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ZASAVJE CANYON REGIONAL ON-LINE AIR POLLUTION MODELING SYSTEM IN HIGHLY COMPLEX TERRAIN AS A SUPPORT TO EU DIRECTIVES

Primož Mlakar[1], Marija Zlata Božnar[1], Boštjan Grašič[1] in Gianni Tinarelli[2]

[1]MEIS d.o.o., Mali Vrh pri Šmarju 78, SI-1293 Šmarje - Sap, Slovenia
[2]ARIANET s.r.l., Via Gilino 9, 20128 Milano, Italy

Abstract: Zasavje is an industrial region in Slovenia. It is located along the Sava river's steep canyon and amongst the surrounding hills and valleys. In the region, PM10 air pollution is a major problem and it is explicitly pointed out by the European Commission. In the area, local inhabitants or environmental associations are strongly against the operation of some industrial plants due to the air pollution they cause although the plants are not the only significant source of pollution. These problems are regulated by the European directive of Integrated Pollution Prevention and Control (IPPC) which requires among others that industrial source's influence on the ambient air is modelled once to obtain the IPPC permit. Future European directives that are now in the preparation phase also emphasize the use of air pollution models in on-line mode for informing the local community as state-of-the-art science enables this already. In the paper a national project with the title "Prognostic and diagnostic integrated regional air pollution modelling system" will be described. We will show that such a project can significantly contribute to the proper understanding of air pollution in smaller regions with very a complex topography. We will show how we solve foreseen scientific problems, perform necessary testing, improvements and validation. The development of a Lagrangian particle model based air pollution modelling system that works in on-line diagnostic and prognostic mode and covers air pollution from several industrial and other sources in the region over a highly complex terrain, will be described. To achieve on-line efficiency some new methods to obtain high resolution short-range meteorological fields derived from meso-scale models have been developed and the implementation of advanced Lagrangian model's acceleration techniques and novel approaches for the whole system integration will be presented. The project's test-bed was established as a novel approach to the overall treatment of the scientific – applicative project goal.

Key words: *Lagrangian particle air-pollution dispersion model, Zasavje region, canyon, IPPC, complex terrain, on-line diagnostic and prognostic mode*

INTRODUCTION

As in many other parts of Europe, Slovenia is facing significant problems with excessive air pollution with PM10. Due to this pollution, many regions of Slovenia will be declared degraded regions in the near future (Ministry of the environment and spatial planning, Republic of Slovenia, 2011a). This will demand the implementation of appropriate measures for reducing pollution by the state, as well as by local communities and other agents. In Slovenia, there is mostly very complex terrain, many industrial plants with emissions into the air, traffic roads and local heating systems are scattered across poorly ventilated valleys and basins, which only worsens the issue of air pollution.In this paper, we will describe a pilot modelling system which helps solve this issue. The system is built for the central Sava valley, but is easily transferable onto other regions, where there is a danger of the same extent of air pollution problems as in the central Sava valley region.

ZASAVJE REGION – EXAMPLE OF A VERY COMPLEX TERRAIN WITH SOURCES OF PM10

The central Sava valley is an example of very complex terrain. It is scattered with high hills with an altitude between 600 m and 1200m, which is intersected by the main canyon of the Sava river, which flows at an altitude of 200 m. Three other larger valleys, which at some places extend almost into the shape of a basin, are diagonally connected to this narrow and deep canyon. Poor ventilation is characteristic of the entire region beneath the hills, and there are multiple occurrences of temperature inversions during the winter, which occur at different altitudes and can be very long-lasting.The complexity of the region can be described with an hlTc = (0.4km, 1.5km) – hlTc meaning the "height and length of Topographic complexity" index, as described in the paper (Božnar, M. Z., P. Mlakar, and B. Grašič, 2011) also published at this conference. Let us point out that we are referring to a region the size of 30km × 30km, which, for Slovene standards, can be called a "region", and corresponds within the context of dispersion model classification to the concept of "local scale" and not regional modelling.

The central Sava valley is facing such problems with PM10 due to numerous reasons. The foremost reasons are the weather conditions, which are unfavourable for dispersion in the air and which cause a pollution episode to be more extreme in comparison with the emissions happened on windy flat terrain. But as there is no air pollution without emissions, this is not the only reason.

