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AIR QUALITY MODELING OF NON-ATTAINMENT AREAS AS A BASIS FOR AIR QUALITY PLANS

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Abstract: Directive 2008/50/EC requires preparation and implementation of the air quality plans for zones and agglomerations where one or more limit values have been exceeded. The air quality plans should be based on source apportionment, so that the measures are targeted effectively.
In 2010 a method has been developed at SHMI, implementing CALPUFF modeling system in order to carry out high resolution modelling and source apportionment of PM_{10} in the non-attainment areas in Slovakia, using routinely available data. The method has been gradually applied to the total of 18 areas over the period of the last 5 years. The results were presented at Harmo 15 (Krajčovičová et al, 2014), since then it has been subject to several improvements and upgrades. This paper presents recent implementation of the upgraded methodology for the air quality management area of Prievidza region. It includes modeling of PM_{10} and $PM_{2.5}$, NO_2, SO_2 and benzo(a)pyrene (BaP). Whole year of 2013 is modeled and the results are compared to the available air quality monitoring data.

Key words: *air quality modeling, CALPUFF, source apportionment, PM_{10}, $PM_{2.5}$, NO_2, SO_2, benzo(a)pyrene*

INTRODUCTION

High concentrations of PM_{10} and $PM_{2.5}$ have been a major problem in most regions of Slovakia for a long time. In addition, exceedances of NO_2 and BaP limit values has been observed in some monitoring locations. Currently, there are 17 so called air quality management areas in Slovakia, which are areas where a limit value of one or more pollutants has been exceeded. Air quality plans has had to be prepared for all such areas and for most of them the plans are regularly revised and updated as the problems with high concentrations persist. Air quality management of Prievidza region is an example. It covers an industrialized district of the size of 960 km^2, with the population of 136 500 inhabitants. The district capital is Prievidza located in the NW. Handlová, located in a narrow valley in the NE is a smaller mining town. Bystričany is a village in the SW, where third monitoring station is located, due to its vicinity to a large chemical plant in Nováky and coal power station in Zemianske Kostoľany. The population density of the district is 142 people per km^2. It has been historically one of the most polluted regions, hosting some heavy chemical and energy production industry and several coal mines producing low quality coal. Today, due to technological advances, the emissions from industry has been continuously decreasing. However, due to increasing costs, local heating has been shifting from natural gas to wood burning, with the emissions replacing in their importance those of the industry.

Slovak Hydrometeorological Institute is responsible for carrying out air quality analyses as a basis for Air quality plans. We carried out an air quality study for Prievidza in 2008 for the first time. It was focused on mainly on PM_{10}. This year we have updated the modeling taking 2013 as a basis. Besides PM_{10}, other pollutants has been included, such as PM_{10} and $PM_{2.5}$, NO_2, SO_2 and BaP.

EMISSION SOURCES

The following source groups have been included in the simulations:

- Large and medium sources from National Emission Information System (NEIS) database
- Seasonal sources of residential heating
- Road transport

Besides these, there are of course other sources, e.g., nearby agricultural activities, temporary construction sites, occasional fires or accidents which can have impact on the PM10 concentrations

during a limited time. As we are not able to quantify their emissions, they are not included in our modelling. Fortunately, they do not have a substantial influence in the long-time perspective.

Large and medium sources from NEIS database

They comprise of seasonal point sources (centralized heating), non-seasonal point sources (industrial stacks), and fugitive industrial sources, represented as volume sources in the simulations.

Seasonal sources of residential heating

Emissions from residential heating are based on the statistical census data (ŠÚSR, 2011), containing number of households using solid fuels for heating, sizes, age and insulation status of houses and other useful parameters for each census element (element being of a size of a small municipality or several streets of a city). Climatological parameters of local heating season have also been included in the model, which computed amount of combusted wood. Consequently emission factors for each pollutant in question have been applied. These emissions has been geographically allocated to residential areas identified using Google Earth.

