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VALIDATION OF LOCAL SCALE PROGNOSTIC AND DIAGNOSTIC AIR POLLUTION MODELING SYSTEM IN EXTREMELY COMPLEX TERRAIN

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Abstract: Zasavje is an industrial region in Slovenia. It is located around the Sava river steep canyon and surrounding hills and valleys. In the region especially PM10 air pollution is a major problem, but also other pollutants such as SO2 and NO2 rich significant level. Beside the industry, region has other sources of pollution such as coal and wood domestic heating, traffic, bio-mass burning and several stone-pits. In the area a research prognostic and diagnostic air pollution modelling system is in operation based on meteorological measurements, prognostic meteorological data obtained by WRF and local scale modelling system based on Swift and numerical Lagrangian particle model Spray (by Arianet, Italy). Presentation will give the most important characteristics of the modelling system. Further one complex meteorological situation is presented as an example of how powerful such a system should be if our goal is to achieve match in time and space of modelled and measured concentrations of major pollutants. Presentation shows good results of validation of the above mentioned modelling system in very complex terrain.

Key words: *enhanced validation, Lagrangian particleair-pollution dispersion model, Zasavje region, complex terrain, on-line diagnostic and prognostic modelling system*

INTRODUCTION

Zasavje is an industrial small region in Slovenia. It is located in the central area of Slovenia around the Sava river steep canyon and surrounding hills and valleys. In the region especially PM10 air pollution is a major problem, but also other pollutants such as SO2 and NO2 rich significant level. Beside the industry, region has other sources of pollution such as coal and wood domestic heating, traffic, bio-mass burning and several stone-pits.

In the area a research prognostic and diagnostic air pollution modelling system is in operation based on meteorological measurements, prognostic meteorological data obtained by WRF and local scale modelling system based on Swift (Desiato, F. et al., 1998) and numerical Lagrangian particle model Spray by Arianet, Italy (Tinarelli, G. et al., 2000).Presentation gives the most important characteristics of the modelling system. It is our goal to achieve match in time and space of modelled and measured concentrations of major pollutants. Qualitative and quantitative validation results are presented.

ZASAVJE REGION – COMPLEXITY OF THE AREA

Zasavje region is a typical 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, vhere river flows at an altitude of 200 m. Three other larger valleys are diagonally connected to this narrow and deep canyon. These three valleys at some places extend almost into the shape of a basin. Main characteristic of the entire region beneath the hills is poor ventilation. During the winter there are multiple occurrences of temperature inversions. They occur at different altitudes and can be very long-lasting. The complexity of the domain can be described with an hlTc = (0.4km, 1.5km). hlTc meaning the “height and length of Topographic complexity” index which is described in the paper (Božnar, M. Z., P. Mlakar, and B. Grašič, 2011) also presented at this conference where also more detailed description of Zasavje region is given. For Slovene standards a domain of size 30 km x 30 km can be called a »region«, but in the context of dispersion model classification it corresponds to the concept of »local scale« modelling.

Emission of air pollution in the region is very diverse. There is a large concentration of industry in the central Sava valley. It ranges from the manufacture of cement, lime and glass, to a thermal power plant and wood processing. There are also many smaller factories and boiler houses which emit dust particles into the atmosphere. Additional problem are the local domestic heating systems, as the region is covered with sparsely scattered private buildings. A significant amount of air pollutants is emitted into the atmosphere by numerous larger quarries, and coal and ash depots. Also the traffic is a significant source of air pollution which consists of direct emissions of exhaust gasses and additional pollution due to the resuspension of dry dust from the road. And finally inappropriate burning of biomass in the countryside and in the settlements also plays an important part in the air pollution. Emissions are described in details in the paper (Mlakar, P., M. Z. Božnar, B. Grašič and G. Tinarelli, 2011) presented at this conference.