There is a large concentration of industry in the central Sava valley, ranging from the manufacture of cement, lime and glass, to a thermal power plant and wood processing. None of these activities are new to the region, but have very long traditions. All of this industry came into existence in the described region due to the brown coal deposits, which provided an energy source, and vast forests, whose wood is also a raw material for processing and was used as an energy source for the glass industry.In addition to the larger industry in this region, there are also many smaller factories and boiler houses which emit dust particles into the atmosphere, which, although their yearly quantity is not very large, contribute significantly to the pollution of air with PM10, because they are located in regions which are not suitable for emissions into the atmosphere. Placing a factory with a low chimney at the foot of a hill in a poorly ventilated basin results in the surrounding inhabitants having heavily polluted air.

A special problem are the local domestic heating systems, as the region, except for three larger settlements, is covered with sparsely scattered private buildings, which do not yet have the option of being connected to the hot water or gas network.

These networks are generally available only in the areas of the three main settlements. As there are quite a few forests in the region, heating with wood is cheap, which is especially important during the times of recession and unemployment.

A further problem in the area is that a significant amount of dust is emitted into the atmosphere by numerous smaller and larger quarries, and coal and ash depots, and that this material is consequentially dispersed across roads by transport lorries (by tyres and open containers and dirt on bodyworks).Traffic is also a source of PM10 pollution. Some of this is the consequence of direct emissions of exhaust gasses, as a large portion of the traffic are transport vehicles, but there is significant additional pollution due to the resuspension of dry dust from the road. The dust is brought there by transport vehicles from quarries and depots, and some of it due to the gritting and salting of the roads during the winter.A part of the pollution is caused by the inappropriate burning of biomass in the countryside and in the settlements.

DEGRADED REGION – MEASURES ARE URGENTLY NEEDED

Of course, the excessive pollution of outdoor air with PM10 urgently necessitates taking measures. A decree is being prepared for the central Sava valley, which will stipulate different measures, whose sum should result in the following years in a significant reduction in the pollution of the air in the region with PM10.The measures encompass the entire range of the sources of PM10 emissions named above.For road traffic, wet cleaning of roads will be implemented. Quarries will be required to carry out their activity so that dust emissions are minimised.There will be a gradual stimulation of connection to the hot water and gas networks where possible. For other local domestic heating systems, the replacement of combustion devices with more efficient ones with lower emissions will be subsidised.

Of course, a special issue is the treatment of the existing industrial sources of PM10 pollution. Reducing their emissions in the periods with very unfavourable weather conditions for the reduction of the concentration of emissions in the air is one of the possibilities, but it is not cheap and will thus have to be implemented on the basis of valid criteria and in proportion to the actual amount of increased concentrations in the atmosphere caused by individual sources.

A MODELLING SYSTEM AS A TOOL FOR RAISING AWARENESS OF AND REDUCING POLLUTION

As there are, as mentioned in the previous chapters, several different types of sources in the subject region, only a modelling system can show us the extent of the contribution of individual sources in the resulting concentration of PM10 in the atmosphere in individual regions. A chemical analysis of the dust captured in filters can also give us only approximate information on possible sources (Slovenian Environment Agency, 2009, Slovenian Environment Agency, 2010).

Here at MEIS, we have developed a modelling system for monitoring the quality of the outdoor air in the central Sava valley, which, for now, is primarily intended for raising the awareness of the inhabitants. Our goal is to calculate, on the basis of as valid meteorological data as possible and data on PM10 emissions, the resulting concentrations of PM10 in the entire area of the subject region. The modelling system operates in two modes. In the diagnostic mode, we wish to obtain valid data on current pollution. In addition, we wish to forecast pollution for a day or two in advance in the prognostic modes.The prognostic mode, along with the diagnostic mode, is intended for managing the implementation of measures for the reduction of PM10 concentrations in the outdoor air during periods with significantly unfavourable weather conditions which slow down the reduction of the concentration.