Road transport

Exhaust and non-exhaust vehicle emissions were calculated using a top-down method from the total national emissions (COPERT 4), based on the ratio of road network length inside the domain to the total road network length. Consequently, the emissions were distributed throughout the roads in the domain based on the road category and length, vehicle counts and categories.

Resuspension of dust was estimated based on the AP 42 (US EPA, 2011) methodology using bottom-up approach.

MODELING TOOLS AND SETUP

As the district of Prievidza is a mountainous region, CALPUFF model (Scire et al., 2000b) was used as our modelling tool, driven by diagnostic meteorological model CALMET (Scire at al., 2000a). The terrain model (SRTM – Farr et al., 2007) and landuse (CORINE – Bossard et al., 2000) together with full year of 2013 meteorological data from three surface meteorological stations within the domain and three upper air sounding stations outside the domain were input to CALMET model, which calculated high resolution three dimensional wind fields reflecting local orography and circulation systems.

The size of the modelling area is 33.5 x 27.5 km, horizontal resolution is 500 m (meteorological fields). There are 10 vertical layers with top at 3000 m. Industrial sources from NEIS database were modeled as point sources (part of them seasonal), residential heating sources were modeled as grids of volume sources with the horizontal resolution of 20 m, and road emissions were modeled as segments consisting of volume sources. As CALPUFF only takes into account emission sources located within the modeling domain, a regional background (nearest available EMEP station has been used) was added to the contributions of the above mentioned source groups in order to compute totals.

RESULTS

Table 1 shows the contributions of different source groups to the total concentrations at the locations of the air quality monitoring stations, compared to measured values. However, some of the pollutants, such as NO2, are not monitored at any of the stations, while other, such as BaP, are monitored only in one of them. In those locations where comparison is possible, the results are rather encouraging.

Although NO_2 measurements are not available, the modeling results suggest that the annual mean limit value might be exceeded at Prievidza monitoring stations. This should be investigated further, using better resolution, as the monitoring station is located rather near a major road (cca 40 m), where the concentration gradients are high.

Figure 1 shows the maps of total annual concentrations for different pollutants. High concentrations of PM_{10} and $PM_{2.5}$ are concentrated in and around residential areas with local heating in Handlová and Bystričany. Prievidza is a larger town where wood combustion does not occur as frequently as in the

previous two cities. As expected, NO_2 is concentrated along the roads, with very small contribution from residential heating. SO_2 is emitted from high industrial stacks and therefore has much more regional character. As it dilutes sufficiently, the total SO_2 values are well under the legislative limits for vegetation protection. Modeling results seem to underestimate SO_2 concentrations.

Table 1. Annual mean values of pollutants as modelled by CALPUFF, compared to measurements at three monitoring stations.

Station	Point ($\mu g.m^{-3}$)	Road ($\mu g.m^{-3}$)	Residential heating ($\mu g.m^{-3}$)	Regional background ($\mu g.m^{-3}$)	Total ($\mu g.m^{-3}$)	Measured ($\mu g.m^{-3}$)
NO_2						
Prievidza	0.6	50.3	0.3	4.3	55.5	-
Bystričany	2.6	14.3	2.2	4.3	23.4	-
Handlová	0.7	22.3	1.5	4.3	28.8	-
SO_2						
Prievidza	1.6	0.1	0.0	1.5	3.1	10.7
Bystričany	9.1	0.0	0.0	1.5	10.6	17.4
Handlová	0.7	0.0	0.0	1.5	2.2	8.3
PM_{10}						
Prievidza	0.5	6.4	1.4	18.1	26.4	32
Bystričany	1.1	2.6	10.8	18.1	32.6	35
Handlová	0.1	3.1	7.5	18.1	28.9	24
$PM_{2.5}$						
Prievidza	0.4	3.2	1.3	11.8	16.7	25
Bystričany	0.7	1.1	10.2	11.8	23.8	22
Handlová	0.1	1.5	7.1	11.8	20.5	16
BaP[1]						
Prievidza	0.0	0.0	0.3	0.7	1.0	1.8
Bystričany	0.0	0.0	2.2	0.7	2.9	-
Handlová	0.0	0.0	1.5	0.7	2.2	-