MODELING SYSTEM OVERALL DESCRIPTION

Modelling system is described in details in the paper (Mlakar, P., M. Z. Božnar, B. Grašič and G. Tinarelli, 2011) presented at this conference. For the diagnostic modelling there are 9 environmental 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.Unfortunately, there is no measurement data available on-line for the wind or temperature profile. Meteorological profile is therefore taken 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 same models are used for in the prognostic modelling, where only the profiles prognosticated using the WRF model are used as input data.Therefore the consistency with the actual state is, of course, not as good. Adequate weather prognosis in fine resolution in this region is still a scientific issue due to the complexity of the terrain (see Božnar, M. Z., P. Mlakar, and B. Grašič, 2011). The modelling system so far surveys the following pollutants: SO2, NO2 and PM10. These pollutants are also measured at 9 environmental stations which are located in this region. This measured data will be used in continuation for the validation.

APLICATION OF WRF MODEL FOR METEOROLOGICAL PROFILES PREDICTION

For meteorological profiles prediction we have applied the WRF Weather Research & Forecast model which is described in details in paper published at this conference (Božnar, M. Z., P. Mlakar, and B. Grašič, 2011). Summary of the configuration is following: two domains, duration of prediction: 2 days and 3 hours, a larger domain (central Europe): 101 × 101 cells in a resolution of 12 km per hour; a smaller domain (Slovenia with surroundings): 76 × 76 cells in a resolution of 4 km per 30 min. The model is run at 5:00 UTC, the simulation runs for 3 to 4 hours, and it is run again at 17:00 UTC.

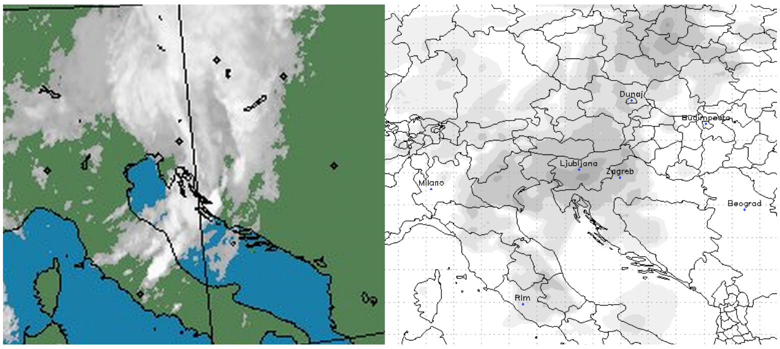

Figure 1. Example of an excellent correlation between measured and forecasted clouds over central Europefor time interval 30.07.2010 at 07:00 hour(left: measured clouds from SEA Weather forecast and data, 2010, right: forecasted clouds by WRF)

QUALITATIVE VALIDATION

For the qualitative validation the 29th of August 2011 has been selected due to measured high SO2 concentrations in the region on several environmental stations as presented on Figure 3. It has been determined that during this period main source of SO2 was Thermal power plant Trbovlje which had been restarted after a 3 weeks of regular maintenance. During the start of the power plant the delsulphurization plant is not in full operation, therefore high concentrations are emitted from the 360 m high stack. At the same period also high concentrations had been modelled in diagnostic and prognostic mode of our modelling system at the same locations as presented on Figures 4 and 5. The results in prognostic mode are slightly worse than the diagnostic one which is expected. Modelled values are lower than the measured ones due to emission parameters that are in our modelling system set to nominal emissions which differ from the emission at the start of power plant (emissions of higher due to inactive delsulphurization plant).We are in the process of reaching an agreement on the transfer of automatic emission measurements to achieve more precise results.