For now, we are publishing our findings on the contributions on individual important industrial sources at the public internet portal. In the testing phase, we are also modelling the dispersion of air pollution from the local heating systems and the main road connections. For industrial sources, there are measurements of emissions available on-line, but they have unfortunately not yet been integrated into the system; for now, we are only considering nominal emissions (we are in the process of reaching an agreement on the transfer of automatic measurements). Unfortunately, there are, as of yet, no emission cadastres for smaller sources and local domestic heating systems, quarries and the road network, but their creation is stipulated by the Decree being prepared pripravi (Ministry of the environment and spatial planning, Republic of Slovenia, 2011b). We thus used in the first phase only a rough estimate of these domestic heating emissions, available at the public internet portal of ENERGIS, which studied the issue of emissions in its study for this region(Cerkvenik, B, et al., 2007, Ministry of the environment and spatial planning, Republic of Slovenia, 2011b).

Figure 1. Public monitors showing air pollution situation in the Zasavje region for the last 24 hours
(left: monitor in public library,right: monitor in regional centre of Administration for civil protection and disaster relief in Trbovlje).

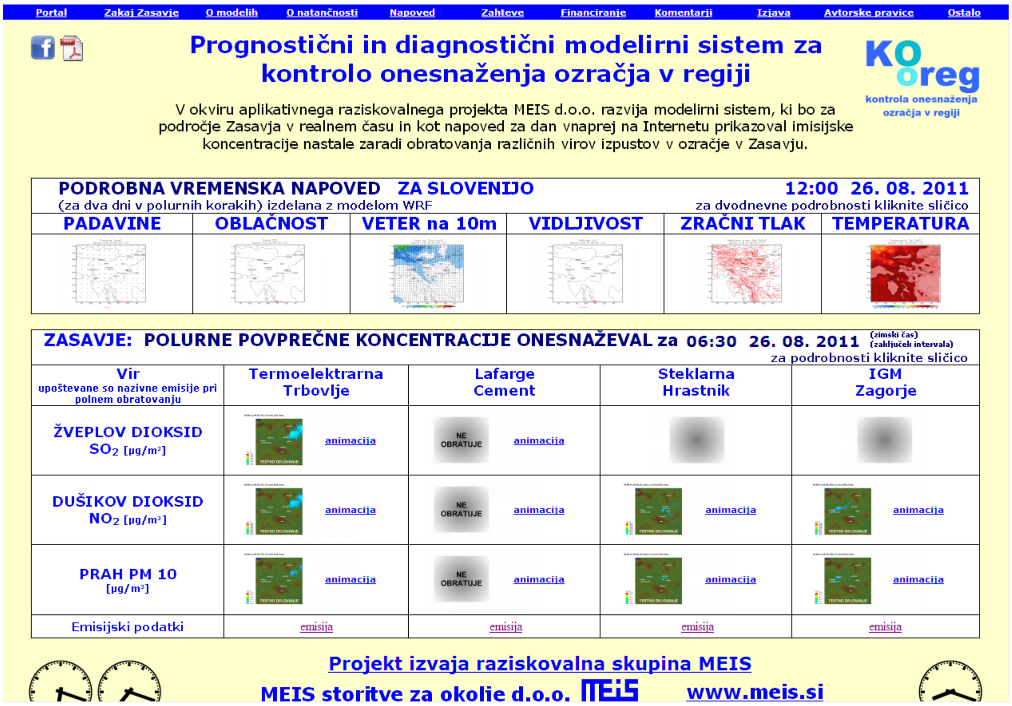

Figure 2. Public portal KOOREG showing weather prognosis (upper set of pictures) and current air pollution situation (lower set of pictures) for four main sources of air pollution in the Zasavje region (columns) and three species (rows).
Portal is available at http://www.kvalitetazraka.si. (KOOREG, 2011)

