02-21-22. White area represents PM2.5 concentrations of 20 (µg/m^3).

Växjö

The impact of wood burning in the town Växjö, Sweden was small. High concentration levels of PM10 were mainly due to long-range transport of air pollutants. This is illustrated in figure 5, showing comparisons between measured PM10 concentrations at the background station Aneboda, situated about 40 km from Växjö, and measurements inside the town.

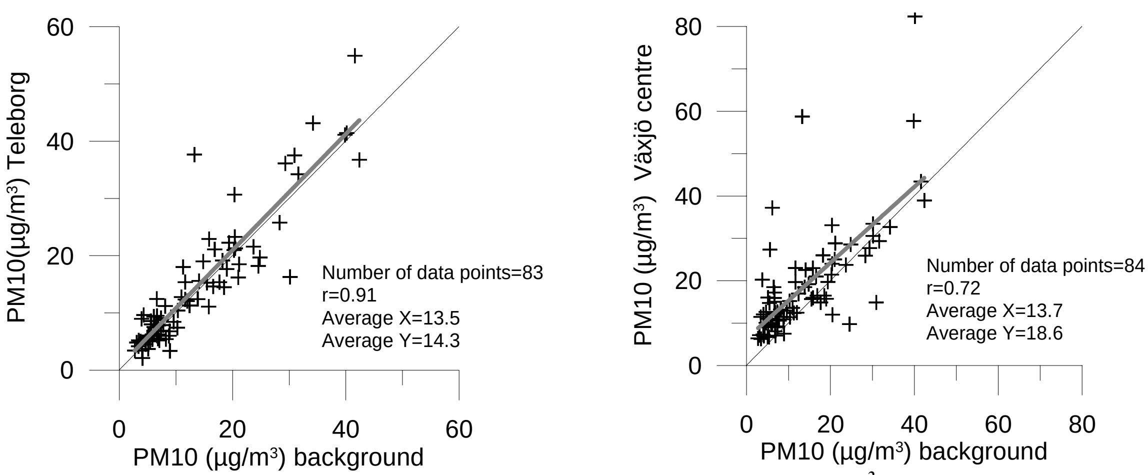


Figure 5. Comparisons between measured daily mean PM10 (µg/m^3) at background station Aneboda and in Växsjö, Sweden. Left figure shows the residential area Teleborg and right figure shows the town centre, r is the correlation coefficient.

CONCLUSIONS

The emission factors and their time variability are very critical parameters for the model assessment of the air quality and its relation to standards in areas with massive use of wood stoves. Environmental air quality standards for PM10 and evaluation thresholds (according to EU directives) were exceeded in rather different meteorological conditions in the two towns. For the northern town the main contribution was from local sources, mainly from biomass burning in old wood stoves, during strongly stable, light wind conditions. For the southern town the main contribution was long-range transport of air pollutants.

ACKNOWLEDGEMENT
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