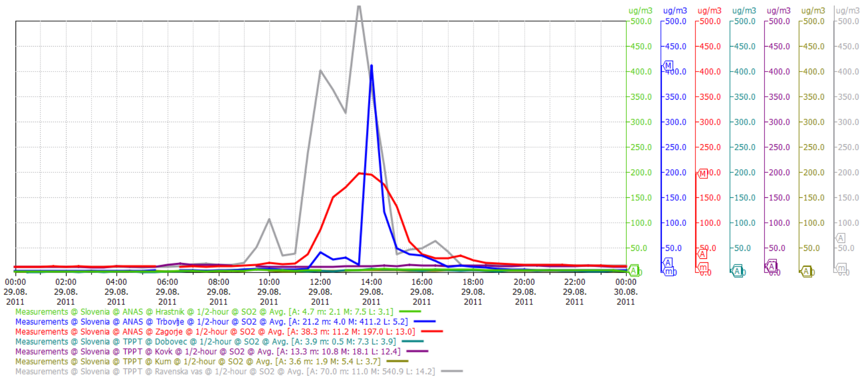

Figure 2. Measured SO2 concentrations in the Zasavje region for 29th of August 2011 at environmental stations (data from public portal okolje.info, 2011)

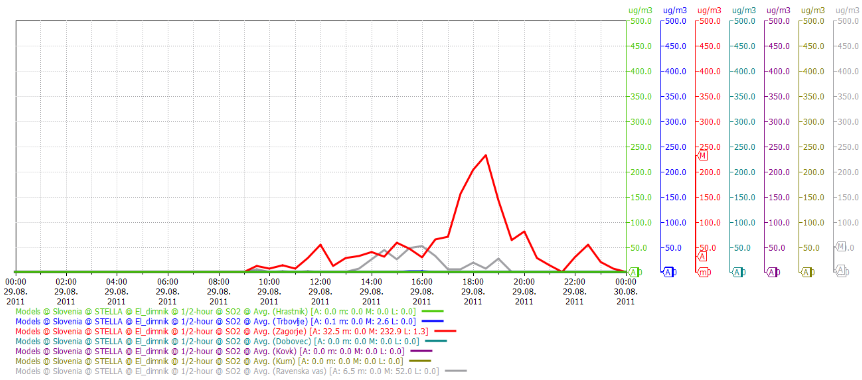

Figure 3. Modelled SO2 concentrations in diagnostic mode in the Zasavje region for 29th of August 2011 at environmental stations