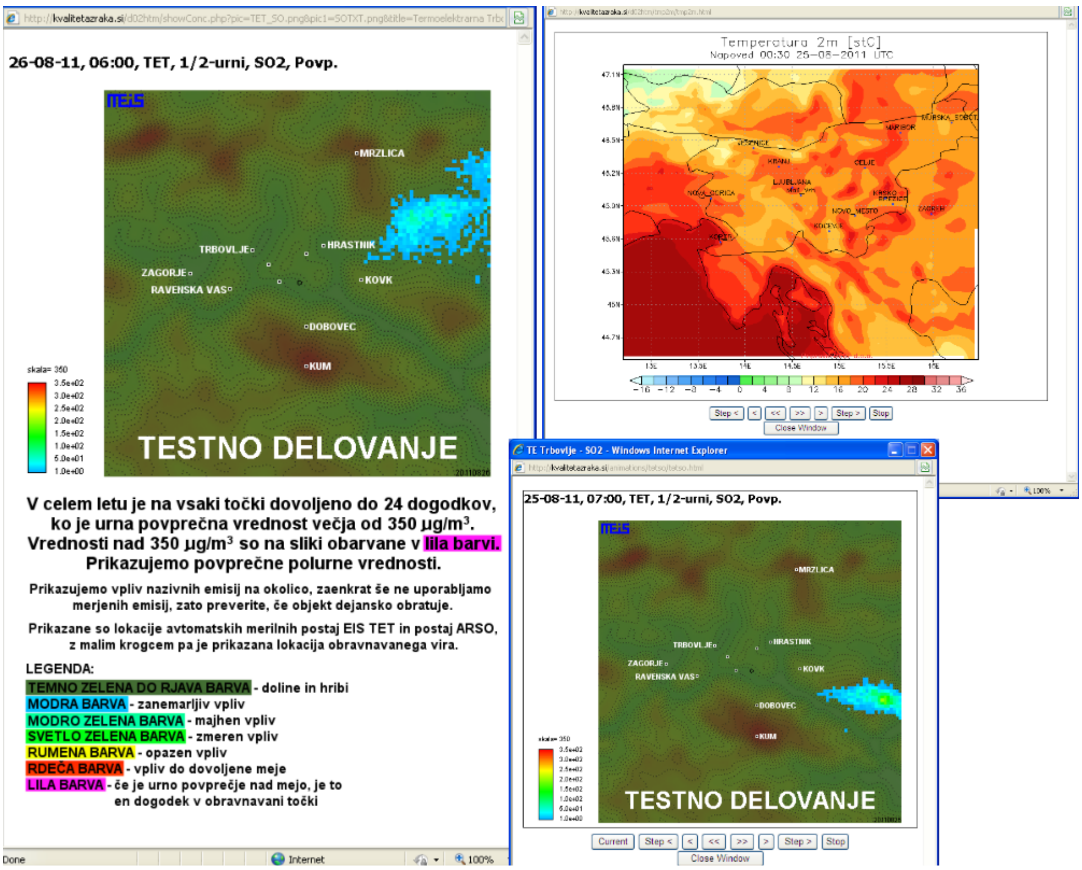

Figure 3. Public portal KOOREG showing results in details in test operation
(left: air pollution over region for one source (thermal power plant Trbovlje) and one specie (sulphur dioxide)
upper right: animation of temperature prognosis for 24hours ahead in ½ hour intervals,
lower right: animation of air pollution for the last 24 hours in ½ hour interval)

DESCRIPTION OF THE MODELLING SYSTEM

We have 9 meteorological stations available in this region for recording meteorological conditions in real time – three from the national outdoor air quality control network and the rest from the Ecological Information System of the Trbovlje Thermal Power Plant. The stations are more or less adequately scattered across elevated points and basins and valleys. Unfortunately, there is no measurement data available on-line for the wind or temperature profile, but there was a efficient SODAR available in the region in the past. We thus obtain the data required for the urgently required meteorological profile from the prognostic modelling system based on the WRF model. The details are described in another paper published at this conference (Božnar, M. Z., P. Mlakar, and B. Grašič, 2011). The meteorological measurement data and the prognosticated profile (we use only a part of the profile for the upper layers of the atmosphere, and not for the ground) are used as the input data for the SURFPRO preprocessor and the Swift 3D mass consistency model (Desiato, F. et al., 1998). The Swift model is applied to a domain the size of 20km × 20km, with its centre at the Trbovlje Thermal Power Plant and with a horizontal resolution of 200m and a temporal resolution of 30 minutes. We input into the thus obtained 3D meteorological field the modelling of the dispersion of pollution in the atmosphere using a Lagrangian particle model SPRAY used in the same resolution. For now, we are using the SPRAY model for all sources(Brusasca, G., G. Tinarelli and D. Anfossi, 1992, Anfossi D. et al., 1993, Tinarelli, G. et al., 1994, Tinarelli, G. et al., 2000), including the local domestic heating systems and traffic, and we are planning on using the FARM Euler model (Pession, G. Et al., 2008) for a better distribution of smaller heating systems and traffic. All the models were developed by ARIANET, Milan and ARIATechnology, Paris.