CONCLUSIONS

Although the modeling results are quite encouraging, it is necessary to make further simulations on smaller domains with higher resolution. We are planning to set three additional smaller domains around Prievidza city, Handlová and Bystričany, and use better resolution of road segments. In the current simulation, we used emission factors for residential wood combustion identical with those used for national emission reporting in Slovakia (MoE, 2008). However, these emission factors are extremely high (all countries around use much lower values) and need to be reevaluated. We also need to improve the road emission data by introducing daily and weekly variability.

[1] BaP values are in $ng.m^{-2}$

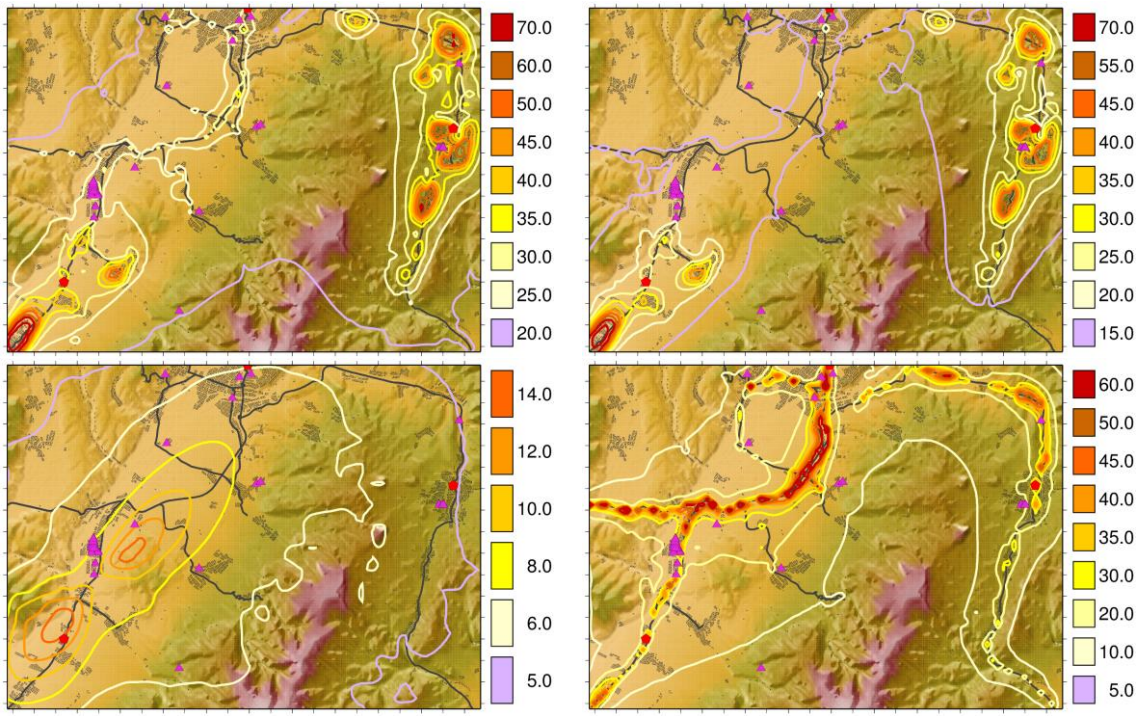

Figure 1. Annual concentrations of PM_{10} (upper left), $PM_{2.5}$ (upper right), SO_2 (lower left) and NO_2 (lower right) modeled by CALPUFF. Red pentagons are monitoring stations, pink triangles are industrial point sources and black lines are major roads.

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