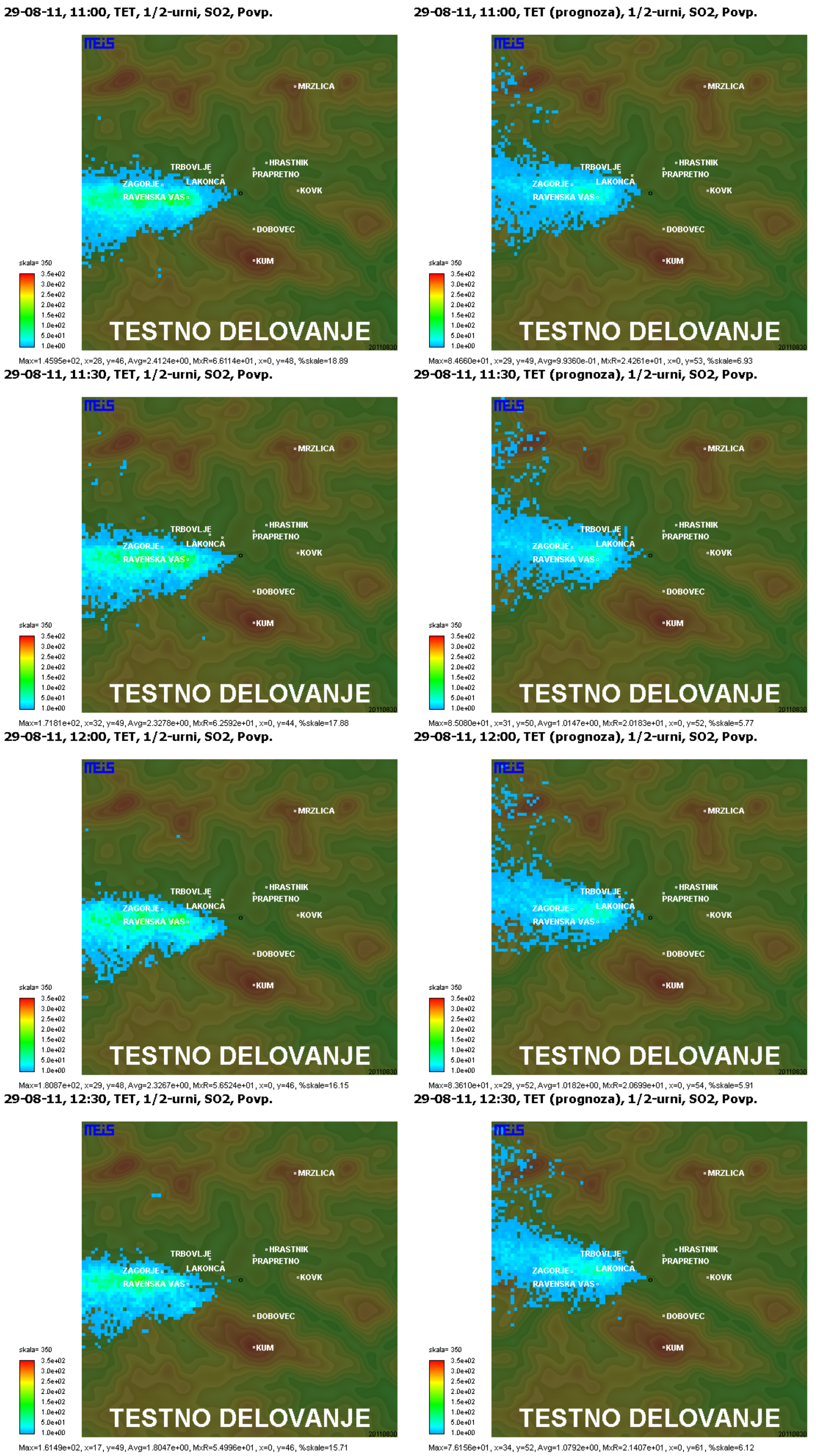

Figure 4. Comparison of modelled air pollution of SO2 over Zasavje region for ½ hour time intervals from 29.08.2011 at 11:00 till 29.08.2011 at 12:30 (left: diagnostic modelling, right: prognostic modelling)