We use the same models in the prognostic mode, but only the profiles prognosticated using the WRF model are used as input data, so the consistency with the actual state is, of course, not as good. Due to the complexity of the local meteorological data, adequate weather prognosis in fine resolution in this region is still a scientific issue (see Božnar, M. Z., P. Mlakar, and B. Grašič, 2011).

In addition to PM10, the modelling system also surveys the following pollutants: SO2, NO2. Ozone and secondary aerosols are not being modelled as of yet, but it is possible that it will be included in the future. It will be possible to carry out 3D modelling using the FARM model, or to only provide forecasts at measurement locations with automatic measurement stations. In the past, we developed a forecasting methodology on the basis of artificial neural networks (Grašič, B., P. Mlakar and M. Z. Božnar, Marija, 2007, Mlakar, P. and M. Z. Božnar, 2011); a similar methodology was being developed by other researchers (Petelin, D., J. Kocijan, and A. Grancharova, 2011).

EXAMPLES OF PRESENTING RESULTS TO THE PUBLIC

For the purpose of presenting results to the public, we have created a portal with a quite simple configuration, which nonetheless enables access to detailed information. We also used a simple design with the intention of making the portal viewable on more sophisticated mobile phones and thus available to interested users anywhere and at any time.We display the real-time status in an expedited view. We display the results of the diagnostic mode for the previous two days and will shortly display the results of the prognosis for the current and following day in a similar manner.All the displays feature appropriate colour legends which help amateurs understand the displayed contents.During the entire process of creating a modelling system which would help solve the issue of air pollution in the central Sava valley, our goal was to include all stakeholders. The project initially gained the support of the mayors of all the municipalities in the region. We gained the interest of the larger industry, which voluntarily joined the project by providing exact emission data. In the final phase, we extensively explained the results and the approach to the inhabitants at a public presentation. The response was excellent, and the volume of visits to the website displaying the results has remained constant even months after its establishment (over 200 different users per month, which is a considerable achievement for such a small region). The entire process is a good example of a Living Laboratory approach to solving an urgent issue, wherein the population receives help through scientific accomplishments as well as through an appropriate technological approach.

CONCLUSIONS

The described modelling system is a suitable tool for understanding the mechanisms of the dispersal of pollution in the atmosphere in the small region of the central Sava valley over very complex terrain and consequentially very complex meteorology.The modelling system, with its display of data in a simple form on the internet, is a suitable tool for educating and raising the awareness of the inhabitants of the region, who are dealing with excessive air pollution.

The modelling system is validated for meteorological prognosis data as well as for pollution modelling for the diagnostic and prognostic parts. The studies are in progress; some validation results have already been published for this region in the past (Božnar, M., B. Grašič, and G. Tinarelli, 2006, Božnar, M., P. Mlakar, and B. Grašič, 2008), some are published at this conference (Božnar, M. Z., P. Mlakar, and B. Grašič, 2011, Grašič, B., M. Z. Božnar, and P. Mlakar, 2011), and they will be published in a more extensive form in the near future.

The validation of both the meteorological part of the modelling system and the system for modelling the concentrations of pollutants in the atmosphere is an urgent and essential first step before the use of such a system for raising the awareness of the public, reporting to the EU and for planning pollution reduction measures. It is especially important for the aforementioned measures, which are very expensive or could negatively affect manufacture in industrial plants, that they are planned on the basis of a system validated for a region of the same complexity as the subject region.

In our case, the case of the central Sava valley, we have the luck of having, in such a small subject region, a great number of meteorological stations and stations for measuring the concentrations of pollutants in the atmosphere, so that it is possible to carry out validation using the data from this exact domain. This is also of paramount importance because the subject region features very complex terrain and there are very little data sets or validation studies available for similarly complex terrain, or they are not comparable to the central Sava valley for other reasons (e.g. different meteorological mechanisms – in coastal regions, for example).

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