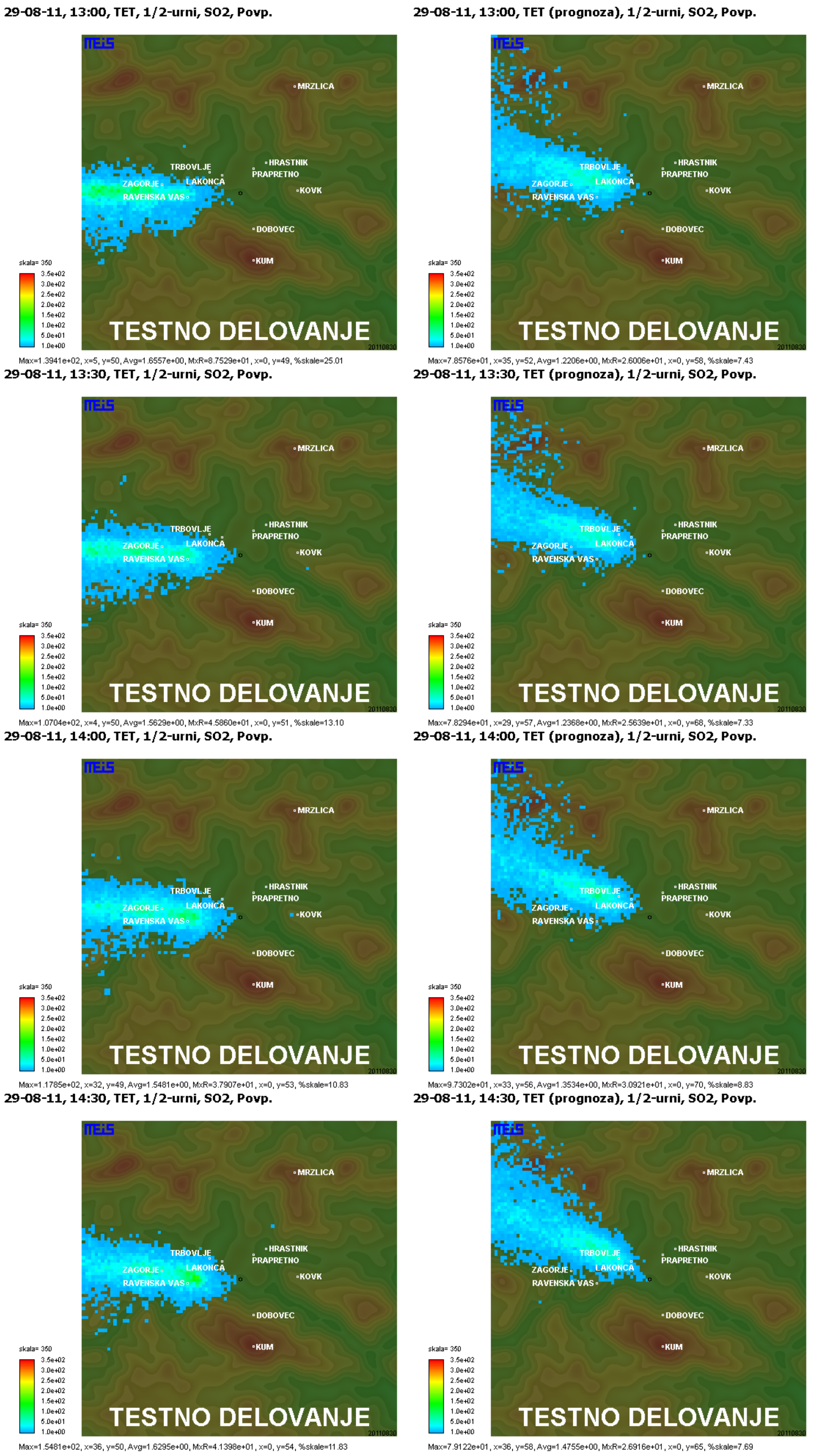

Figure 5. Comparison of modelled air pollution of SO2 over Zasavje region for ½ hour time intervals
from 29.08.2011 at 13:00 till 29.08.2011 at 14:30
(left: diagnostic modelling, right: prognostic modelling)

QUANTITATIVE VALIDATION – NEW METHOD FOR DETERMINATION OF "LENGTH OF ACHIEVEMENT IN SPACE AND TIME"

First extensive validation of the air pollution modelling system for the Zasavje region had been performed for the year 2006 when SODAR measurements were available (Božnar, M., P. Mlakar, and B. Grašič, 2008). Results of this validation showed good behaviour of Lagrangian particle model approach. Another important conclusion was that foundation for good modelling is good database without any corrupted data measurements. New method for determination of "length of achievement in space and time" is defined in paper by Grašič, B., P. Mlakar and M. Z. Božnar (2011) which is available online on the Internet.

FUTURE WORK

The above mentioned quantitative validation is made only for diagnostic mode of modelling system where also SODAR data was available. We plan to extend this validation over longer period to obtain more statistically valid results for the diagnostic mode without SODAR measurements available and also for prognostic mode. Validation will be made using advanced validation method described in papers (Grašič, B. et al., 2008, Grašič, B., P. Mlakar and M. Z. Božnar, 2011).The results will be published in more extensive form in near future.

CONCLUSIONS

Validation of the modelling system is a necessary first step. Where possible, validation should be done at least partially locally in the same area as further use of the system is planned. If there are no adequate measurements available to make the validation locally, then application of the modelling system is reliable only if it has been validated on meteorologically similar area with similar topographic complexity.

In the case of Zasavje region modelling system there are several possibilities for validation as several present and past air pollution and meteorological measurements exist.Due to complexity of the area under examination we have done validation both in qualitative way and in quantitative way to show the degrees of agreement and disagreement of measurements and modelling results and to point out the reasons for the achievements.

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